J. E. LILIENFELD.

PROCESS AND APPARATUS FOR PRODUCING ROENTGEN RAYS.

APPLICATION FILED OCT. 2, 1912.

1,122,011.

Patented Dec. 22, 1914.

4 SHEETS—SHEET 1.

Fig. 1.

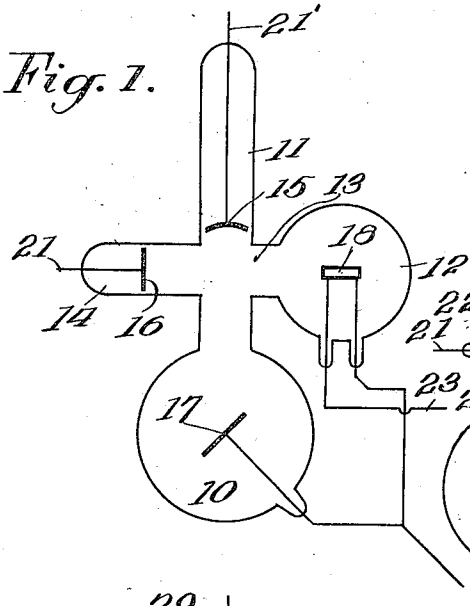


Fig. 2.

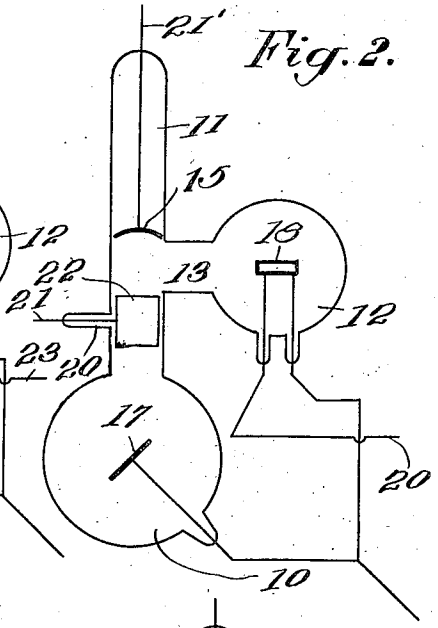


Fig. 3.

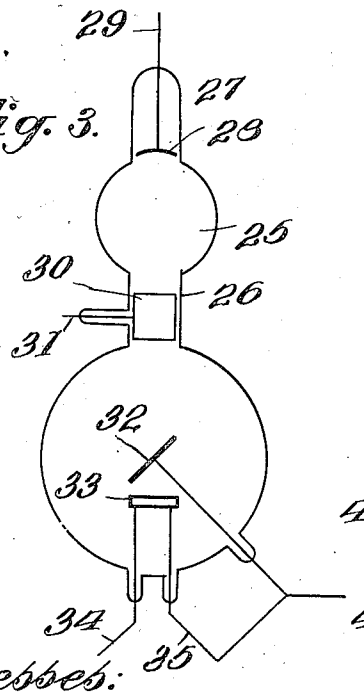
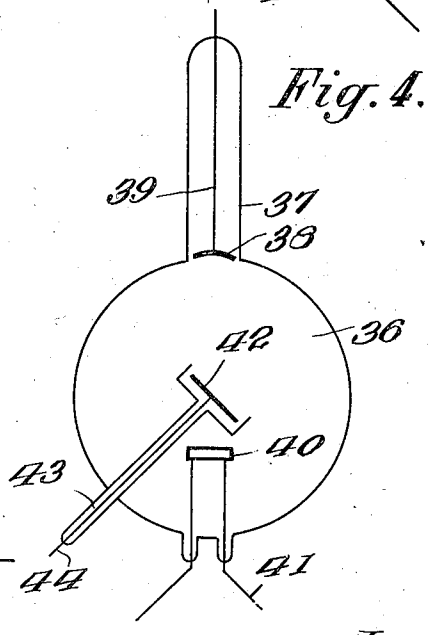


Fig. 4.



