

Jan. 14, 1930.

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1,743,238

VACUUM ELECTRIC TUBE

Filed March 14, 1924

3 Sheets-Sheet 1

Fig. 1.

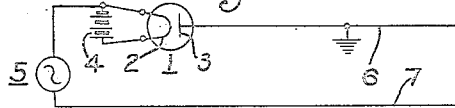


Fig. 2.

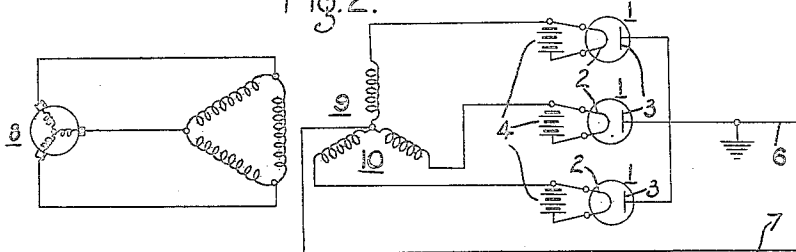


Fig. 3.

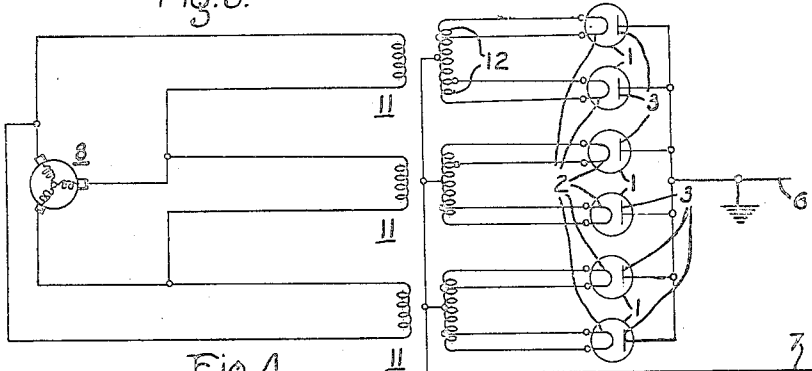
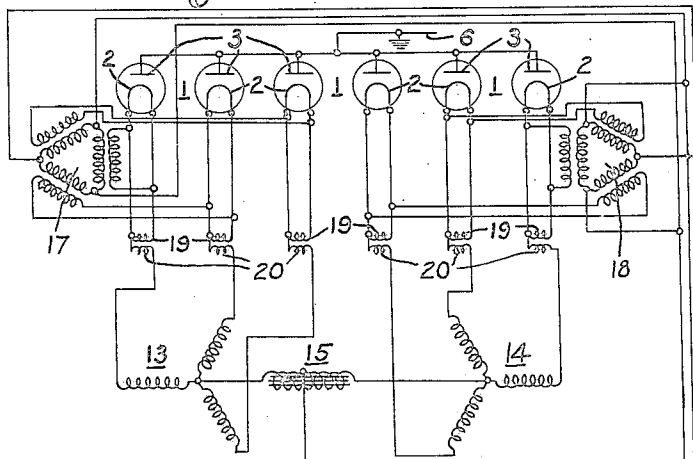


Fig. 4.



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Fig. 5.

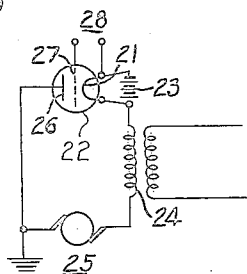


Fig. 6.

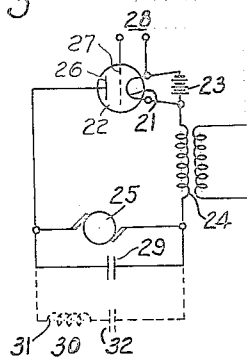


Fig. 7.

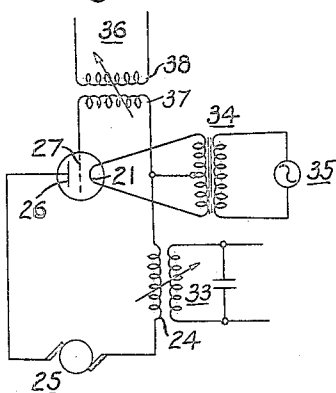
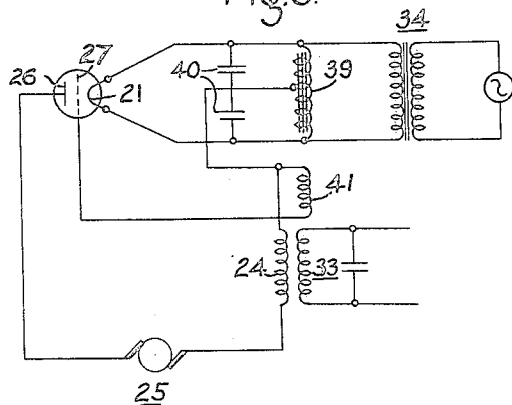


Fig. 8.



