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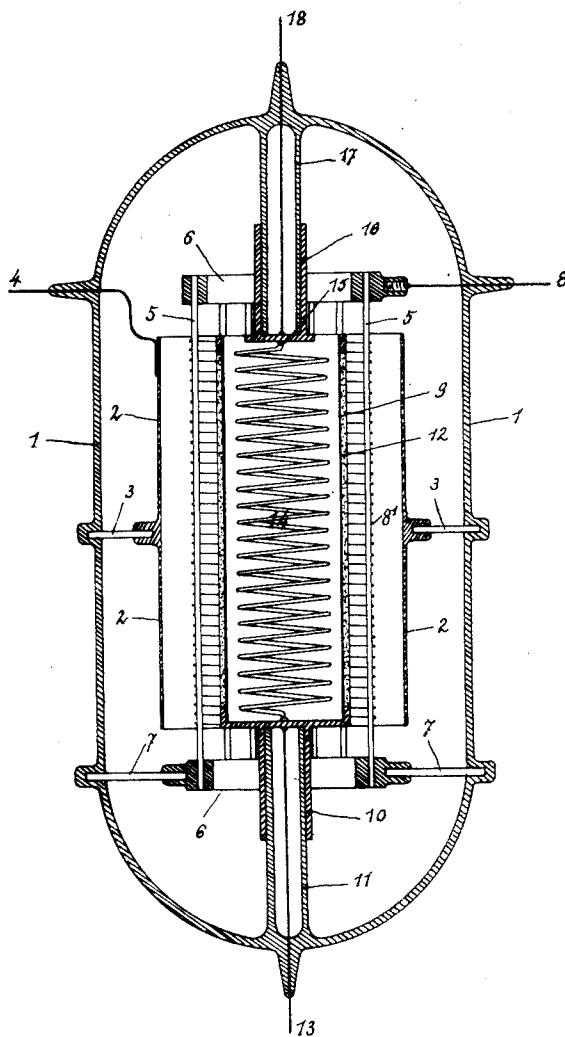
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ELECTRON TUBE

