PATENT SPECIFICATION

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COMPLETE SPECIFICATION.

Improvements in or relating to Vacuum Tubes particularly for use in Radio Sets.

We, ARCTURUS RADIO TUBE COMPANY, a corporation of the State of Delaware, United States of America, of 260, Sherman Avenue, Newark, New Jersey, United States of America, Assignees of WALTER LOUIS KRAHL, a citizen of the United States of America, residing at 73, Orange Road, Montclair, New Jersey, United States of America, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to indirectly heated, alternating current vacuum tubes and particularly to a means for balancing out or compensating for the capacity between certain elements of the tube.

It has been found by careful study of the causes which produce hum in the output circuit of a radio receiving set using alternating current tubes that very minute alternating currents flowing through the grid circuit of the detector tube will produce variations upon the grid, which, when magnified by the detector tube and the amplifying tubes of the radio set will produce variations in the output voltage of the set to cause a hum in the loud speaker. The grid leak, due to its high resistance, causes considerable drop in potential in the grid circuit when even minute alternating currents flow therein; such potential drop being transferred to the grid and this alternating current flowing through the grid circuit may be due to the capacity between the grid and the heater circuit of the tube.

It is therefore one of the objects of the invention to provide means to balance out the capacity effect between the grid and the heater circuit of an indirectly heated alternating current vacuum tube.

Inasmuch as capacities between the elements of different tubes vary somewhat, it is also another object of the invention to provide a means in a radio set which may be adjusted to compensate for this interelement capacity in any tube which may be inserted in the set.

Another object of the invention is to prevent any fluctuating current from flowing through the grid leak of a detector tube energized by fluctuating current.

Other objects of the invention will be apparent as the description thereof proceeds.

The invention is illustrated in the accompanying drawings, in which

Fig. 1 is a curve showing the variable output voltage of a direct current radio set with respect to the capacity which is in series with the grid and a source of alternating current of a predetermined voltage;

Fig. 2 is a circuit diagram of a four terminal alternating current tube showing the manner of connecting the compensating means in the circuit;

Fig. 3 is a diagrammatic interpretation of the figure shown in Fig. 2;

Fig. 4 is a circuit diagram of a five terminal tube showing the manner of connecting the compensating means in the circuit therefor; and

Fig. 5 is a diagrammatic interpretation of the circuit shown in Fig. 4.

With the use of a very small capacity condenser connected in series with the secondary of a transformer across which a 60-cycle potential of 15 volts was maintained and also connected in series to the input circuit of a direct current detector tube to the output of which an amplifier was connected, we were able to ascertain the voltage variation produced in the output circuit by the alternating current passing through the small capacity condenser. The usual condenser and grid leak were connected between the grid and the cathode of the detector tube, so that any current passing through the small capacity condenser could complete the circuit through the grid leak.

The results of these experiments were somewhat astounding, as will be evident from an inspection of Fig. 1. From almost zero capacity the voltage curve rises sharply to about two and one-half volts when the capacity of the condenser is only one micromicrofarad, and to about sixteen volts when the capacity of the condenser is about five micromicrofarads. An output voltage variation of two volts

[*Price* 1/-]

with the average radio amplifier now in use will produce an audible hum in the loud speaker, but inasmuch as it is extremely difficult to define what is an audible hum, as such a sound will depend entirely upon the sensitiveness of the amplifier and of the speaker, as well as of the ear of the listener, we desire to use the word " hum " as meaning any voltage variation in the output circuit caused by the alternating heater potential.

In certain types of alternating current tubes the cathode is connected to the heater circuit inside of the tube so that the tube has four terminals. Such a tube is illustrated in Fig. 2, in which a plate 10 is shown connected to a terminal 11; a grid 12 is shown connected to a terminal 13; a cathode 14 is shown connected to a terminal 15; and a heater 16 is shown with its lower end connected to a terminal 17 and with its upper end also connected to the cathode terminal 15. The terminal 11 is connected through a B battery 18 to an output terminal 19 in the circuit, and the grid terminal 13 is connected through a grid leak 20 with its usual by-pass condenser 21 to an input terminal 22, which forms the usual connection for a detector tube. The terminal 23 forms the other terminal for both the input and output, as indicated, and is connected to the cathode terminal 15. Thus both the input and output circuits are connected to the cathode.

