Aug. 17, 1926. 1,596,758

A. MUTSCHELLER

METHOD AND APPARATUS FOR CONTROLLING ELECTRICAL DISCHARGES BY MEANS OF ULTRA VIOLET LIGHT

Filed May 12, 1920 4 Sheets-Sheet 1

Figure 1.

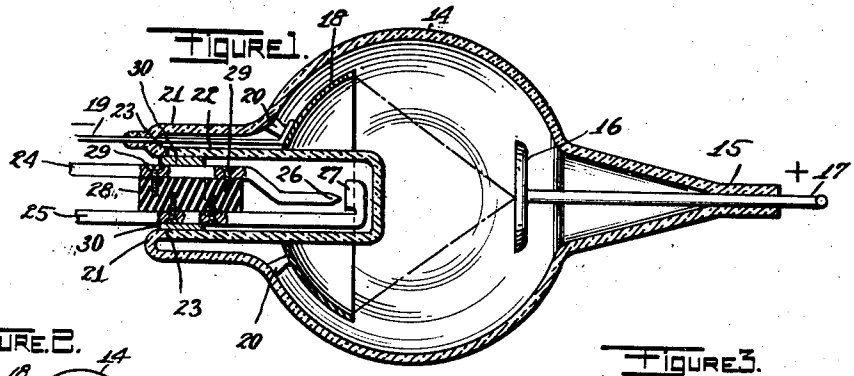



Figure 2.

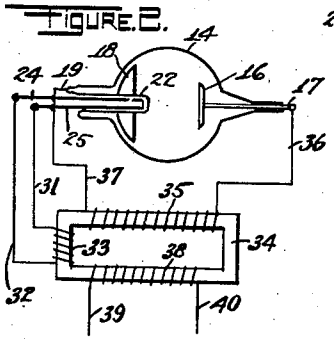



Figure 3.

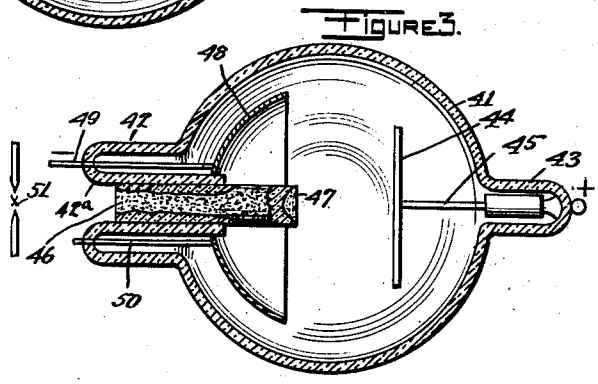



Figure 4.

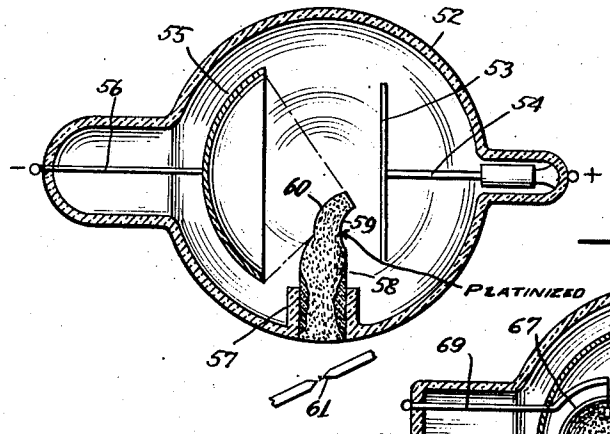
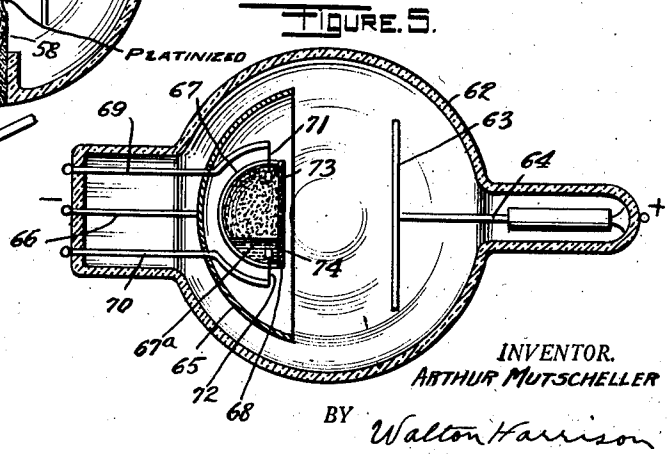



Figure 5.