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Fig. 9.

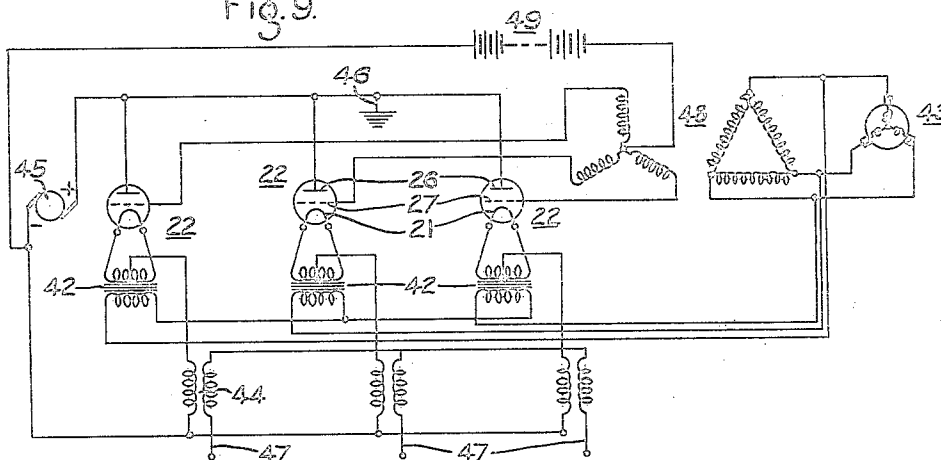
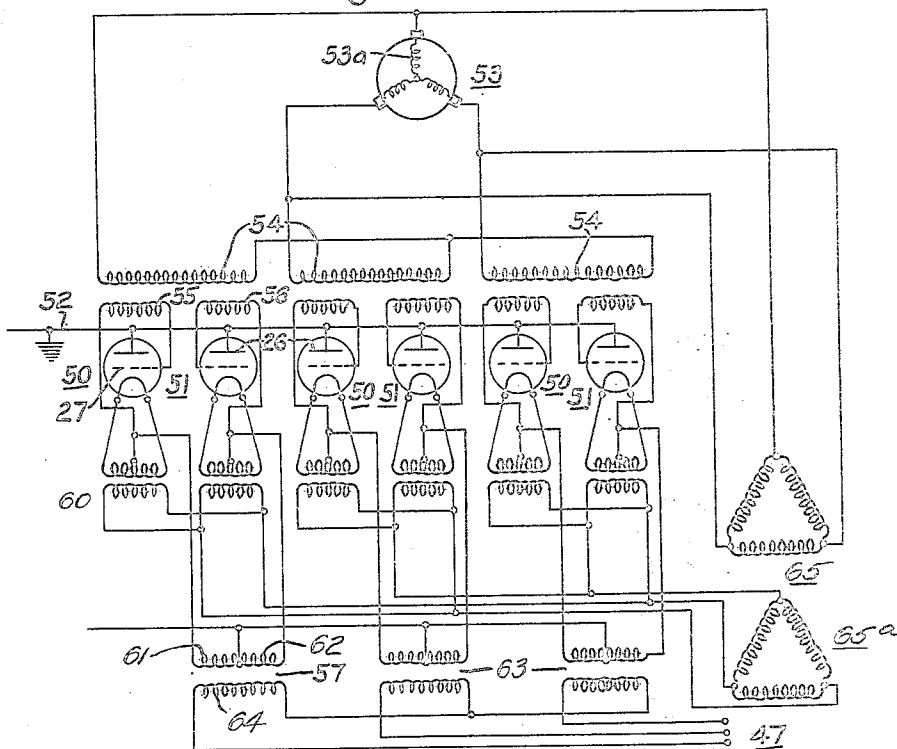


Fig. 10.



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VACUUM ELECTRIC TUBE

Application filed March 14, 1924, Serial No. 699,185, and in Great Britain March 15, 1923.