Filed March 22, 1921

3 Sheets-Sheet 1

Fig. 1



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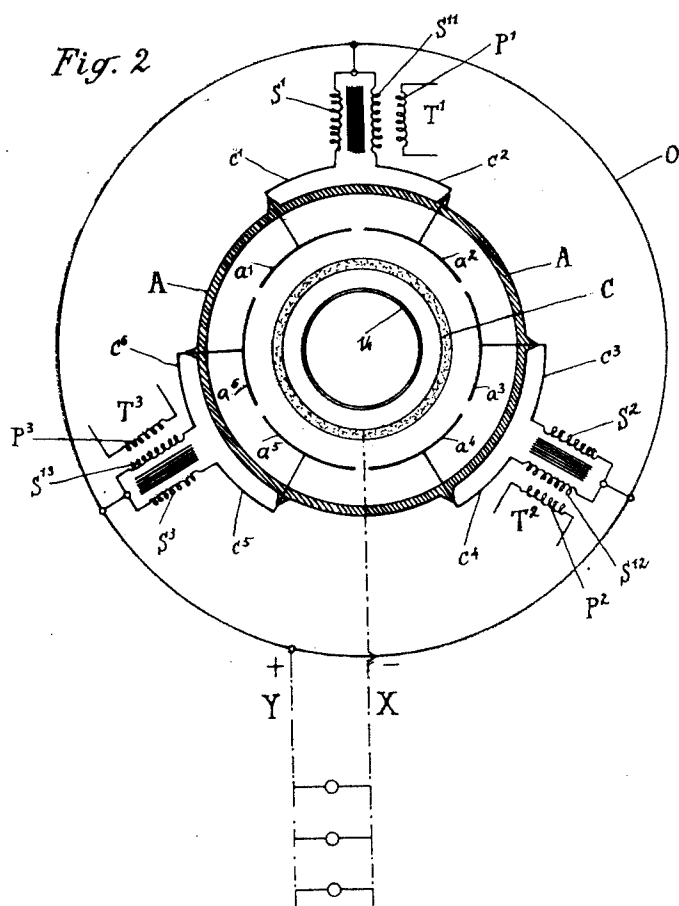
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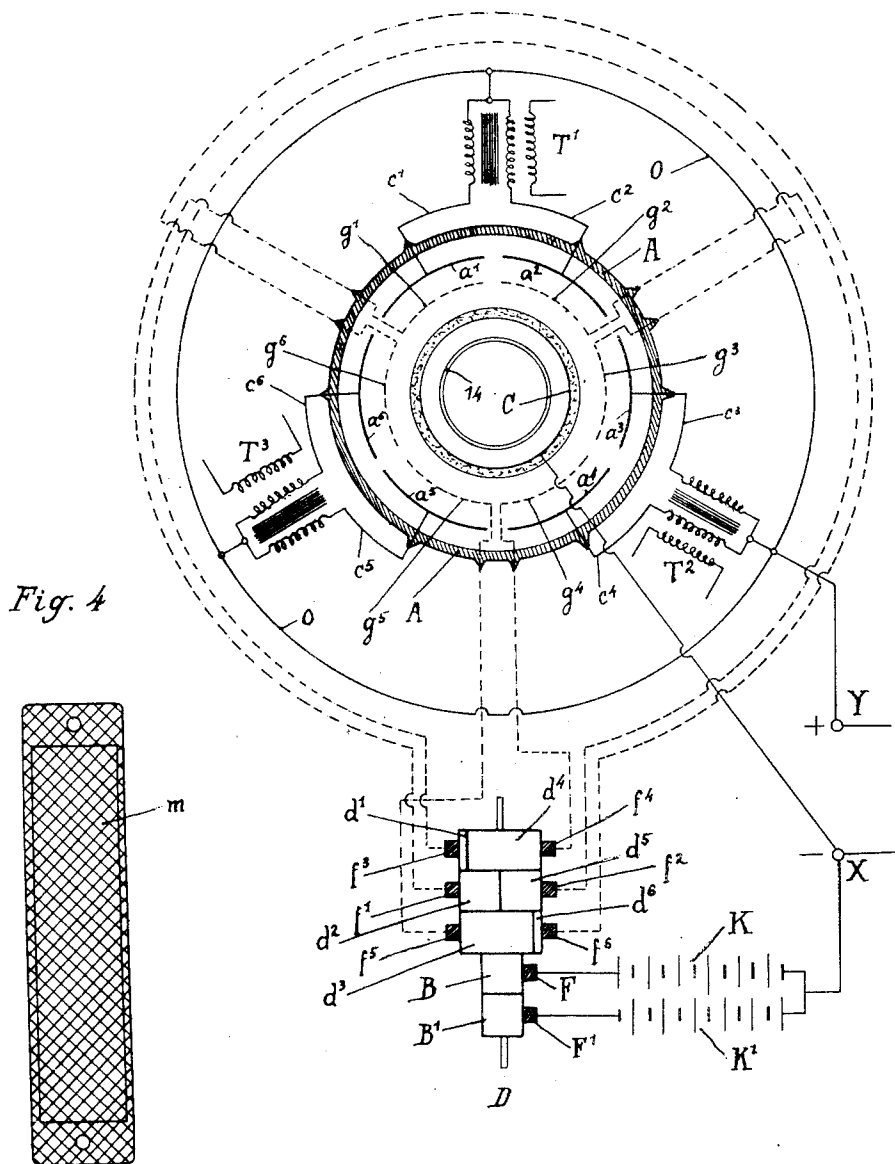
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Fig. 3



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UNITED STATES PATENT OFFICE.

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ELECTRON TUBE.

Application filed March 22, 1921. Serial No. 454,359.

To all whom it may concern:

Be it known that I, CHARLES LÉONARD ARMAND MAURICE LEBLANC, a citizen of the Republic of France, residing at Paris, France, engineer, have invented certain new and useful Improvements in and Relating to Electron Tubes; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, and to letters or figures of reference marked thereon, which form a part of this specification.

This invention relates to electron tubes and has for its object to provide an improved tube with two or three electrodes for large outputs. This tube, in which the vacuum is made as high as possible, possesses the feature that the cathode is in the form of a hollow cylinder, and is heated by radiation from a resistance disposed in the interior of the cylinder and raised to incandescence.

Further, the exterior surface of the cathode is covered with metallic oxides such as become permeable to the electrons, which they enclose, at the lowest temperature possible. The grid and the anode are in the form of cylinders co-axial with that of the cathode which they surround and consist of a metal which is impermeable to the electrons at the temperature at which the cathode should operate; the cylinder constituting the anode being carefully polished both inside and out. The grid may be dispensed with in certain cases.