It will be evident that the upper end of the heater is connected through the input transformer and the grid leak to the grid, and inasmuch as there is no resistance in any part of this circuit carrying alternating current, there is no drop of potential and hence, the capacity between the wires connected to the terminal 15 and the grid of the tube produces no disadvantageous result and need not be considered. However, it will also be evident from an inspection of the drawing that between the grid and the lower end of the filament which is connected to the terminal 17 following the metallic circuit through the input, there is interposed the entire resistance of the heater. Thus the circuit extends from the grid terminal 13 through the grid leak 20, terminal 22, through the input circuit, terminal 23, heater cathode terminal 15, through the high resistance heater to the terminal 17. Inasmuch as the resistance of the heater is in this circuit, it will be evident that there will be a difference in alternating current potential between the terminal 17 and associated wires, and the grid terminal 13 and its associated wires. If, then, there is a capacity, as represented by the condenser 24 shown in dotted lines, between these two terminals 13 and 17, an alternating current will flow therebetween. Stated in another way the input, grid leak and capacity 24 are connected in series directly across the heater leads and a current will flow in this circuit depending on the size of the capacity 24 and the voltage across the heater leads. This current flowing through the grid leak causes a voltage drop and produces a variation on the grid which, as can be readily seen, will be amplified by the remaining tubes in the circuit to produce a variable voltage in the output of the set.

In order to determine just what the capacity was between the grid terminal of an indirectly heated alternating current tube and the terminal connected to the lower end of the heater, we carefully measured these capacities in a number of tubes and found that it is about 0.4 of a micromicrofarad. We also measured a standard four terminal tube socket and found that the capacity between the grid and this heater terminal, which in this case is the adjacent heater terminal, is about .65 micromicrofarads. It will be evident that the sum of these two capacities, which represents the capacity when the tube is in the socket, will be 1.05 micromicrofarads, and from an inspection of the curve in Fig. 1, it will be seen that this capacity when subject to a pressure of fifteen volts, will produce a voltage variation in the output circuit of nearly three volts which, as has been stated above, will produce a hum in the speaker.

The invention is designed to compensate for the capacity between the grid and the lower end of the heater, and to this end we have introduced a resistance 25, one end of which is connected to the terminal 15 and the other end of which is connected to one side 26 of the power supply line at terminal 27. The secondary 28 of the transformer 29 is connected to the wire 26, and the other side of the secondary is connected by means of wire 30 to the terminal 17, thus placing the secondary 28 in series with the resistance 25 and across the heater terminals 15 and 17. A primary winding 31 connected to a source of alternating current 32 furnishes the power supply, as will be evident, to energize the heater and cathode of the tube. A variable condenser 33 is also connected between the terminal 13 and the terminal 27.

With the addition of the resistance 25 and the variable condenser 33, the resistances and capacities of the circuit may be represented as indicated at Fig. 3. This circuit, as will be seen, takes the

form of a Wheatstone bridge with the terminals 13, 17, 15 and 27 as the four terminals of the bridge. The heater 16 and additional resistance 25 form the resistance on one leg of the bridge, and the capacity 24 between the terminals 13 and 17 and the variable condenser 33 form the other leg, with the grid leak 20 and the grid condenser 21 forming the diagonal. If a fixed resistance is inserted at 25, it will be clearly evident that the variable condenser 33 may be adjusted to such a point that no current will flow through the grid leak 20, and this adjustment will entirely balance out the capacity effect between the grid and lower end of the heater so that no alternating current whatever will flow in the grid leak circuit, and, hence, no hum will be reproduced.

It will be understood that, if desired, the condenser 33 may be made fixed and the resistance 25 may be varied until a point is reached giving the same result, or this result may be attained by varying one or more of the other elements of the bridge.

If desired, the by-pass condenser 21 may be connected to the terminal 27 and utilized as the balancing capacity. This is advantagous, since it eliminates the condenser 33 which affects the tuning of the input circuit.

With tubes having five terminals in which the cathode is not connected at all to the heater circuit within the tube, there is a somewhat different result set up by the capacities between the grid and the ends of the heater. The combined base and socket capacity for the grid and heater terminals of this type of tube is approximately .68 micromicrofarads, which, it will be seen from reference again to Fig. 1, may produce a hum in the output of the set. A circuit connection embodying a five terminal tube is shown in Fig. 4 in which the plate 34 is shown connected to terminal 35; the grid 36 to terminal 37; the cathode 38 to terminal 39; the lower end of the heater 40 to terminal 41; and the upper end of the heater to terminal 42. The plate terminal 35 is connected to the B battery 43; the grid terminal 37 is connected to the grid leak 44 and the grid condenser 45 and both the negative side of the B battery, and the other end of the grid leak are connected to terminals 46 and 47 respectively, forming one terminal each of the output and the input for the circuit. The other terminal 48 of the output and the other terminal 49 of the input are connected together and to the lead 50, which is connected to the cathode terminal 39. The secondary 51 of the transformer 52, having a primary 53 connected across a source 54 of alternating current energy, is connected by means of the wires 55 and 56 to terminals 41 and 42, respectively, which are the heater terminals of the set. The wire 50 connecting the terminals 48 and 49 to the cathode terminal 39 is also connected to the arm of potentiometer 57 which is connected across the heater leads 55 and 56.