This invention relates to vacuum electric tubes and more especially to methods of employing vacuum devices such for example as thermionic oscillators and rectifiers, and other electronic devices, mercury arcs, glow discharge devices and the like which may be used for the production of alternating current or the rectification thereof. In these devices there is at least an anode and a cathode. Hitherto it has been the practice to operate such devices so that the anode may be at a considerable potential with respect to earth; generally where one of the electrodes has been earthed the cathode has been the earthed electrode. In order that the capacity of the anode for the dissipation of heat may be increased it is usual in such devices to cool the anode by means of a cooling fluid. Inasmuch as the anode may have a considerable potential with respect to earth it has been necessary to resort to means such as storing the cooling fluid in an insulated reservoir or providing a long thin column of liquid in the inlet and outlet pipes of the cooling jacket. Moreover it is often desirable in these devices to employ metallic casings or envelopes which may serve as anodes and sometimes such devices are continuously exhausted during operation in order that they may deal with a large amount of power and consequently be rendered suitable for industrial engineering purposes. It is therefore necessary to provide for the interposition of one or more insulating breaks between said device and the vacuum pumps in order to insulate the anode from earth. When the devices are constructed in large sizes the insulating breaks impose mechanical difficulties of construction. According to the invention the devices and circuits are so arranged that the anode is always earthed whereby the anode when it comprises a portion of the envelope of the valve may be directly connected to the vacuum pump and the cooling of the anode may be effected in a simple manner. For instance the anode cooling jacket may be fed directly from a water main. Thus, considering the simple case of a thermionic valve employed as a rectifier, the source of single phase alternating current has one terminal thereof connected to the cathode which is heated by any suitable means whilst the other terminal of said source is connected to one conductor of the rectifier current or output circuit the other conductor of which is connected to the anode and is earthed. The first mentioned conductor is thus at a positive potential with respect to the second mentioned conductor and also to earth and the mean potential of the alternating current source is positive and substantially equal to that of the first mentioned conductor. To enable the invention to be clearly understood several arrangements for carrying it into effect will now be described by way of example with reference to the accompanying drawings wherein Figure 1 is an electrical diagram of the simple case of a single-phase rectifier; Fig. 2 is a similar diagram of a three-phase rectifier; Fig. 3 is a similar diagram of a six-phase rectifier; Fig. 4 is a diagram of another rectifying system using half-wave rectifiers; Figs. 5, 6, 7 and 8 are diagrams of arrangements in accordance with the invention for generating single-phase alternating current or oscillations; Fig. 9 is a diagram of an arrangement for generating three-phase alternating current and Fig. 10 is a diagram of another form of generator of three-phase currents, using half-wave rectifiers. In all the figures thermionic valves are diagrammatically illustrated. Such valves may be of various kinds, for instance the cathodes thereof may consist of filaments heated by the passage therethrough of an electric current, or of metal tubes or plates heated by thermionic bombardment; the anode will usually be fluid cooled although not so illustrated and in some cases the valves may be continuously evacuated during operation. Referring first to Fig. 1 of the drawings, 1 is a thermionic valve of the diode type having an incandescent cathode 2 and an anode 3. The cathode 2 is heated from a suitable source of current illustrated in this case as a battery 4. The source 5 of alternating current to be rectified has one terminal connected to the cathode 2 whilst the other terminal is con-

connected to one conductor 7 of the rectified current or output circuit, the other conductor 6 of which is connected to the anode 3 and is earthed as conventionally indicated. The conductor 7 is thus at a positive potential with respect to the conductor 6 and also to earth and the mean potential of the source 5 is positive and substantially equal to that of the conductor 7. It may here be noted in contradistinction to the above that in the arrangements usually heretofore employed the mean potential of the alternating current source is zero with respect to earth or in some cases is at a potential intermediate between the earth potential and that of the rectified current.

Referring to Fig. 2, a source of three-phase current such as a generator 8 is connected to the primary winding of a three-phase transformer 9 the star-connected secondary winding 10 of which has its mid-point connected to one of the conductors 7 of the rectified current circuit. The secondary phase-windings of the transformer 9 are connected to the cathodes of three valves 1, each cathode having a separate source of heating current illustrated in this case as the battery 4. The anodes 3 of the valves are connected to the other conductor 6 of the output circuit which conductor is earthed as indicated. It will be noted that the potential of the star-point, that is to say, the mean potential of the transformer secondary winding will be at the potential of the conductor 7 of the output circuit.