INVENTOR.
ARTHUR MUTSCHELLER

BY Walton Harrison

ATTORNEY

Aug. 17, 1926. 1,596,758

A. MUTSCHELLER

METHOD AND APPARATUS FOR CONTROLLING ELECTRICAL DISCHARGES BY MEANS OF ULTRA VIOLET LIGHT

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Figure 6.

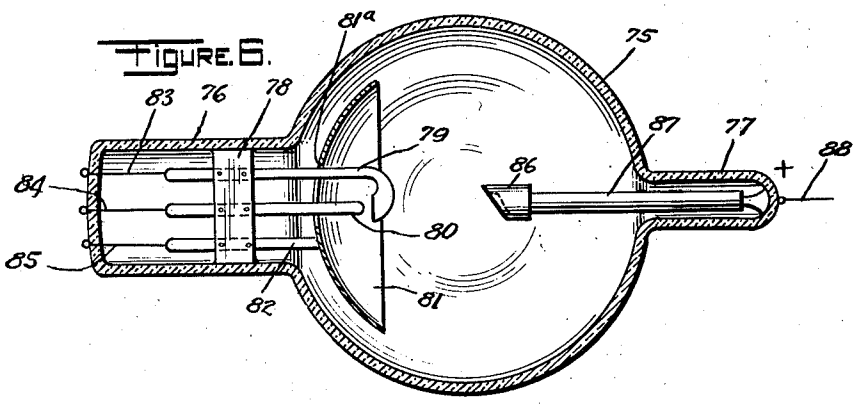



Figure 7.

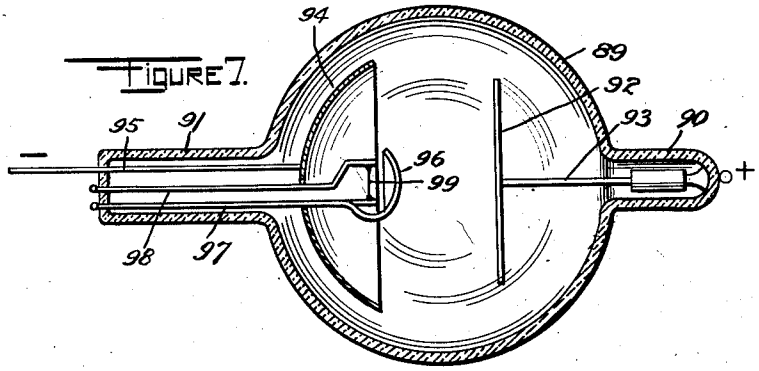



Figure 8.

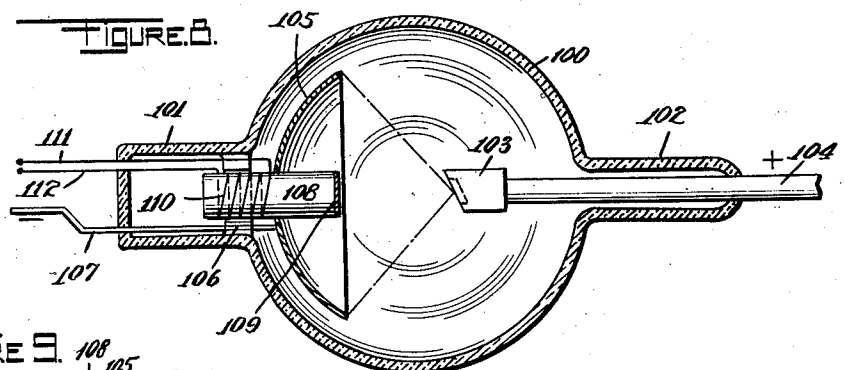
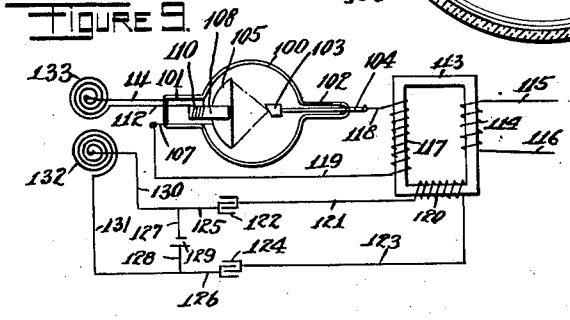



Figure 9.




INVENTOR.
ARTHUR MUTSCHELLER

BY Walton Harrison,
ATTORNEY

Aug. 17, 1926. 1,596,758

A. MUTSCHELLER

METHOD AND APPARATUS FOR CONTROLLING ELECTRICAL DISCHARGES BY MEANS OF ULTRA VIOLET LIGHT

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Figure.10.