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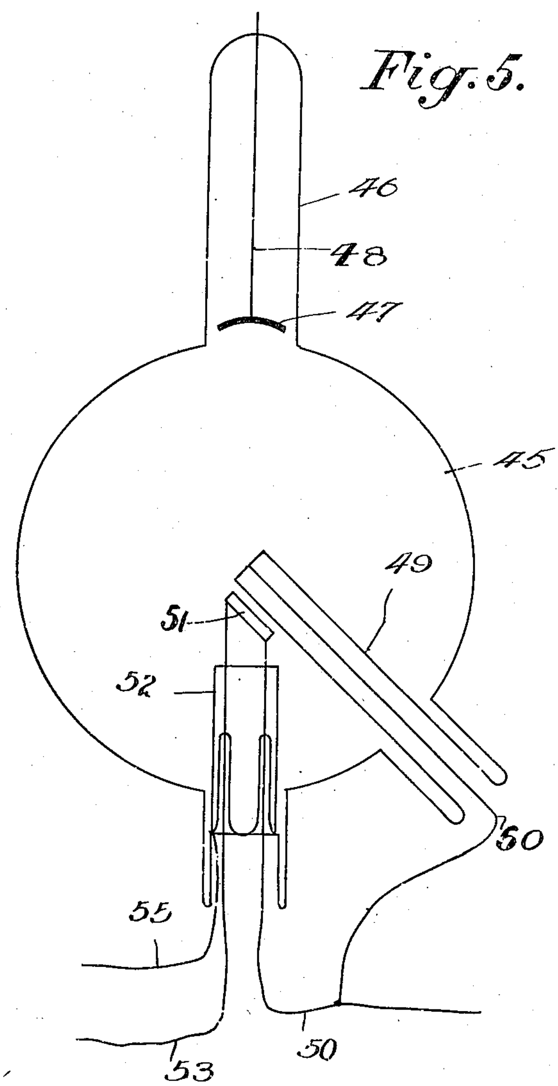
4 SHEETS—SHEET 2.

Fig. 5.



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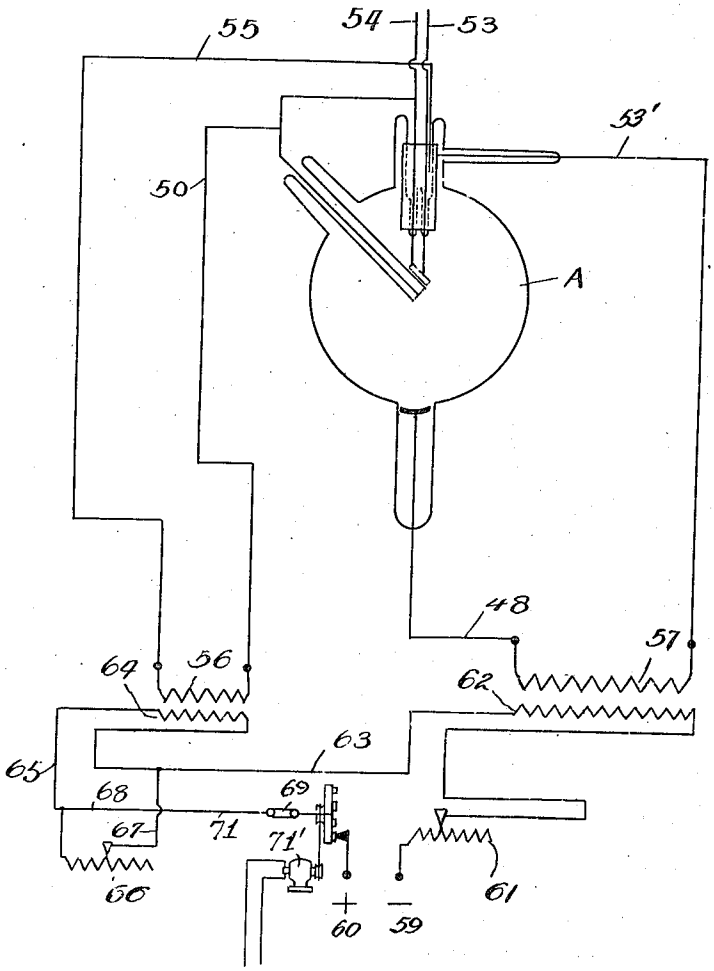
4 SHEETS—SHEET 3.

Fig. 6.



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4 SHEETS—SHEET 4.

Fig. 7.