A suitable arrangement for six-phase rectification comprises a three-phase generator connected either through a single transformer or as illustrated in Fig. 3 through three transformers 11 so as to supply six-phase current to the respective cathodes of six valves 1, the mid-points of the three secondary windings of the illustrated transformers being connected together and to the conductor 7 of the output circuit. The anodes 3 of the six valves are connected together and to the other conductor 6 of the output circuit which conductor is earthed as in the arrangements previously herein described. The cathodes 2 of the valves 1 may be supplied with heating current from separate sources such as batteries or transformers as illustrated and described with respect to Figs. 1 and 2 or they may be supplied with current as illustrated in Fig. 3 by connecting them across a few of the end turns of the individual secondary windings of the transformers.

When separate transformers are employed for supplying the filament current it may be arranged that the heating current is 90° out of phase with the space current in order to reduce unequal heating of the filament. Also in any of these circuit arrangements, means may be provided whereby when valves having filament cathodes are employed the space

current is led into the filament equally at both ends thereof, or is led into the filament ends or to the ends and additional taps thereon so that it divides therein in any predetermined ratio as described in the specifications of my British applications Nos. 19,002 of 1923 and 27,182 of 1923.

In the arrangement shown in Fig. 4, two three-phase half-wave rectifiers are employed and the transformer secondary windings 13 and 14 have their respective phases displaced by 180° with respect to one another and the mid-points of these windings are connected to a device for maintaining the rectified current to each transformer substantially constant. This device comprises a reactance coil 15 connected between the two star points of the transformer secondary windings. In practice the two windings 13 and 14 may be wound on the same core and supplied by a common primary winding 16 as will be well understood by those skilled in the art. With two such three-phase half-wave rectifiers of this known type, each rectifying valve functions during one-third of the cycle and at the same time harmonics of the output current are reduced while even harmonics of the alternating input current of the rectifier are eliminated. In the system illustrated the anodes 3 of the valves, of which only one per phase leg is represented, are, according to the invention, all connected together and are connected to earth as indicated at 6. The filaments of the valves are supplied with heating current from transformers 17 and 18 which are energized from the source of current to be rectified such for example as the illustrated alternating-current generator 17^a. In order to reduce unequal heating of the filament when the space current flows the latter is caused to be displaced 90° in phase with respect to the filament current, this result being obtained by suitably connecting individual filaments to the filament heating transformers. The space current may be caused to enter each filament substantially equally at each end thereof by leading the space current to the mid-point of an inductive winding. In the arrangement of Fig. 4 inductances 19 are connected across the filaments and the space current is led into a compensating winding 20 which serves to distribute the space current equally or in any predetermined ratio between the filament lead-in wires while the inductances 19 prevent short-circuiting of the filament heating current as described in the specification of my British application No. 27,182 of 1923.

For the generation of alternating current the filament 21 of a triode 22 (Fig. 5) may be heated from a suitable source such as a battery 23 and connected to a source of negative potential through a transformer winding 24. The source of negative potential may be a direct current generator 25 having its posi-

tive terminal connected to the earthed anode 26 and its negative terminal connected to the transformer winding 24. The transformer winding 24 may be replaced by an inductance or resistance. Alternating potentials from any suitable source 28 are provided between the grid 27 and the cathode 21 in order to produce an alternating or pulsating current in the transformer winding 24. The potential of the cathode being continuously varying it is necessary that the grid potential should be varied with respect to the cathode. The battery 23 may be replaced by the secondary winding of a transformer the primary winding of which may be supplied with current from the output side of the valve. When filaments are thus heated from the output side of the valve generator it is necessary to employ auxiliary means for initially heating the filament and a change-over switch may be provided for switching over from source of heating current to the other and such switch may be automatically operated by the generated current. In addition the space current in the valve may be caused to be 90° out of phase with the filament heating current.

The source of direct current may have connected in parallel with it a condenser, or a tuned admittance which may comprise a series oscillatory circuit tuned to the frequency of the generated current. By such arrangement the alternating component of the space current may be short-circuited through the source of direct current. Thus, in Fig. 6 the generator 25 is connected in parallel with the condenser 29 and with a tuned admittance 30, comprising the inductive winding 31 and the condenser 32. Either the condenser 29 or the tuned admittance 30 may be omitted.

It may be arranged that the space current is led in through filament taps in any predetermined ratio.

