July 21, 1936. H. A. SNOW 2,048,228

VACUUM TUBE

Original Filed June 26, 1930

Fig. 1.

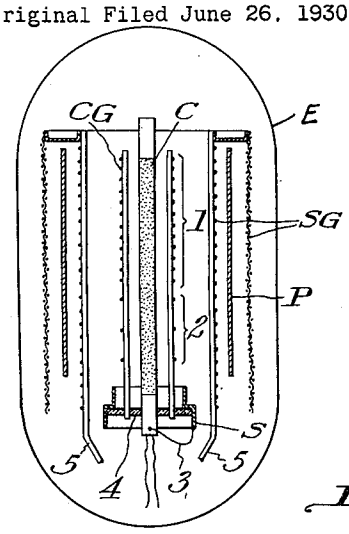


Fig. 2.

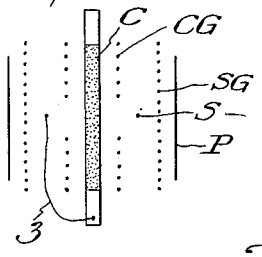


Fig. 3.

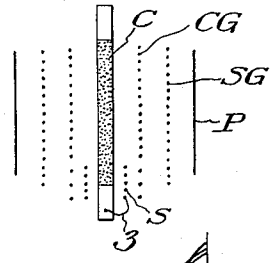
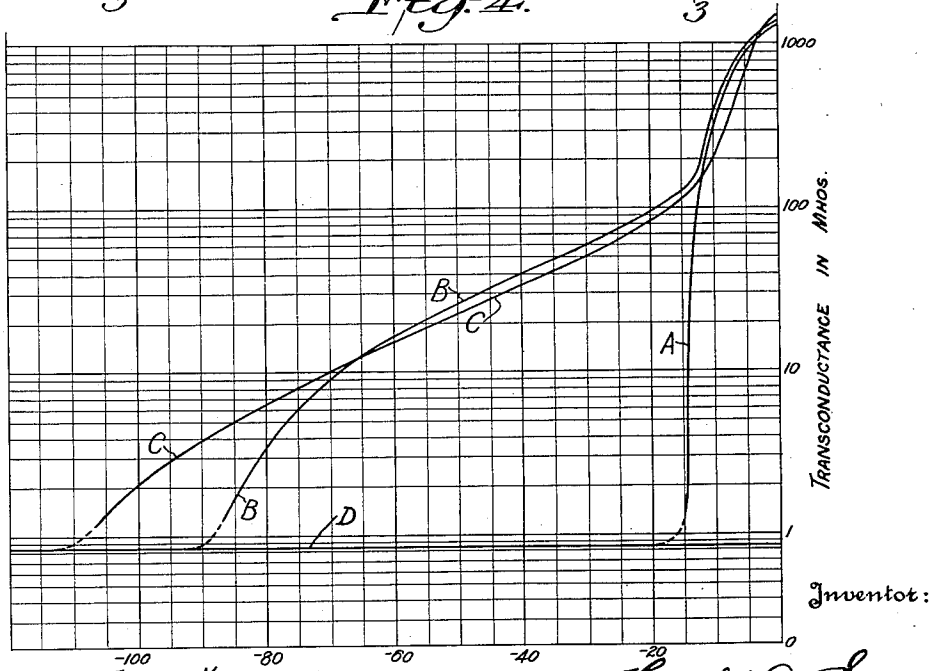


Fig. 4.



CURVE A- TRANSCONDUCTANCE OF "224"
" B- " " FIG. 2.
WITHOUT SHIELD S
" C- TRANSCONDUCTANCE " FIG. 1.
" D- LEAKAGE CONDUCTANCE.
CURVE OF ALL TUBES

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UNITED STATES PATENT OFFICE

2,048,228

VACUUM TUBE

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Application June 26, 1930, Serial No. 464,053
Renewed June 1, 1935

19 Claims. (Cl. 250—27.5)

This invention relates to vacuum tubes of the type including a cathode, a control grid and a plate.

