July 21, 1936. H. A. SNOW 2,048,225

VACUUM TUBE

Original Filed March 19, 1930

Fig. 1.

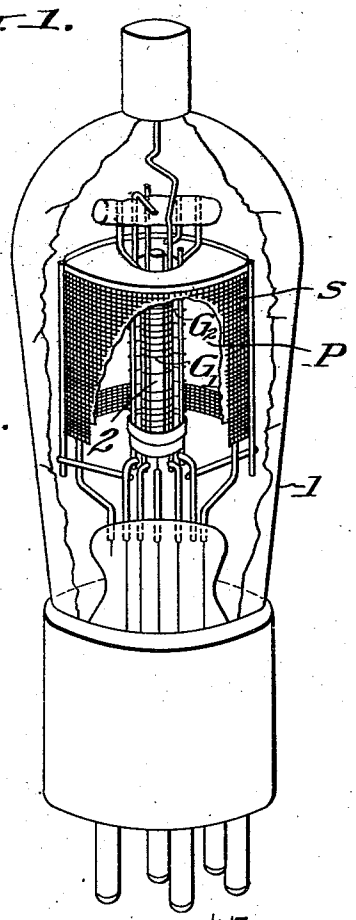


Fig. 2.

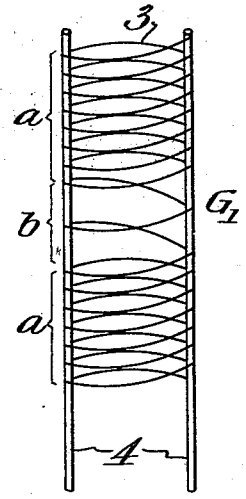


Fig. 3.

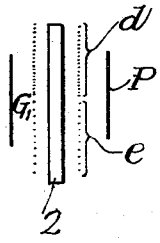


Fig. 4.

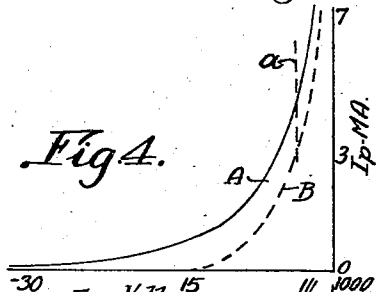
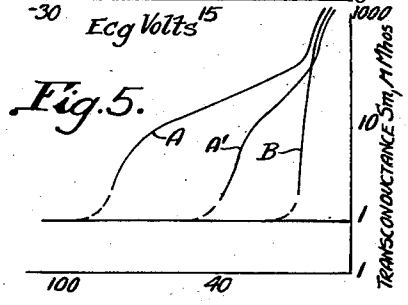


Fig. 5.



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UNITED STATES PATENT OFFICE

2,048,225

VACUUM TUBE

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Original application March 19, 1930, Serial No. 437,225. Divided and this application March 12, 1931, Serial No. 522,062. Renewed January 18, 1936. In Canada September 13, 1930

7 Claims. (Cl. 250—27.5)

This invention relates to vacuum or electronic tubes suitable for the amplification of modulated carrier waves.

This application is a division of my copending application, Ser. No. 437,225, filed March 19, 1930 and, for a more extended discussion of the method of operation and the advantages of vacuum tubes of the poly-mu, or variable mu-factor, type disclosed and claimed in this application, reference is made to the aforesaid application and to the article by Stuart Ballantine and Harold A. Snow in the "Proceedings of the Institute of Radio Engineers", December, 1930, pages 2102 to 2127, "Reduction of distortion and cross-talk in radio receivers by means of variable-mu tetrodes".

An object of the invention is to provide a vacuum tube in which the electrodes are constructed and arranged to produce a desired relation between the current flow in one electrode circuit and the voltage on another electrode, for example, between plate current and control grid voltage whereby practically no distortion is introduced when, for increasing signal strengths, the operating potentials are so adjusted that the amplification rate is reduced to a small fraction of the maximum amplification, and the tube will give an undistorted output of approximately constant magnitude over a wide range of applied carrier voltages. A further object is to provide a tube of the type stated in which the control grid is so constructed that the space current path adjacent different parts of the cathode is characterized by substantially different mu factors and transconductance values so that when the potentials are adjusted to give a relatively low amplification of strong signals, the change in transconductance for a given change in the gain control voltage is much lower than is the case with the known types of tubes. A further object is to provide a vacuum tube of the type stated having an equipotential cathode and in which the control grid has the form of a helical winding of non-uniform pitch. More specifically, an object of the invention is to provide a vacuum tube of the type stated having coaxial cylindrical elements and in which the control grid has the form of a winding made up of a plurality of sections of helical windings, each section being of substantially uniform pitch but of different pitch than the adjoining section.