Fig. 7 illustrates an arrangement in which the space current is led in equally to the filament by making a space current tap to the mid-point of the secondary of the filament heating transformer. The cathode 21 is connected as previously described to the negative terminal of a direct current generator 25 the connection being made through an inductance 24 which may be coupled to an oscillatory circuit 33. The circuit 33 may for example be a wireless antenna. A condenser or a tuned admittance may be connected in parallel with the generator as previously herein described. The connection of the inductance 24 with the cathode is preferably made as illustrated to the mid-point of the secondary winding of the transformer 34 the primary winding of which is supplied by means of an alternating current generator 35. The two halves of the secondary winding of the transformer 34 may be shunted by means of condensers in the manner similar to that herein-

after described with reference to Fig. 8. Referring again to Fig. 7 the controlling oscillations for the valve are derived from a suitable source and may be transferred to the grid 27 by means of a transformer 36 one end of the secondary winding 37 of which is connected to the grid and the other end thereof to the mid-point of the secondary winding of the transformer 34 whilst the primary winding 38 is connected to the source of controlling operations.

The oscillatory circuit 33 is preferably resonant to the produced oscillation in which case the grid may be excited by means of a back coupling from the oscillatory circuit 33. An alternative method of coupling the output circuit to the filament consists in connecting the anode inductance to the mid-point of a choke coil 39 which is connected across the filament 21 which is supplied by means of the transformer 34 as indicated in Fig. 8, the two portions of the choke coil 39 being shunted by means of condensers 40 if desired. With this arrangement current is led-in equally at both ends of the filament. Any other method of controlling the distribution of space current to the filament leads may be employed. If on the other hand the cathode comprises a metal tube heated by bombardment from an auxiliary member it will be understood that it is not necessary to lead-in the space current equally at the ends of such a cathode. In Fig. 8 also a back coupling coil 41 is provided whereby the grid 27 may be excited from the output current of the oscillation generator.

The arrangement illustrated in Fig. 9 is suitable for the generation of three-phase current and comprises three triode valves 22 the cathodes 21 of which are heated by current derived from transformers 42 which are supplied with three-phase current from a three phase alternator 43 which may also serve to excite the grids 27 of the valves as will be hereinafter described. The filaments 21 are connected from the mid-points of the secondary windings of the transformers 42 through the respective primary windings of other transformers 44 to a source of negative potential such as the direct current generator 45 the positive terminal of which is connected to the anodes 26 which are earthed as indicated at 46, the secondary windings of said second mentioned transformers being connected to the three-phase output current circuit the phase conductors of which are indicated at 47. The grids 27 of the valves are supplied with alternating electromotive force from the alternator 43 by way of a transformer 48 the secondary phase windings of which are connected to the respective grids. The mean voltage of the grids may be adjusted by regulating the potential of the star-point of said secondary winding by means of a battery 49 connected between the star point and the

negative terminal of the direct current generator 45. Alternatively the necessary grid biasing voltage may be obtained by connecting the aforesaid star point through a high resistance either to earth or to the negative terminal of the generator 45, such resistance being preferably variable so that it may be adjusted as the insulating resistance of the transformer 48 varies. It may for example be adjusted by means of an automatic relay operated by the mean voltage at the star point.

It will be noticed that to produce a given output the voltage applied to the grids when operated as above described will require to be many times that which is necessary in valves as usually employed. If the voltage amplification factor of the valves is V then the grid voltage must be $V+1$ times the amplitude necessary in a valve as operated according to the usual method. In order to reduce the grid voltage necessary each grid may be connected to its filament and the electromotive force to operate the devices may be produced therein by means of a transformer as will be hereinafter described. In the arrangement above described the valves must operate substantially at the mid-points of their characteristics and the operation is therefore not efficient.

In the arrangement shown in Fig. 10 for the generation of three-phase current, three groups of two valves coupled back to back are employed, that is to say, one group per phase. Thus the two valves 50 and 51 operate alternatively and supply the current of one phase to the output circuit 47. The anodes 26 of the valves 50 and 51 are coupled together and to the anodes of the other valves and are connected by means of a conductor 52 to earth, as indicated. The grid potentials are derived from the local three-phase alternator 53 which supplies the primary windings 54 of three transformers each having two secondary windings 55 and 56. The secondary winding 55 is connected at one end to the grid 27 and at the other end to the filament preferably as shown, through the mid-point of the secondary winding of the corresponding filament heating transformer 60. Any other connection to the filament may be employed which ensures that the average grid voltage is independent of the filament voltage. The secondary winding 56 of the transformer 54 is similarly connected to the valve 51.