This electron tube with the two or three electrodes may be employed in numerous applications; especially it may be used for transforming industrial currents, that is to say, large currents, and thus polyphase alternating currents may be transferred into direct currents or direct currents into alternating currents of any frequency whatever and variable as desired. For this purpose certain modifications may be made as hereinafter described.

The following description with reference to the accompanying drawing by way of example will enable the features of the said tube and the manner in which it is constructed to be understood.

Figure 1 is a vertical section of an electron tube or bulb constructed in accordance with the invention.

Figure 2 shows, in a section perpendicular to its axis, a two electrode tube or "valve" for transforming triphase currents into direct currents and also the connections for effecting this transforming.

Figure 3 is a similar section of a three electrode tube constituting a "triple valve" and designed to transform continuous current into triphase currents by means of the installation diagrammatically represented in this figure.

Figure 4 shows a metallic frame for the grid element.

The bulb 1 which incloses the three electrodes (viz, anode, cathode, and the intermediate electrode called the grid) as represented in Figure 1, may be of glass, quartz, or metal, and in the figure it is assumed to be of glass. It should be exhausted as highly as possible so that the current can only be transmitted from the anode to the cathode by the electrons emitted by the latter without the risk of producing ions.

The anode comprises a metal cylinder 2, for example of iron, supported by pins of highly refractory enamel 3, 3 which are fused into the walls of the bulb. The cylinder is connected with the exterior by a conductor 4 and the internal and external surfaces are highly polished.

The grid consists of a "squirrel-cage", the bars 5, 5 of which, may be of tungsten. The extremities of these bars are fitted into two metallic rings 6, 6 which are supported, like the anode, by pins of enamel 7, 7. One of the rings 6 is connected with the exterior by a conductor 8.

On the bars 5 of this cage is wound a helix of strongly refractory and very thin metal wire. This helix constitutes the actual grid and the bars of the cage only serve to support it.

The cathode consists of a hollow cylinder 9 of iron or any other difficultly fusible metal. The base of the cylinder 9 is provided with a stem 10, also of cylindrical form, which surrounds an insulating tube 11 permanently attached to the envelope or bulb 1 and consisting, in the example shown, of a glass tube which is fused to the wall of

the bulb. The cylinder 9 is thus supported and maintained in position.

The exterior of the cylinder 9 is covered with a layer 12 of metallic oxide, for example, oxide of barium, and the inner surface is covered with lamp black. The bottom of the cylinder is connected with the exterior by a conductor 13.

Within the cylinder 9 is arranged a resistance 14 of iron or other metal wire the resistance of which increases rapidly with the temperature. The wire employed is coated with lamp black. One end of the resistance wire 14 of its ends is connected to the bottom of the cylinder 9 and it is thus connected with the exterior by the conductor 13. The other end of the wire 14 is connected to a metallic plate 15 constituting the bottom portion a cylinder 16 surrounding an insulating tube 17 which is fixed to the wall of the bulb. The plate 15 is connected with the exterior by conductor 18.

A current is passed through this resistance by means of a source of electricity in a local circuit between the conductors 13 and 18 and it is in this way raised to incandescence. It heats the cathode by radiation and permits the same to emit the electrons necessary for allowing a current entering the bulb by the conductor 4 to pass from the anode to the cathode and leave by the conductor 13.

The particular arrangements of this bulb with three electrodes have been adapted for the followings reasons:—

The cathode has a large surface to permit it to conduct currents sufficiently large to be measured in amperes rather than milliamperes as in actual tubes wherein the cathode consists of a simple filament. In the latter, the same filament serves for conducting the current which heats it and the current which the anode conducts and the intensity of which would be notably variable with the consumption requisite in industrial apparatus.

As the temperature of the cathode should remain substantially constant, this arrangement is only admissible if the intensity of the current entering the anode remains very weak in relation to the strength of the heating current. This is easy when the anode transmits only a few milliamperes but if it conducts current of considerable intensity, it would be necessary to pass through the walls of the bulb a heating current of very great strength, furnished, it is true, at a very low pressure. But it would be very difficult to make it pass through the walls of the bulb.