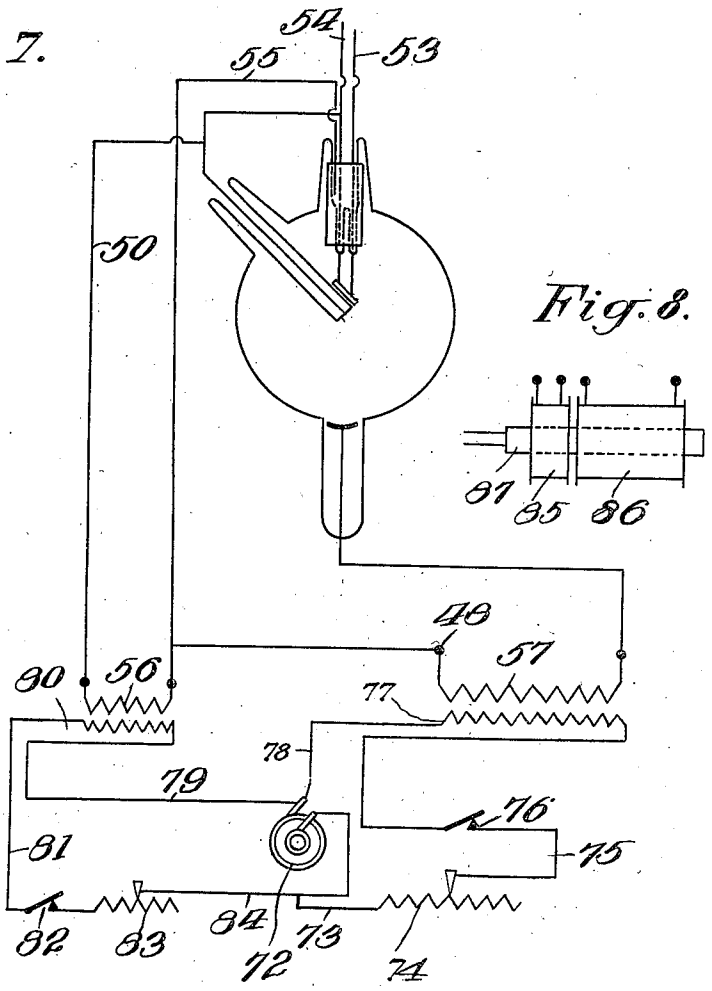

Fig. 8.

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UNITED STATES PATENT OFFICE.

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PROCESS AND APPARATUS FOR PRODUCING ROENTGEN RAYS.

1,122,011. Specification of Letters Patent. Patented Dec. 22, 1914.

Application filed October 2, 1912. Serial No. 723,583.

To all whom it may concern:

Be it known that I, JULIUS EDGAR LILIENFELD, a subject of the Emperor of Austria-Hungary, and a resident of Leipzig, Germany, have invented certain new and useful Improvements in a Process and Apparatus for Producing Roentgen Rays, of which the following is a specification.

In the production of Roentgen rays it is common to use a tube or bulb which is provided with an anode and a cathode, the tube being evacuated to produce a vacuum corresponding to the desired degree of hardness of the radiation.

When the vacuum produced is high enough the tension between the anode and cathode is so great that an electric current cannot pass from one to the other and thus the Roentgen rays cannot be produced. On the contrary, when the gas pressure is too high in the tube, the current flows too readily and no useful rays can be produced. Thus, in a given Roentgen tube of the usual type what is termed the "hardness" of the radiation is determined by the density of the gas within the tube. However, practice has shown that it is desirable to eliminate the effect of gas pressure in the production of the rays on account of the difficulty of controlling the pressure satisfactorily. One of the methods of controlling this pressure is to provide, in the tube, a body capable of giving off a certain small amount of gas, when the cathodic rays impinge thereon. This process is open to the objection of irregularity.

The principal object of this invention is, therefore, to provide a process and apparatus wherein the hardness of radiation is not brought about by the alteration of the density of the gas within the tube, but on the contrary, by means of an auxiliary electrode actuated independently of the means for producing the Roentgen rays, this independent electrode being capable of starting a discharge in such a high vacuum that the ordinary anode and cathode would be prevented from operation. It is to be understood that this electrode works substantially independently of the degree of vacuum provided this vacuum is high, for example above the limiting value for the production of Roentgen rays in the ordinary manner.

The invention has three distinct purposes to accomplish. The first of these is to provide a novel process and apparatus wherein a tube may be used which is primarily so highly evacuated that the resistance between the cathode and anticathode cannot be overcome by the ordinary tension, and consequently the production of Roentgen rays can not be accomplished.

The second object is to provide an improved means for so reducing this resistance that the production of Roentgen rays may be accomplished with a high degree of evacuation of the tube.

The third of these objects is the provision of means for and the process of using an alternating current for the production of Roentgen rays in a tube of this description.