Where a five terminal tube is used, as in the present instance, and the cathode is entirely independent from the heater circuit, some means is necessary to make a connection between the cathode and the heater circuit. This has been accomplished by the use of the potentiometer 57, the grid and plate returns of the circuit being connected to the arm 58 which contacts at some point spaced from the ends of the coil. Thus the grid terminal 37 is connected electrically to the terminal 41 through a portion of the potentiometer coil, and the terminal 42 is connected to the grid terminal through the other portion of the potentiometer coil. It is evident that the grid is thus connected to a point having an alternative potential with relation to both terminals of the heater, and that a small capacity 59 exists between the grid and one terminal of the heater, and a small capacity 60 exists between the grid and the other terminal of the heater.

The various parts of the circuit shown in Fig. 4 may be represented by the diagram shown in Fig. 5, wherein the terminal 37 and the arm 58 of the potentiometer are shown at opposite ends of the grid leak 44 and condenser 45, which form the diagonal of a Wheatstone bridge, and terminals 41 and 42 are shown indicating the other two corners of the bridge circuit. Power is supplied at the terminals 41 and 42 from the source 54. The capacity between terminals 41 and 37 is represented by the condenser 59, and that between the terminals 42 and 37 is represented by the condenser 60. The arm of the potentiometer connects at a point on the coil thereof, forming two resistances—61 and 62, the former between the arm of the potentiometer and the terminal 41 and the latter between the arm and the terminal 42. It will be evident from an inspection of this diagram that by shifting the arm 58 of the potentiometer a point may be reached upon the coil where no current will flow through the grid leak 44, and when this point is found the capacities between the ends of the heater and the grid will be compensated for.

While a potentiometer has been used in this place before, attention is drawn to

the fact that the sole purpose of this potentiometer has been to connect the grid and plate return circuits to a point having the potential of the midpoint of the filament, or at a point which divides the filament into two sections from which the electronic emission is equal. It is to be noted that our invention does more than this, as it finds a point whereby the circuit is balanced so that the interelement capacities are compensated for and no alternating current flows through the grid leak. This point is oftentimes not at the center of the filament or at a point which divides the filament into two sections having equal emission. If merely the latter results are obtained, there may still be a hum in the output circuit arising from the interelement capacities described above.

Besides the capacity which exists between the grid and heater terminals and the wires associated therewith, there is also a conductance across the surface of the glass seal which although very slight, aids the current flow in the circuit, and it will be evident that the effect of this conductance may also be eliminated by the invention.

Certain modifications may be made in the invention, such as changing the elements of the Wheatstone bridge circuits as shown in Figs 3 and 5, without departing from the spirit of the invention, and we desire, therefore, to interpret the invention broadly within the scope of the appended claims.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. An indirectly heated vacuum tube comprising cathode plate and grid elements, a circuit associated with the cathode for energizing the cathode by a fluctuating current and an output circuit and an input circuit whereof the first is connected between the cathode and the plate and the second is connected between the cathode and the grid and includes a grid leak, and including a connection between the output and input circuits and the energizing circuit, and means for preventing fluctuating current from flowing through the grid leak due to the capacity or conductance between said grid and associated circuit and said energizing circuit.

2. A vacuum tube circuit as claimed in claim 1, in which the means for preventing fluctuating current from flowing through the grid leak includes a resistance.

3. A vacuum tube circuit as claimed in claim 1 or 2, including a capacity between the grid and one side of the energizing circuit and between the grid and the other side of said energizing circuit.

4. A vacuum tube circuit as claimed in any of claims 1 to 3, including a balancing resistance interposed between one side of the energizing circuit and the connection thereof with the input and output circuits.

5. A vacuum tube circuit as claimed in any of the preceding claims, including a separate heater for the cathode, which heater is connected to the energizing circuit.