It is then necessary to cause the heating current to pass in a special circuit. Since all insulators become conductors at high temperature, the cathode cannot be heated by the resistor 14 by thermal conduction by

insulating the cathode 9 from the resistor. This is why in the three electrode bulb of this invention, the cathode is heated by radiation, and for facilitating this heating, the interior walls of the hollow cylindrical cathode and the surface of the resistance wire arranged inside it are coated with lamp black.

The resistance 14 constitutes an actual thermometer and by measuring its resistance, the temperature inside the cathode can be deduced. In employing, therefore, a wire of iron or any other metal having a high temperature co-efficient, an automatic regulation of the strength of the heating current is obtained, the intensity thereof rapidly diminishing when the temperature rises if a constant potential is maintained between the two ends of the resistance.

The surface of the cathode is covered with metallic oxides which, on becoming conductors under the influence of the heat, emit the electrons. These oxides actually emit large quantities of electrons at relatively low temperatures, such as a dull red heat, whereas the metals remain practically impermeable to the electrons. It is thus possible to make, for example, a tungsten wire grid completely incapable of emitting electrons even if it is at the same temperature as the cathode.

On the contrary, if the cathode were entirely of metal it would be necessary that it should be very hot in relation to the grid and much more so with respect to the anode. There would then be a big flow of heat from the cathode from which a considerable loss of energy would result since a metallic cathode should be raised to a temperature of at least 2000° C.

In the arrangement of the tube according to the invention, not only does the cathode emit less heat because it is much lower in temperature but most of the heat can be returned to the cathode by making the interior surface of the anode highly reflecting.

The bombardment of the anode by the electrons will tend to heat it. The quantity of heat thus evolved will be small as the difference in potential between the anode and the cathode, when a current passes from one to the other, will always be very small in these tubes and the electrodes can be brought closer together on account of the enormous electrostatic rigidity of high vacua. The intensity of the field will, in effect, be the smaller as there will be fewer electrons liberated between the anode and the cathode and consequently they will be nearer together. The heating of the anode will tend to raise the temperature of the cathode but it will result in a diminution of the heating current which will rapidly limit the increase of temperature.

Thus, in expending very little heat a cathode capable of high electron emission will be maintained hot. This will permit a large output to be obtained provided a moderate quantity of energy is transmitted by means of this emission. This tube with the three electrodes and wherein the grid has substantially the same temperature as the cathode, with currents of low tension, can thus be used industrially.

On the other hand, if the coating of oxide is not used and if a cathode consists of a hollow cylinder of pure metal but heated in the same manner, a good yield could only be had by employing very high tension currents.

With this three-electrode tube it is possible to obtain all the effects obtainable with the audions of wireless telegraphy, yet the apparatus gives greater power and excellent yield while being of small dimensions.

If the grid is connected to the anode by a very high resistance, all current from the anode to the cathode will traverse the tube without having to surmount any appreciable resistance, provided that its intensity is inferior to that of the saturation current of the cathode. No current in the reverse direction can pass through the tube, unless it has an unusually high tension, the electrostatic rigidity of the space between the cathode and the anode may reach a million volts per centimetre in the vacua such as are known to be obtainable in tubes. An electric valve is thus obtained.

If the tube does not have to be employed for other purposes, it is useless to provide it with a grid and the one represented in Figure 1 may therefore be omitted and a bulb with two electrodes, anode and cathode, is thus obtained.

If, while a current is passing from the anode to the cathode, the grid is isolated, or better, if it is rendered negative with respect to the latter, the emission of electrons is suppressed and the current immediately arrested. It can be re-established by giving to the grid a positive potential with respect to the cathode, for example, by connecting it to the anode through the intermediary of a high resistance. As the capacity of the grid is extremely small the quantity of energy expended for charging it is practically nil and an actual electric "gate" is thus obtained, the operation of which does not require the expenditure of any quantity of work and which when it is open, only causes an insignificant loss of current.

Finally, by gradually varying the charge of the grid, the output of the anode may be varied.

It will be understood that the method of

construction represented in Fig. 1 is only given by way of example. It may be varied indefinitely provided the essential features of the invention as above described are retained.

By means of certain simple modifications the bulb may be used either for transforming polyphase alternating-currents into direct-current, or, for transforming a direct-current into alternating-currents the frequency of which may have any value and may be varied as desired.