The output current from the valve 50 and 51 flows alternatively in the two half windings 61 and 62 of a transformer 63 in the secondary winding 64 of which is produced the alternating current. By means of the six valves, the three-transformers 54, the six transformers 60, and the three transformers 63, three-phase power is supplied to the output circuit 47. As in the other arrangements herein described it may be arranged that the filament heating current is 90° out of phase

with the space current in the valves and for this purpose a common generator may be employed for supplying the grid potentials and also the filament current. The filament current is supplied through a three-phase transformer 65 the secondary winding of which is connected to the filaments and the primary winding of which is energized by the generator 53. Considering for example the pair of valves 50 and 51, they are supplied with grid potential derived from the phase winding 53^a of the generator 53 the filament current being derived from the leg 65^a of the secondary winding of the transformer which is delta connected and therefore since the alternator is star wound the electromotive force induced in the phase winding 53^a will be 90° out of phase with the current flowing in the winding 65^a. If the load on the valve generator is mainly resistive the space current will be substantially 90° out of phase with the filament heating current.

It will be understood that the invention is not limited to the arrangements specifically herein described and illustrated which are given by way of example only. It will be further understood that the invention in its application to systems of generating alternating current may be operated in combination with a device employing other methods of controlling or periodically interrupting the space current. For example a valve of the type employing a substantially pure electron discharge in which the space current is controlled by the magnetic field produced by the current flowing in a control element may be employed instead of an electron discharge device of the type illustrated, in which the current in the device is controlled by the potential of a control element.

I claim as my invention:—

1. An electrical system for generating poly-phase alternating currents having in combination, a plurality of vacuum electric tube devices the space current in each of which may be controlled by a control electrode, a source of direct current, an output circuit and means for supplying space current controlling electromotive forces to said control electrodes, characterized by the fact that the anodes of the tube devices are connected directly to earth and the output circuit and the source of direct current are connected in series, one terminal of the source being connected to the cathodes of the tube devices and the other terminal to earth.

2. An electrical system for generating poly-phase current as claimed in claim 1, wherein space current controlling electromotive forces are supplied from the secondary winding of a polyphase transformer and a source of biasing electromotive force connected to the neutral point of said transformer.

3. An electrical system as claimed in claim 1, in which the space current controlling elec-

tromotive forces are supplied from the secondary winding of a polyphase transformer, the neutral point of which is connected to a source of biasing electromotive force comprising a resistance connected to a convenient point of the system for the purpose set forth.

4. In an electrical system, a plurality of vacuum-tube devices, water-cooled electrodes, at least one in each of said devices, said water-cooled electrodes being directly and immediately connected to earth, whereby they are maintained at earth potential, said system including means for producing other potentials at other portions of the system.

5. In a polyphase electrical system, a plurality of vacuum-tube devices, at least one in each phase of the system, an anode in each vacuum-tube device, means directly and immediately connecting all said anodes together and to earth, whereby they are maintained at earth potential, a source of polyphase potential, means energized from said source for producing alternating potential-differences between the filaments and grids of the respective devices, the said potential difference being supplied from different phases of said source in the devices in the respective different phases of the system.

6. An oscillation-generation system comprising a thermionic device having a cathode, an anode and a control electrode, means for supplying the anode of said device with positive potential, and means whereby the said anode is directly connected to ground.

7. An oscillation-generation system comprising a plurality of thermionic devices each having a cathode, an anode and a control electrode, a high-potential source, a direct connection between the positive terminal of said source and the anodes of said devices, an individual connection from the negative terminal of said source to each of the cathodes of said devices, each of said connections including an output inductor, means for heating the cathodes of said devices from an alternating-current source, means for energizing the grids of said devices from said source, and a direct connection from ground to the common connection to said anodes.

8. In an electrical system, at least one thermionic device having a cathode, an anode and a control electrode, means for applying a high positive potential to said anode with respect to said cathode, means for impressing appropriate potentials on said control electrode whereby the system will generate oscillations, and a direct connection between the anode and ground.

9. In an electrical system, at least one thermionic device having a cathode, an anode, and a control electrode, means for impressing a high positive potential on the anode of said device with respect to the cathode thereof, means for coupling the input and output circuits of said device for the generation of oscillations, and means whereby the anode of said device is maintained at ground potential.

In testimony whereof I have hereunto subscribed my name this 29th day of February, 1924.

ERNEST YEOMAN ROBINSON.

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