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

Fig. 1 is a perspective view of a vacuum tube embodying the invention, parts being broken away to illustrate the construction of the control grid,

Fig. 2 is an enlarged detail view of a control grid such as shown in Fig. 1,

Fig. 3 is a diagrammatic view illustrating another embodiment of the invention.

Figure 4 is a curve sheet showing the variations of plate current with grid bias for a tube such as shown in Figure 1.

Figure 5 is a curve sheet showing the relation between control grid voltage and transconductance for tubes embodying the invention.

In Fig. 1, the invention is illustrated as embodied in a form of vacuum tube known commercially as a screen grid tube having a separate heater for energizing an equal-potential cathode. As is well known, this particular type of tube comprises an evacuated envelope 1 enclosing a cathode 2 heated by a resistance (not shown) within the cathode, an inner or control grid G_1, a screen grid G_2, a plate P and an outer screen S. Except for the novel construction of the control grid G_1 and its novel functional relationship to the remaining elements of the tube, the several elements of the tube and their physical arrangement may be substantially the same as that employed in the present commercial tubes.

In tubes of this general type, the control grid G_1 comprises a helical winding, of uniform pitch, supported by one or more wires which extend parallel to the axis of the cathode 2.

In accordance with the present invention, the desired operating characteristics of the tube, as explained in my copending application and the aforesaid publication, are obtained by making the control grid winding of non-uniform pitch.

As shown in Fig. 2, the control grid G_1 takes the form of a continuous helical winding 3 with its turns constituting transverse conductors connected to and supported by one or more foundation supports or wires 4, and having a pitch such that each turn of the helical winding is spaced from the adjacent turns a distance greater than the diameter of the wire and sufficient to permit the space current or electron stream from the cathode to the anode to pass through and to be controlled by substantially all of the winding of the grid. In the particular form of control grid shown, the end sections *a* of the winding have the same relatively close pitch and the central section *b* has a longer pitch, i. e., a greater spacing between turns of the winding than the adjoining end section *a*.

The invention may be employed with triodes, as illustrated in Fig. 3, and various arrangements of a plurality of sections of different pitch may be employed in tubes of the triode and tetrode or other multi-electrode types. As shown in Fig. 3, the winding G_1 has the form of a helical winding having one uniform pitch throughout section *d* and another uniform pitch throughout section *e*.

By transconductance is meant the ratio of the change in the current in the circuit of an electrode to the change in the voltage on another electrode, under the condition that all other voltages remain unchanged. By mu-factor is meant the ratio of the change in one electrode voltage to a change in the other electrode voltage, under the condition that a specified current remains unchanged.

As explained in more detail in my copending application of which this application is a division, the amplification of a vacuum tube may be regulated by adjusting the bias voltage upon the control grid, the amplification decreasing as the bias voltage becomes more negative. Curves showing the relation between plate current and grid bias, i. e., transfer characteristics, afford an indication of the amplification at different bias voltages, since the slope of the curve at any point is a measure of the amplification when the tube is biased for operation at that point.

In Figure 4, the solid line curve A is the transfer characteristic for a tube such as shown in Figure 1, and the dotted line curve B is a similar curve for a commercial screen grid tube of the same general type, but having a continuous control grid winding of uniform pitch. An examination of curve A shows that, with tubes embodying the invention, a control of amplification extends over a range of control grid bias of from zero to more than −30 volts. With known tubes, the curvature of the transfer characteristic approaches zero at a control grid bias of about −15 volts.

In other words, an increase in the grid bias above approximately 15 volts negative will not be accompanied by a decrease in amplification when the known type of tube construction is employed, but with tubes embodying the invention, the amplification may be varied with changes of control grid bias throughout a range of from zero to upwardly of −30 volts. The tubes will still pass signals, by leakage transmission when the control grid biases exceed these respective values, but control of amplification is no longer possible in regions where the transconductance curves become substantially horizontal.

The curves of Figure 5 show the relation between control grid bias and transconductance for two tubes embodying the invention, and for a similar tube which has the usual grid construction. Curve A is the transconductance-control grid bias curve for a screen grid tube of the type shown in Figure 1, having two turns omitted from the center of the control grid. The data for this curve and for curve A of Figure 4 relates to the same tube. Curve A′ is a similar curve for a screen grid tube in which only one turn was removed from the center of the control grid, and curve B shows the characteristic properties of the conventional type of tube having a continuous control grid winding.