For example, if it is a question of transforming triphase currents into direct-current, the grid in this case is of no use and valve is made of a tube with two electrodes, anode and cathode, such as that shown in Fig. 2 which is a section at a plane perpendicular to the axis of the bulb designated A. No changes are made in the arrangements of the cathode except that the cylinder constituting the anode is split up into six equi-distant surfaces. There are thus six elementary anodes $a^1, a^2, \dots, a^6$ connected individually with the exterior by six conductors $c^1, c^2, \dots, c^6$.

Three similar transformers T^1, T^2, T^3 are connected to the apparatus, each of which is provided with two secondary windings $S^1, S^{11}, \dots$ having the same number of turns and as closely linked with the corresponding primary circuits P^1 as possible, the connections, however, being crossed in such a manner that they behave as if they were oppositely wound.

The ends of the windings S^1, S^2, S^3 are connected to the conductors c^1, c^2, c^3 , respectively and the ends of the windings S^{11}, S^{12}, S^{13} are connected to the conductors c^2, c^4, c^6 . All the outer ends of the six secondary windings $S^1, S^{11}, \dots, S^{13}$ are connected to a neutral point 0.

To the cathode and the neutral point are connected two conductors X and Y across which are connected the devices which utilize the continuous current. The primary circuits P of the three transformers T^1, T^2, T^3 are connected either in star or delta to the three leads of the system supplying alternating-currents to the transformer.

For example, considering the transformer, the secondary circuits of which are connected to the conductors c^1 and c^2 , it tends at each instant to cause a current to pass in one direction through the circuit S^1 and a current in the opposite direction in the circuit S^{11} , the direction of the currents being reversed at the end of each half period of the alternating-current. But the current being only able to traverse the tube in passing from an anode to the cathode, only one of the circuits S^1 and S^{11} yields a current at a given moment. During a half-period of the alternating-current it is the circuit S^1 which yields; during the succeeding half-

period it is the circuit S^{11} , and so on; but the currents which traverse them always go from the neutral point to the cathode C.

The same phenomena are reproduced in the two other transformers at the end of times respectively equal to one-third and two-thirds of the duration of the period of the alternating-current above described. There will then be currents always traversing the circuits between the service conductors X and Y in the same direction.

If, on the other hand, it is desired to transform direct-current into three-phase alternating-current, it is necessary to make a triple "tap" with a tube having three electrodes, and for this purpose the modification represented in Fig. 3 is used.

To the apparatus represented in Fig. 2 with the three transformers, is added a grid divided also into six elements $g^1, g^2, g^3, g^4, g^5, g^6$. The grid elements g^1 and g^2 cover the two anodes connected by the conductor c^1 and c^2 to the two secondary circuits of a transformer.

These grid elements may consist, for example, of metal frames, such as illustrated in Fig. 4, upon which is stretched a metal fabric m soldered to the edges of the frames.

The upper and lower parts of the frames are fixed to the walls of the bulb A either by means of the conductors by which they are connected with the exterior or by pins sealed in the glass, as are those in Fig. 1.

A commutator device D is added which comprises:—

1. Six half rings d^1, d^2, d^3 , and d^4, d^5, d^6 connected in pairs, the two half rings of one group being separated by insulators situated in one diametrical plane; passing from one pair of rings to the next, this diametrical plane is displaced by 120° . The rings d^1, d^2, d^3 are thus successively displaced by 120° and also the rings d^4, d^5, d^6 .

2. Two rings B and B¹ to which two brushes F and F¹ respectively are applied. The ring B is electrically connected with the rings d^1, d^2, d^3 , and the ring B¹ with the rings d^4, d^5, d^6 , for example, by means of internal conductors (not shown).

On the rings $d^1, d^2, d^3, d^4, d^5, d^6$, are applied six brushes, three of which f^1, f^2, f^3 are in one line while the other three f^4, f^5, f^6 are in a line diametrically opposite, and are connected respectively to the corresponding grid elements, as shown in the diagram. The brush F of the ring B is connected through a battery K to the cathode, which renders the brush positive with respect to the cathode, as well as all the conductors with which it is in connection while the brush F¹ of the ring B¹ is connected through a battery K¹ to the cathode, and renders the brush F negative with respect to the cathode, as well as all the conductors with which it is in connection.

Considering now the grid elements g^1 and g^2 , at each instant one will be positive with respect to the cathode and the other negative; if the commutator is given a half turn, the element which was positive becomes negative and conversely.