6. A vacuum tube circuit as claimed in claim 5, including a connection between the cathode and one end of the heater.

7. A vacuum tube circuit as claimed in claim 6 and in any of claims 2 to 5, in which the resistance is arranged in series with the end of the heater having the cathode connected thereto, and a variable condenser is arranged between the grid and the extreme end of said resistance.

8. A vacuum tube circuit as claimed in claim 6 and in any of claims 1 to 5, and having five terminals in which the heater is entirely separate from the cathode and is connected to two of the terminals while the cathode is connected to a third terminal, and including a resistance across the heater circuit, and a connection from the input and output circuits of the tube to a point on said resistance at which the circuits are so balanced that no fluctuating current will flow through the grid leak.

9. The improved indirectly heated vacuum tube circuit substantially as hereinbefore described and illustrated, for the purpose specified.

Dated the 6th day of December 1929.

For ARCTURUS RADIO TUBE COMPANY.

White, Langner, Stevens, Parry & Rollinson,
Chartered Patent Agents
5—9, Quality Court, Chancery Lane,
London, W.C. 2, and at
17, John Street, New York, U.S.A.

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[This Drawing is a reproduction of the Original on a reduced scale.]

Fig. 1.

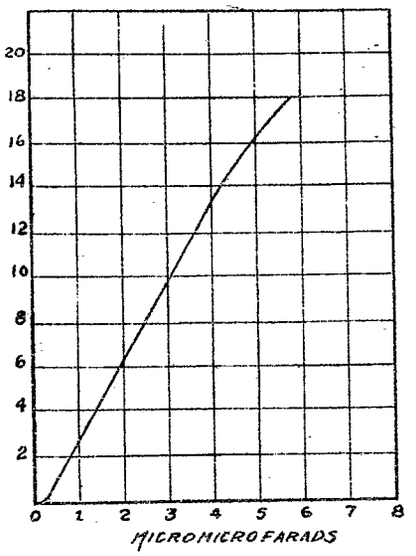


Fig. 2.

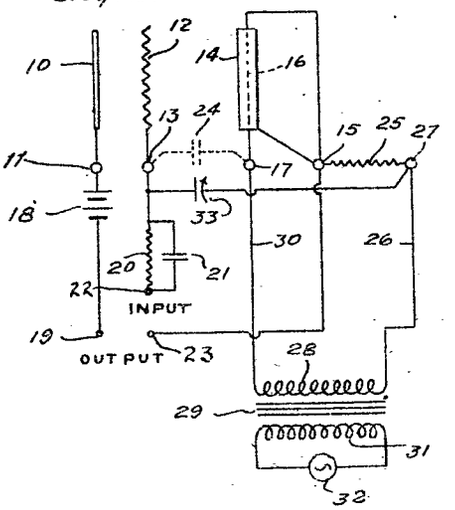
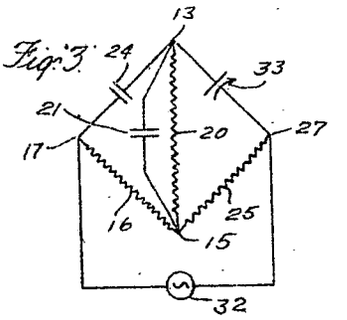


Fig. 3.



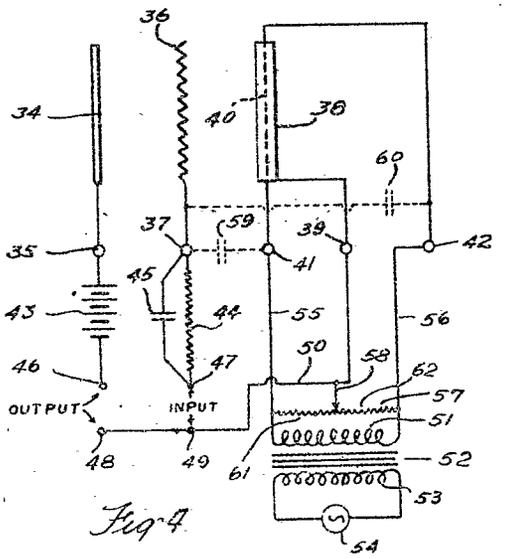
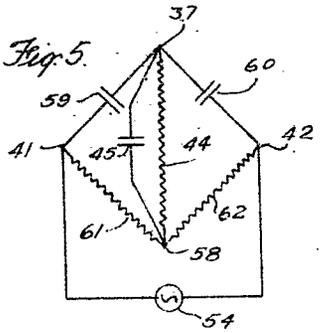


Fig. 4.

Fig. 5.



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