With the above and other objects in view, the invention consists in general of a certain novel means for producing these results and apparatus having details of construction and combination of parts hereinafter fully described, illustrated in the accompanying drawings, and specifically claimed.

In the accompanying drawings, like characters of reference indicate like parts in the several views, and;—Figures 1 to 5 are forms of tubes especially adapted for use in this connection, the forms being modifications, one of the other. Figs. 6 and 7 show a certain tube, the tube being that indicated in Fig. 5, and connections therefor adapted for use in combination with transformers producing alternating currents. Fig. 8 is a detail showing the modified form of transformer adapted to be used therewith.

In carrying out the process used herewith there is employed a Roentgen ray tube having an anode and cathode. Besides an anode and cathode there is also employed an electrode which can be raised to a high degree of temperature, such as incandescency, by the passage of a current therethrough, said electrode acting as a cathode and there may be used a second anode also.

The tube, of whatever form may be desired, has produced therein such a degree of vacuum as is sufficient to inhibit the passage of the discharge, which is intended to generate the Roentgen rays, from the anode to the cathode. Of course the glowing electrode is, during the pumping process, raised to extreme incandescence, so that the heating after the sealing off of the tube may thereafter be prevented from liberating any occluded gases. In the operation of the appa-

ratus, however, the resistance between the anode and cathode is reduced by breaking down said resistance by the activity of the incandescent cathode. Moreover, in carrying out the objects of this invention the process is furthermore modified by producing a discharge between the incandescent cathode and its anode at the same time that a current impulse with its consequent raise of tension is produced in the main circuit, so that the tension is raised between the cathode and anticathode in the same moment the resistance in the tube is overcome by the discharge between the glower and its anode with the resultant production of Roentgen rays. In the apparatus used to accomplish this purpose, a number of variations are shown in the present application.

There is disclosed in Fig. 1 a tube which is provided with the bulb 10 having a tubular extension 11. At 12 is a second bulb which is connected to the extension 11 by a short neck 13 and opposite this short neck 13 is a tubular branch 14. Within the tubular extension 11 above the branch 14 and neck 13 is located a cathode 15 while an anode 16 is located in the branch 14. Within the bulb 10 is located an anti-cathode 17, while within the bulb 12 is located a cathode 18 adapted to receive heating current flowing therethrough. Connecting the anti-cathode 17 and the cathode 18 is a wire 19 while from the cathode 18 extends a wire 20, said wire of course leading out of the respective bulb. The anode 16 and cathode 15 likewise are connected to wires 21 and 21′. The form shown in Fig. 2 employs all of these parts with the exception of the cathode 16 and branch 14. In place of the cathode 16 there is located between the neck 13 and the bulb 10 an anode 22 consisting of a cylindrical piece of suitable material which is connected to one of the wires 21.

In the form shown in Fig. 3 there is provided a tube consisting of a pair of bulbs 24 and 25 which are joined by a neck 26. From the upper bulb 25 extends a tubular extension 27 and located at the mouth of this tubular extension is a cathode 28 from which leads a wire 29. In the neck 26 is a cylindrical anode 30 which is connected to a wire 31. In the bulb 24 is an anti-cathode 32 and below this anti-cathode is provided a cathode 33, said cathode and anti-cathode being connected in series by means of the wires 34 and 35, the wires being arranged to cause incandescence of the cathode 33.

In the form shown in Fig. 4 there is provided a single bulb 36 from which extends a tubular neck 37. At the mouth of this tubular neck is located the cathode 38 which is connected to a wire 39 leading to the outside of the bulb. At 40, in the lower part of the bulb 36, is the cathode which is adapted to be rendered incandescent by a current passing through the wire 41, while at 42 is an electrode which combines in itself the function of the anode 16 and anti-cathode 17 of the form shown in Fig. 1. A suitable guard member 43 surrounds said electrode 42 and the electrode is connected to a wire 44 for the purpose of transmitting current therethrough.

In the form shown in Fig. 5 there is provided a bulb 45 having an upwardly extending tubular portion 46. At the mouth of this tubular portion 46 is arranged the cathode 47 which is connected to a wire 48 leading to the outside of the tube. Furthermore at 49 is arranged an electrode which is connected to the outside of the tube by a wire 50, while the cathode 51 is arranged near the electrode 49, and is connected to the wire 54 to which the wire 50 is also connected so that the electrodes 49 and 51 are connected in parallel. In this form there is also provided the anode 52 which is connected to the source of supply by the wire 55.