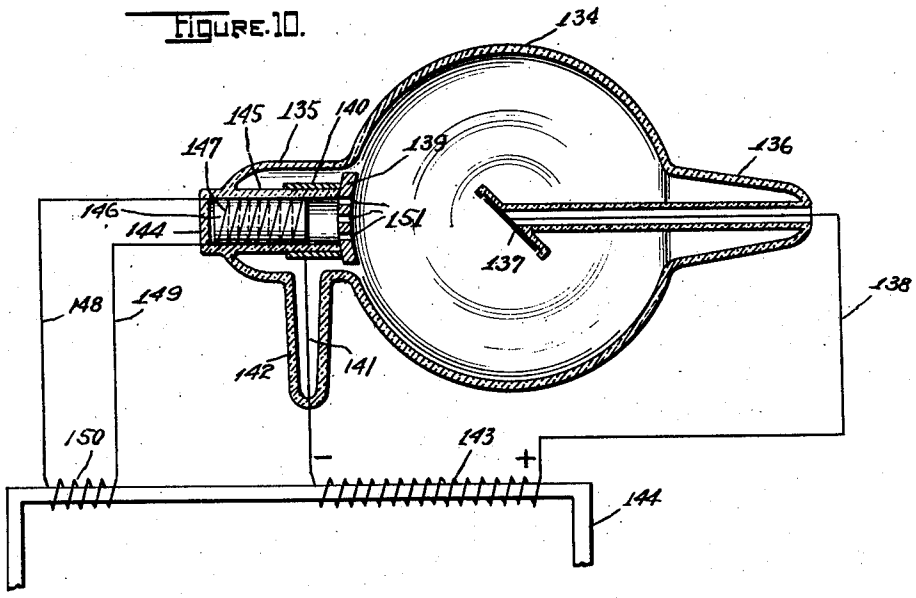
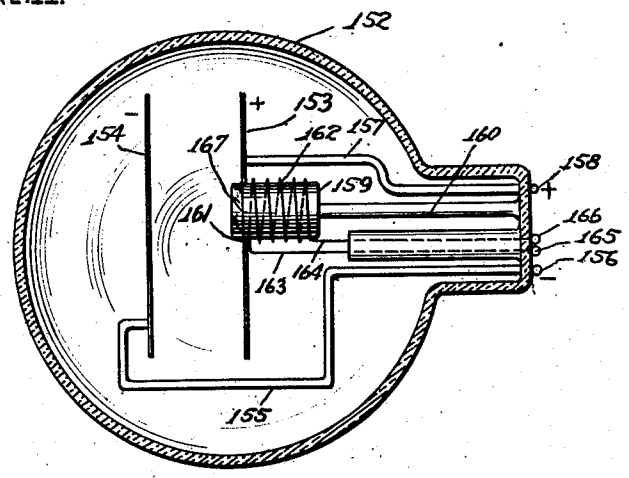



Figure.11.




Inventor
ARTHUR MUTSCHELLER

By his Attorney
Walton Harrison.

Aug. 17, 1926. 1,596,758

A. MUTSCHELLER

METHOD AND APPARATUS FOR CONTROLLING ELECTRICAL DISCHARGES BY MEANS OF ULTRA VIOLET LIGHT

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Figure 12.