Now, a source X, Y of electromotive force tends to drive a current always in the same direction from the neutral point 0 to the cathode; it can only pass the positive grids and is stopped by the negative grids. This current can then always pass one of the two circuits S¹ or S¹¹ and so on, of the same transformer, but never the two at the same time. If the commutator is rotated the current will traverse the several circuits successively but these circuits being wound oppositely the currents induced in the circuit P¹, which has become the secondary circuit, will be the same as if they were only a single primary circuit S traversed by an alternating current.

The circuit P¹ of the transformer T¹ will thus become the seat of an alternating electromotive force of frequency equal to the speed of rotation (expressed in revolutions per second) of the commutator which is caused to turn at the desired speed (which may be varied as required) by means of any small motor (not shown).

The circuits P² and P³ of the transformers T², T³ will be the seat of alternating electromotive forces of the same frequency, and the same effective magnitude, but successively displayed by 120° .

Finally, if it is desired to transform alternating currents of a given frequency to alternating currents of another desired frequency, a "valve" system as is shown in Fig. 2, is associated with a derectifying system, such as is shown in Fig. 3.

The "valve" system will transform the former currents into a direct current and the derectifying system will transform the latter into alternating currents of the desired frequency.

It will be understood that the several applications have been given by way of example only, and that the invention may be used in still other ways. For example, the invention may be adapted for circuits of any number of phases by merely changing the number of sets of grid and plate elements and their associated adjuncts to correspond to such number of phases.

What I claim is:

1. A thermionic device comprising an evacuated bulb, a cylindrical metallic cathode contained therein and having the inner surface thereof provided with a coating of lamp black, an anode associated with said cathode, and means for heating said cathode by thermoradiation only.

2. A thermionic device comprising an evacuated bulb, a tubular cathode contained

therein, and an electrically heated element disposed within said cathode and having one end thereof directly electrically connected with said cathode, said heated element
 5 being provided with a coating of lamp black.

3. A thermionic device comprising an evacuated bulb, a tubular cathode contained therein and having its inner surface coated with lamp black and its outer surface coated
 10 with a metallic oxide, and a heating element disposed within said cathode and having a coating of lamp black.

4. A thermionic device comprising an evacuated bulb, a cathode contained therein,
 15 means for heating said cathode, a pair of anodes associated with said cathode, a pair of grid elements each disposed between an anode and said cathode, means for alternately connecting said grid elements to independent sources of continuous current,
 20 whereby they are given a predetermined and fixed potential either positive or negative with regard to the cathode, and means for connecting a direct current circuit between
 25 said cathode and said anodes.

5. A thermionic device comprising an evacuated bulb, a cathode contained therein, means for heating said cathode, a pair of anodes associated with said cathode, a pair
 30 of grid elements each disposed between an anode and said cathode, means for alternately connecting said grid elements to independent sources of continuous current, whereby they are given a predetermined and
 35 fixed potential either positive or negative with regard to the cathode, and a transformer having a single primary winding and a pair of equal and oppositely wound secondary windings, one end of each of said
 40 secondary windings being connected to one of the said pairs of anodes and the other

end of said secondary windings being connected to said cathode through a direct current circuit.

6. A device of the character described for
 45 converting a direct current into n phase alternating current of a desired frequency comprising an evacuated bulb, a cathode contained therein, means for heating said
 cathode, n pairs of anodes associated with
 50 said cathode, a pair of grid elements disposed between each pair of anodes and said cathode, and means for alternately rendering the respective grid elements of each pair
 positive and negative with respect to said
 55 cathode at the desired frequency.

7. A device of the character described for converting a direct current into n phase
 alternating current of a desired frequency comprising an evacuated bulb, a cathode
 60 contained therein, means for heating the said cathode, n pairs of anodes associated with said cathode, a pair of grid elements disposed between each pair of anodes and said cathode, means for alternately rendering
 65 the respective grid elements of each pair positive and negative with respect to said cathode at the desired frequency, and n transformers each having a single primary
 winding in which are produced the converted
 70 n phase currents, and a pair of equal and oppositely wound secondary windings, one end of each secondary winding being connected to one of the said pair of anodes, and all of the other ends of the secondary
 75 windings being connected together and to the positive side of a direct current circuit, the cathode being connected to the negative side of said circuit.

In testimony that I claim the foregoing
 80 as my invention I have signed my name.

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