In my copending application Serial No. 437,225, filed March 19, 1930, I have described vacuum tubes that are particularly useful as transmission control elements in amplifier systems. With the known tube constructions, it is not possible to effect a distortionless transmission, at low amplification, of strong signals if the tube design is such as to provide high amplification for weak signals. As described in my prior application, distortionless volume or transmission control for high input voltages may be secured when the elements of the tube are so constructed and arranged that different portions of the electron stream are influenced at different rates by the signal voltages applied to the control grid. This particular characteristic may be obtained in several ways, such as, for example, the omission of one or more turns from an end or an intermediate portion of the control grid winding, or by the use of a control grid winding of non-uniform pitch.

Tubes of such construction exhibit the desired transconductance characteristics which prevent distortion when the operating potentials are so adjusted as to reduce the amplification to a small fraction of its maximum value, but there is, in general, a relatively large flow of plate current (direct current) at the portion of the tube where the control grid is omitted or is of relatively coarse pitch.

An object of the present invention is to provide a vacuum tube exhibiting improved transmission control characteristics in that no distortion is introduced even though the input signal voltage is raised to values substantially higher than was previously permissible. An additional object is to provide a vacuum tube capable of transmitting high signal voltages without substantial distortion or with distortion which is slight, but substantially constant over a wide range of signal voltage, and exhibiting a lower plate current drain and higher plate resistance than tubes of the general type described in my copending application. A further object is to provide, in a vacuum tube which at different portions thereof exhibits the properties of a high mu and of a low mu tube, a shield or grid for reducing the flow of plate current at the low mu section of the tube. More specifically, an object is to provide, in a vacuum tube having a control grid of the general type of a winding of non-uniform pitch, a low potential element for reducing the flow of plate current at the portion of the electron stream which is controlled by the relatively open or coarse section of the grid.

These and other objects of the invention will be apparent from the following specification when taken with the accompanying drawing in which:

Figs. 1, 2 and 3 are somewhat diagrammatic views, in vertical central section, of typical embodiments of the invention, and

Fig. 4 is a curve sheet illustrating transconductance characteristics of a tube embodying the invention and other tubes of the same general type.

The invention is illustrated in connection with tubes of the known screen grid type employing concentric cylindrical elements, but it is to be understood that the invention is not limited to screen grid tubes or to the cylindrical type of electrodes.

As shown in Fig. 1, the tube includes within the usual evacuated envelope E, an equipotential cathode C, screen grid SG and a plate P. The control grid CG is constructed in accordance with the invention described in my copending application and takes the form of a helical winding having a section 1 of close and uniform pitch and another more open section 2 of uniform but coarser pitch.

This general type of control grid results in a tube which exhibits the characteristics of a high mu tube when the control grid bias falls within the range of bias voltages corresponding to relatively high amplification of weak signals. As the signal strength increases, an effective and practically distortionless control of amplification is afforded by that portion of the electron stream that is influenced by the relatively coarse or more open section 2 of the control grid CG. As is explained in my copending application, this increase in the effective range of distortionless amplification is accompanied by a high plate current flow which may be reduced by an appropriate design or location of the other tube elements.

In accordance with the present invention, an additional element or shield S is located adjacent the low mu section of the tube to prevent an excessive flow of plate current when the grid bias is adjusted for high amplification. The shield element S is maintained at a fixed or constant potential materially lower than that of the screen grid, and preferably is connected directly to the cathode by a lead 3. The shield S therefore lowers the positive field from the screen grid, thereby raising the plate resistance and reducing the plate current flow at the coarser section of the control grid.

The shield S may be supported by the insulator disk 4 and, in tubes of the general type known commercially as the "224 tube", may be constituted by the metal sleeve to which, in the known commercial tubes, the supporting wires 5 of the screen grid SG are attached. The tube as shown in Fig. 1 may therefore conform to the standard 224 tube construction so far as concerns the structural details other than the special form of control grid winding and the electrical connection of the shield or sleeve S to the cathode instead of the screen grid.

Except for the addition of a shield element, the tube shown diagrammatically in Fig. 2 may be substantially identical with the tube illustrated in Fig. 1 of my copending application, i. e., it may conform to standard design of a high mu screen grid tube except for the omission of a plurality of turns from the central section of the helical winding which constitutes the control grid CG. In accordance with the invention, the shield element S comprises a ring which is located between the control grid CG and screen grid SG at approximately the longitudinal center of that portion of the control grid from which two turns are omitted to form a more open portion. The shield S is maintained at a potential lower than that of the plate, or if desired, at cathode potential by means of a connecting lead 3.