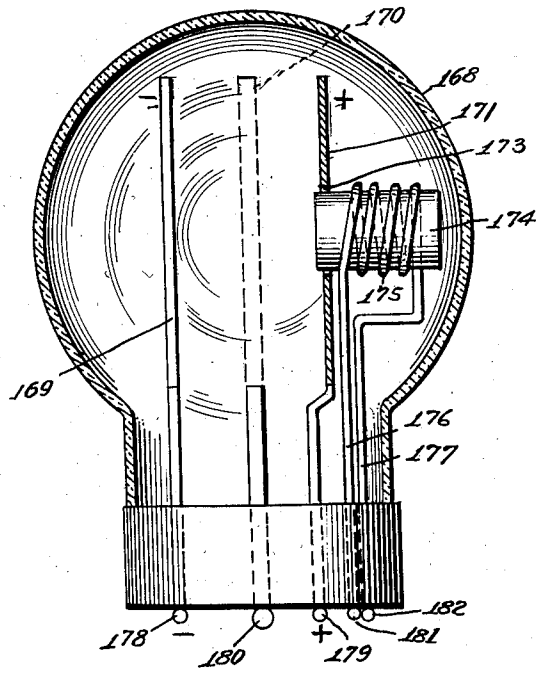
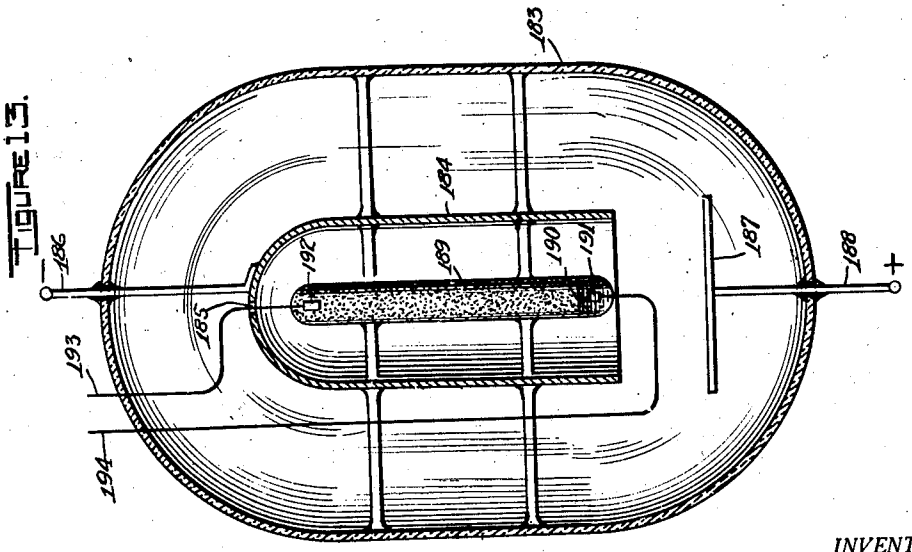



Figure 13.




INVENTOR.
ARTHUR MUTSCHELLER
BY Walton Harrison
ATTORNEY

Patented Aug. 17, 1926. 1,596,758

# UNITED STATES PATENT OFFICE.

ARTHUR MUTSCHELLER, OF NEW YORK, N. Y.

## METHOD AND APPARATUS FOR CONTROLLING ELECTRICAL DISCHARGES BY MEANS OF ULTRA-VIOLET LIGHT.

Application filed May 12, 1920. Serial No. 380,896.

My invention relates to vacuum discharge tubes of the kind in which the discharge of electrons from the cathode is controlled by means of ultra-violet light.

The method by which I produce a cathode discharge differs so radically from the methods heretofore used, in the gas-containing X-ray and valve tubes, or in the thermo-electric discharge tubes, that some entirely new principles of operation and of operating characteristics are obtained. Thus by merely controlling the electron discharge from the cathode there may be obtained either a valve tube rectifier for high tension currents, a detector and amplifier of electrical oscillations, or a new type of X-ray tube.

In some devices of the prior art a discharge from the cathode to the anode is effected by means of a comparatively few gas particles left in the tube. These residual gas particles give rise, through ionization by impact, to positive ions which, upon being attracted to the cathode, pick up negative charges and are then repelled from the cathode. Again, in an extreme vacuum a pure electronic discharge is obtained from a hot surface such as that of a filament.

In order to thus use the residual gas left in the tube, however, it becomes necessary to control the gas pressure within the tube; whereas in order to obtain a pure or nearly pure electronic discharge it becomes necessary to free the tube and the electrodes almost entirely of all traces of gas. Either of the two conditions just mentioned is difficult to attain, for the simple reason that regulation of the vacuum to an exact degree is not easy of accomplishment, and there are difficulties in producing and maintaining a very high vacuum in the presence of metallic electrodes; further, a vacuum so obtained and answering the requirements practically necessitates the use of certain metals which are expensive and also difficult to prepare.

Again, in the prior art for the purpose of focusing the cathode rays from their source to the anti-cathode target, within the gas-containing tube, special devices are required in order to prevent the discharge from striking the glass wall of the tube. Thus in the gas-containing tube it is difficult to prevent heating and the accumulation of a charge of static electricity tending to oppose the flow of current.

In the thermionic discharge tube it is difficult to control the emission of the electrons so that they will all strike in a small area upon an anti-cathode target. For accomplishing the result just mentioned, complicated electrostatic focusing devices must be employed.

These difficulties and many others are avoided by the use of my invention, in that a discharge is obtained only from the illuminated surface, without the use of heat, which would otherwise make changes in the discharge. I adjust the source of ultra-violet light in such a way that only the cathode side, from which a discharge is desired, is illuminated. For this reason, this surface is the only one emitting the electrons which constitute the discharge.