It is to be specially noted that in all of these forms there is employed such a cathode as is indicated at 18 in Figs. 1 and 2, at 33 in Fig. 3, at 40 in Fig. 4, and at 51 in Fig. 5. Moreover this particular cathode is arranged to glow upon the passage of a low tension heating current and for the purposes of this specification will be hereinafter referred to as a glower or glowing cathode.

It is to be particularly observed that in the form shown in Fig. 5 the electrodes are in axial alinement in the tube and the discharges from the cathodes flow in the same direction to the anodes, so that the electrons are nowhere retarded in their passage by an interfering electric field.

In the form shown in Figs. 6 and 7 the tube A which is the same as shown in Fig. 5, has its wires 50 and 55 connected to the secondary 56 of an induction transformer while the wire 48 of each of these forms is also connected to one terminal of the secondary 57 of an induction transformer. In the form shown in Fig. 6 a branch from the wire 53 indicated at 53′ is connected to the remaining terminal of the secondary 57, while in the form shown in Fig. 7 the remaining terminal of said secondary is connected by a wire 58 with the wire 55. In the form shown in Fig. 6, the device is provided with certain leads 59 and 60. One of these leads 59 is connected to a tuning resistance 61 which is in turn connected to the primary 62 of the secondary 57 of one transformer, a wire 63 leading from this primary to the primary 64 of the other transformer. From this other transformer a wire 65 leads to a tuning resistance 66 which is connected by a wire 67 with the wire 63. The wire 65 is connected by a branch 68 with a switch 69 which has its remaining pole connected to one pole of an interrupter 70 by means of a

wire 71, the other pole of an interrupter connected to the lead 60. This interrupter is preferably actuated by a motor 71'. In the form shown in Fig. 7 there is provided a suitable source of alternating current supply as indicated at 72, and this source of current supply is connected by a wire 73 to a tuning resistance 74 which is connected by a wire 75 to a switch 76 with the primary 77 of the transformer having the secondary 57. This primary 77 is connected by a wire 78 with the source of current 72 and from the wire 78 branches a wire 79 which is connected to the primary 80 of the remaining transformer. This primary 80 is connected by means of a wire 81 through a switch 82 with the tuning resistance 83 which is connected by a wire 84 with the wire 73. Thus these tuning resistances 74 and 83 are connected in multiple circuit with the primaries 80 and 77. The primaries 62 and 64, it is to be noted, are connected in series. It is also to be noted that the leads 59 and 60, in Fig. 6, receive their current from a source of constant current which is interrupted by the interrupter 70, while the source 72 is alternating. By these means the primaries in both of these cases are subjected to alternating fluxes, but as the fluxes are of the same phase and synchronous the tension will be increased between the cathode and anticathode at the same time that the discharge is induced between the glower and its anode.

It is to be noted that the anticathode 49 is connected to the auxiliary circuit 50 in the form shown in Figs. 5, 6 and 7 so that there may be an increase of current in discharge from the glower cathode to its anode simultaneously with the increase of tension between the cathode and anticathode. It will be observed that this is due to synchronism of the phase in the alternating currents in both branches, the glower being kept constantly supplied through the wire 53, and 54, with current of low voltage but having at periodic intervals its potential increased by the flow of current through the wire 50.

In Fig. 7 there is shown a form wherein the two secondaries are combined on one primary, and magnetic core, the secondaries being indicated at 85 and 86 respectively while the primary is indicated at 87.

What I claim is:—

1. In X-ray apparatus, the combination with an X-ray tube having X-ray electrodes and an electrode constituting a heating element, and means for imposing a series of current impulses upon said electrodes and a series of current impulses upon said heating element, the impulses of the two being regularly timed with relation to each other.

2. In X-ray apparatus, the combination with an X-ray tube having X-ray electrodes and an electrode constituting a heating element and means for imposing a series of current impulses upon said electrodes and a series of current impulses upon said heating element, the impulses of the two series being synchronous.

3. In X-ray apparatus, the combination with an X-ray tube having X-ray electrodes and an electrode constituting a heating element, and means for imposing synchronous, alternating current impulses upon said electrodes and element.

4. In X-ray apparatus, the combination with an X-ray tube having X-ray electrodes and an electrode constituting a heating element, and means for imposing synchronous, rectified, alternating current impulses upon said electrodes and element.