It will be apparent that the same reduction of plate current may be effected when the shield is located at any place between the control grid and the accelerating grid SG. As shown in Fig. 3, the shield S comprises a grid positioned between the cathode C and control grid CG, and opposite one end of that portion of the control grid which is more open and of coarser pitch.

Tests made with tubes embodying the present invention have shown that the transconductance characteristics of tubes having control grids of the non-uniform pitch type are not, within the range of control grid bias voltages appropriate for such tubes, substantially affected by the introduction of a shield element which establishes a desirable low potential field between the highly positive screen grid SG and the zero potential cathode, the shield and the screen grid constituting field electrodes which cooperate to produce the desired kind of a positive electrostatic field. The total space current in a tube containing the shield S may be, however, about one-half that of a similar tube not containing a shield.

As will be evident from the transconductance curves of Fig. 4, the shield S has the further advantage of considerably extending the range of practically distortionless amplification control. In Fig. 4, the curve A is the transconductance curve for a commercial tube of the 224 type and curve B is a similar curve for a tube which differed from standard design by the omission of two turns from the center of the control grid. The curve C is the transconductance curve for a tube which includes the low potential shield element adjacent the coarse section of the control grid. It will be noted that curves B and C substantially coincide throughout a wide range of control grid bias voltages, i. e., up to about —65 volts. As the bias voltage is made more negative to effect a further reduction in amplification, the characteristic for the tube embodying the invention, i. e., curve C, falls off less rapidly than the characteristic, curve B, of a tube which does not include the shield element. For each tube, the possibility of amplification control is lost when the bias voltage reaches the value at which the transconductance curve meets the leakage conductance, curve D, which is substantially identical for all of the tubes.

An examination of the transconductance control grid bias curves of Fig. 4 shows that the addition of the shield electrode S increases considerably the useful range of transmission control which was a feature of the invention described and claimed in my aforesaid co-pendng application. Since modulation distortion arises when the tube is operated upon a sharply curved portion of the transconductance characteristic, it will be evident that the invention also increases the range of signal voltages which may be transmitted without distortion since the curvature of characteristic C is less than that of characteristic B, particularly at those portions of curve B which are most sharply curved.

The particular tube designs which I have illustrated and the data obtained in one series of tests are to be taken as illustrative of the invention. To one familiar with the design and operation of vacuum tubes, it will be apparent that the invention is applicable to other types of tubes and to other physical arrangements of the electrodes in tubes of various types.

I claim:

1. A vacuum tube including an equipotential cathode, a plate and a control grid coextensive with the cathode and which exercises different rates of control over different portions of the electron stream, and a shield element disposed adjacent said grid for establishing a low potential field only at that portion of the electron stream over which the said control grid exercises a lesser control.

2. An electron discharge tube including an equipotential cathode, anode, screen grid and a control grid coextensive with the cathode and which exercises different rates of control over different portions of the electron stream, a shield element adjacent said cathode for establishing a low potential field at that portion of the electron stream over which the said control grid exercises a lesser control, and a direct electrical connection from said shield element to the cathode.

3. A vacuum tube having a cathode, a plate, and a control grid constituted by a winding of non-uniform pitch, of a shield element adjacent only that portion of said control grid which is of the coarser pitch.

4. A vacuum tube having a cathode, a plate, and a control grid constituted by a winding of non-uniform pitch, of a shield element adjacent only that portion of said control grid which is of the coarser pitch, and a direct electrical connection from said shield element to the cathode.

5. A vacuum tube comprising a cylindrical cathode, a control grid constituted by a helical winding surrounding said cathode, the pitch of said winding being non-uniform and more open adjacent one end of said cathode, a screen grid, a plate, and a shield element positioned between said cathode and screen grid, said element being in transverse alinement with a portion of the more open section of said control grid.

6. The invention as set forth in claim 5, wherein said shield element is located between said control grid and said screen grid.

7. The invention as set forth in claim 5, in combination with an insulating disk fitted over the

said end of the cathode, said shield element constituting a sleeve supported by said disk and electrically connected to said cathode.