An examination of these curves shows that the useful range of transmission control is considerably extended by the present invention. With the known constructions, a decrease of the transconductance from about 500 micromhos to the value, about 0.8 micromho, at which leakage transmission prevents further amplification control, corresponds to a change in control grid bias of about ten volts. The corresponding ranges of control grid bias for the tubes of curves A′ and A are, respectively, about 30 and 60 volts.

As stated above, modulation distortion may occur when, for a given signal strength, the amplification is so adjusted as to bring the output down to a desired, or standard, level. Since such distortion is due to the curvature of the transfer characteristic, it will be apparent that a tube having a curve of lower curvature can transmit, without distortion, higher voltage signals than a tube having a characteristic which exhibits a region of higher curvature. An examination of the curves of Figure 4, will show that the maximum curvature of curve A is substantially lower than that of curve B.

An analysis of curve A′ will show that the maximum signal strength which may, without undue distortion, be transmitted to give the desired constant output voltage is about 1.1 volts, corresponding to a control grid bias of about −38 volts. For the tube with two turns removed from the control grid, curve A shows a permissible input voltage of 3 volts, with a bias of −95 volts. Furthermore, by so restricting the control grid bias voltages that the maximum can never exceed about 28 volts negative in the case of the tube of curve A′, and about 65 volts in the case of the tube of curve A, the maximum carrier voltages which may be transmitted are approximately 7 and 22 volts, respectively.

Observations of actual performance in a receiver check closely with the results plotted in Figure 5 for single stages. By employing tubes constructed in accordance with the invention, the permissible input voltage was raised from 0.3 volt to 17 volts, i. e., volume control with good quality reproduction can be had with input voltages about 57 times as great as those which may be applied when the known commercial form of tube is employed.

It will be apparent to those skilled in the art that my invention provides means for extending the range of signal voltages which may be transmitted without distortion, the signals being either of audio or radio frequency, and if of radio frequency, either continuous wave or modulated.

I claim:

1. A control grid adapted for use in a variable mu-factor tube having an equi-potential cathode, anode and screen grid, and comprising a helical winding having a pair of sections of different pitch with the turns of each section spaced to permit an electron stream to flow through and be controlled by said section, the pitch throughout each of the sections being uniform.

2. A control grid adapted for use in a variable mu-factor tube having an equi-potential cathode, anode and screen grid, and comprising a helical winding including two sections of the same uniform and sufficiently great pitch to permit an electron stream to flow through and be controlled by each of said sections, and an intermediate section of a uniform wider pitch proportioned to control an electron stream through said intermediate section.

3. An electron discharge device having as elements a cathode, an anode, and a control grid interposed between said cathode and said anode, said grid comprising foundation supports and

spaced transverse conductors connecting said supports and having two adjoining sections of different spacing, each section being of a uniform spacing and having between said conductors a space greater than the thickness of said conductors.

4. An electron discharge device comprising a cathode, an anode, and a control grid interposed between said cathode and said anode, said grid comprising foundation supports and spaced transverse conductors connected to said supports and having two sections of substantially the same spacing and an intermediate section of greater spacing, said sections being mounted end to end and each section having all its conductors spaced apart.

5. An electron discharge device comprising an equipotential cathode, a cylindrical anode surrounding and coaxial with said cathode, and a cylindrical control grid interposed between and coaxial with said cathode and said anode and comprising a wire helically wound into adjoining sections each of uniform pitch and with all its turns spaced apart, said sections being mounted end to end to form said grid with one section in registry with one longitudinal portion of said cathode and another section having a pitch greater than the average pitch of said grid in registry with another longitudinal portion of said cathode.

6. A thermionic electron discharge tube comprising a cathode, an anode, and an interposed control grid comprising foundation supports and transverse conductors connecting said supports, said grid having a plurality of sections adjoined end to end, each section being of uniform spacing and having its conductors spaced to control the electron current from said cathode to said anode, one of said sections extending along one portion of the length of said cathode and another of said sections having its conductors spaced a greater distance than the other section extending along another portion of the length of said cathode.

7. An electron discharge device comprising a cathode, a control grid surrounding said cathode, a screen surrounding said control grid, and an anode surrounding said screen, said control grid comprising foundation supports with transverse conductors connected to said supports and spaced to control the electron current from said cathode to said plate and having a plurality of sections each of uniform pitch and adjoined end to end with one of said sections covering one part of said cathode and another section having a spacing greater than the average spacing of said grid covering another part of said cathode.

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