5. In discharge tubes of the kind described, the combination with the bulb of a set of electrodes allowing of a primary discharge taking place, a set of electrodes allowing of a secondary discharge taking place and means adapted to supply to said sets of electrodes two approximately synchronous alternating currents adapted to produce the said primary and secondary discharge, substantially as and for the purpose set forth.

6. In discharge tubes of the kind described, the combination with the bulb of a set of electrodes allowing of a primary discharge taking place, a set of electrodes allowing of a secondary discharge taking place, two separate secondary coils adapted to supply to the said sets of electrodes the tensions necessary for bringing about the said discharges and means for causing primary currents having the same primary tension to induce in the said secondary coils the said secondary tensions necessary for bringing about the said discharge, substantially as and for the purpose set forth.

7. A process for producing Roentgen rays having any desired degree of hardness in a tube having a vacuum sufficient to inhibit the passage of the high tension discharge which is intended to generate the Roentgen rays, consisting in creating in the tube independently to the means for generating Roentgen rays, a conductivity sufficient to permit the passage of said discharge while maintaining the said high vacuum.

8. The process for producing Roentgen rays having any desired degree of hardness in a tube having a vacuum sufficient to inhibit the passage of the high tension discharge which is intended to generate the rays, consisting in creating in the tube the conductivity necessary for lowering the resistance in said tube independently to the means for generating the Roentgen rays while maintaining the said high vacuum.

9. The process for producing Roentgen rays having any desired degree of hardness in a tube having a vacuum sufficient to in-

hibit the passage of the high tension discharge which is intended to generate the Roentgen rays between the electrodes of the tube, consisting in creating in the tube independently to the means for generating Roentgen rays, a conductivity sufficient to permit the passage of said discharge and simultaneously raising the tension between the electrodes.

10. The process of utilizing an alternating current in the production of Roentgen rays in a tube evacuated to an extent sufficient to inhibit the passage of the high tension discharge which is intended to generate said rays, consisting in impressing synchronous current impulses upon the tube electrodes and thereby simultaneously reducing the resistance in the tube and increasing the tension between the electrodes arranged for the production of the rays.

11. In a device for producing Roentgen rays, a tube provided with a cathode and an anticathode arranged for the production of said rays, said tube being further provided with a glower cathode.

12. In a device for producing Roentgen rays, a tube provided with a cathode and an anti-cathode arranged for the production of said rays, said tube being further provided with a glower cathode connected to the same terminal as the anti-cathode.

13. In a device for producing Roentgen rays, a tube provided with a cathode, an anode, an anticathode, and a glower cathode.

14. In a device for producing Roentgen rays, a tube provided with a bulb connected thereto, a cathode and an anode in said tube, an anticathode in said tube, and a glower cathode in said tube.

15. In a device for producing Roentgen rays, a tube provided with a bulb connected thereto, a cathode and an anode in said tube, an anticathode in said tube, and a glower cathode in said bulb connected to the same terminal as said anticathode.

16. In a device for producing Roentgen rays, a tube provided with a cathode and an anti-cathode, said tube being further provided with a glower cathode and an anode, and means to cause simultaneous increase of tension between the glower cathode and anode and between the cathode and anti-cathode.

17. In a device for producing Roentgen rays, a tube provided with a cathode and an anticathode, said tube being further provided with a glower cathode and an anode connected to the same terminal, and means to cause simultaneous increase of tension between the glower cathode and anode and between the cathode and anti-cathode.

18. In a device for producing Roentgen rays, a tube provided with a bulb connected thereto, a cathode and an anode in said tube, an anticathode in said tube, a glower cathode in said bulb, and means to cause simultaneous increase of tension between the glower cathode and its anode and between the cathode and anticathode.

19. In a device for producing Roentgen rays, a tube consisting of a bulb having a tubular extension leading therefrom, and a second tubular extension diametrically opposed to the first extension, a cathode at the mouth of the first extension, an anode projecting inward from the second extension, a glower cathode, and an anticathode projecting into said bulb adjacent to the glower cathode.

20. In a Roentgen ray apparatus, a tube having a plurality of electrodes including more than one cathode arranged to permit flow of electrons in the same direction, one of said electrodes being a glower electrode.

21. In a Roentgen ray apparatus, a tube having a plurality of electrodes including more than one cathode arranged in the axis of the tube and further arranged to permit flow of electrons in one direction, one of said electrodes being a glower electrode.

In testimony whereof I have hereunto set my hand in presence of two witnesses.

JULIUS EDGAR LILIENFELD.

Witnesses:

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