8. An electron discharge tube including a cathode, anode, screen grid and a control grid which exercises different rates of control over different portions of the electron stream, and a shield element adjacent said cathode for establishing a low potential field at that portion of the electron stream over which the said control grid exercises a lesser control, said element being connected to said cathode, said shield element being disposed between said screen grid and cathode.

9. An electron discharge tube including a cathode, anode, screen grid and a control grid which exercises different rates of control over different portions of the electron stream, and a shield element adjacent said cathode for establishing a low potential field at that portion of the electron stream over which the said control grid exercises a lesser control, and a direct electrical connection from said shield element to the cathode.

10. An electron discharge tube including a cathode, anode, screen grid and a control grid which exercises different rates of control over different portions of the electron stream, and a shield element adjacent said cathode for establishing a low potential field at that portion of the electron stream over which the said control grid exercises a lesser control, said element being connected to said cathode, said control grid being provided with fine and coarse spaces, said shield surrounding said coarse space and being disposed between said screen and control grid.

11. An electron discharge tube including a cathode, anode, screen grid and a control grid which exercises different rates of control over different portions of the electron stream, and a shield element adjacent said cathode for establishing a low potential field at that portion of the electron stream over which the said control grid exercises a lesser control, said element being connected to said cathode, said control grid being provided with an open portion at substantially its longitudinal center, and said shield surrounding said open portion.

12. An electron discharge tube including a cathode, anode, screen grid and a control grid which exercises different rates of control over different portions of the electron stream, and a shield element adjacent said cathode for establishing a low potential field at that portion of the electron stream over which the said control grid exercises a lesser control, said element being connected to said cathode, said control grid being provided with a more open portion adjacent one end of said cathode, said shield surrounding said cathode and being disposed between the control grid and cathode adjacent said open portion.

13. A vacuum tube comprising an electron emitting element, a screen grid, a plate, and a control grid which exercises different rates of control over different portions of the electron stream, and means for reducing the flow of plate current at that portion of the electron stream over which the said control grid exercises a lesser control comprising a shield element disposed adjacent that portion of the control grid which exercises the lesser control.

14. A vacuum tube comprising a control grid constituted by a winding of non-uniform pitch, a cathode, a plate, a screen grid, and means for reducing the flow of plate current at that portion where the control grid is of coarser pitch, without substantially altering the transconductance of the tube, comprising a shield element disposed adjacent the coarser-pitched portion of the control grid.

15. An electron discharge device comprising a cathode, a control grid which exercises different rates of control over different portions of the electron stream from said cathode, a plate and a shield electrode adjacent only that portion of said grid which exercises a lesser rate of control than elsewhere, and means for maintaining said shield electrode at a fixed potential different than the potential of said grid.

16. An electron discharge device comprising a cathode, a control grid coextensive with and surrounding said cathode and having a portion which is more open and exercises a lesser rate of control over the electron stream from said cathode than the remainder of said grid, a plate, and a shield electrode cooperating only with the more open portion of said grid to exercise on the electron stream from said cathode through the more open portion of said grid a rate of control which differs from the rate of control exercised by the other portions of said grid.

17. An electron discharge device comprising a cathode, an anode, a control grid coextensive with said cathode and interposed between said cathode and said anode and having a portion more open than other portions and exercising a lesser rate of control on the electron stream from said cathode to said anode, and an electrode of fixed potential adjacent only the more open portion of said grid for making the positive field of said anode weaker at said more open portion of said grid than at other portions.

18. An electron discharge device comprising a cathode, a control grid coextensive with and surrounding said cathode and having a portion more open than other portions and exercising a lesser rate of control on the electron stream from said cathode, a positive electrode surrounding said control grid, an auxiliary cold electrode disposed adjacent only said more open portion of said control grid, and means for establishing on said auxiliary electrode a fixed potential different than the potential of said positive electrode.

19. An electron discharge device comprising a cathode, a high potential plate surrounding said cathode, a control grid coextensive with and interposed between said cathode and said anode and having a portion more open than other portions and exercising a lesser rate of control on the electron stream from said cathode to said plate, and an element which is disposed adjacent only the more open portion of said control grid and which at a fixed potential lower than the potential of said anode reduces the flow of plate current at said more open portion.

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