As a source of ultra-violet light I employ any convenient device producing a sufficient intensity of ultra-violet rays, and I place this source either outside of the vacuum bulb or within the same, as conditions may require. If the source of ultra-violet light is outside of the vacuum, the rays are admitted through a window made of suitable material to offer but little resistance to them, and thus I cause them to irradiate the surface from which a discharge is desired. If the source of the ultra-violet light is inside of the tube, it is located near the cathode to be illuminated. By this expedient, coupled with the high degree of vacuum, there is hardly any absorption of the ultra-violet rays. Thus by illuminating the cathode and placing it parallel with the anode, whenever the cathode side is illuminated a negative discharge can be obtained, and this discharge is proportionate to the intensity of the illumination. A discharge in the opposite direction, that is, from the non-illuminated anode to the cathode illuminated by ultra-violet rays, does not ordinarily take place.

I regulate the intensity of the ultra-violet light by varying the strength of the current used in producing the ultra-violet light. If desired however, the intensity of the ultra-violet light may be varied in any other suitable manner.

In employing my device as a receiver and amplifier of oscillations set up in wires by electromagnetic wave action as in wireless telegraphy or telephony, I so arrange the electrodes that the grid is either illuminated by ultra-violet light at the same time as the

cathode plate, or that no ultra-violet rays fall upon it. In the case last mentioned, if the grid is not connected at all it will to a certain extent obstruct the flow of electronic current across the instrument. This is due to the negative charge accumulating on the grid when the latter is exposed to the bombardment of electrons passing from the illuminated electrode to the electrode which is not illuminated.

However, when the grid is not connected and ultra-violet rays fall upon it, the grid loses all negative charge and may assume a positive charge. This is a distinct advantage. Instead of requiring a potential to be applied from outside of the tube in order to adjust the grid to zero or to confer upon it a slightly positive potential, when the tube is capable of handling the largest amount of energy, for instance as an amplifier, and the grid is exposed to the ultra-violet light, the grid loses all negative charges because of the effects of the ultra-violet rays, and the accumulating positive charges are proportionately neutralized by the negative discharge from the illuminated plate. My device, therefore, is self-adjusting to a maximum of efficiency. In order to adjust the magnitude of the positive charge accumulating on the grid, it is only necessary to select, as a metal for the grid, that metal which, under exposure to ultra-violet light, charges up to the most favorable velocity voltage.

From the illumination of the grid by means of ultra-violet light, there arises another advantage. If the instrument is used as a detector for incoming waves of high frequency with a telephone receiver the grid, because illuminated with ultra-violet light, does not assume a negative charge and can only assume a positive charge. Thus there is no necessity to employ a second wave rectifier or valve in order to hold back the negative half-impulses, and only positive impulses are passed through the telephone receiver. The result is, that the receiver diaphragm to be drawn in one direction only, the magnetic pull upon the diaphragm being in proportion to the amplitude of the wave train.

It is a fact well known in this art that by connecting two audions in series, so that one audion acts as a rectifier for the other, the aggregate effect of the two audions is increased considerably as compared with that of a single audion, used alone. My instrument, however, used in single form, produces an effect equal to that of the two audions in the relation stated.

In some instances I use still another way of increasing the amplitude of the current variations. Instead of illuminating the negative plate or the plate and grid continuously, the illumination can be rendered intermittent at suitable intervals, so that the frequency of the impulses passing into the receiver is such as to cause the receiver to respond to a maximum degree. Since it is a fact that most frequencies commonly used in wireless telephony are too high to give good audibility. It is an advantage to be able to receive the waves at frequencies much lower and such as are best adapted to energize the telephone receiver. As no waves pass through my device when the plate or the plate and grid are not illuminated, it follows that the illumination can be interrupted periodically; that is, the oscillation period of the exciting current for the source of ultra violet light can be so adjusted, and the illuminations so varied in consequence, that the oscillation trains, when rectified and passed through the telephone receiver, cause the latter to give the loudest and clearest sounds.

My device, in the form of an X-ray tube with a curved cathode, offers many advantages over the X-ray tubes of the prior art. Both in the Lilienfeld and Coolidge tubes the liberation of electrons is obtained with the aid of one electrode heated to a very high temperature. Particularly, the Coolidge tube operates only well and regularly if the vacuum is of the highest degree possible. But when there is a heated filament in the vacuous space, then it is found that small traces of gases in the bulb cause irregularities in the electron emission. The problem of producing and maintaining such a high degree of vacuum requires special metals for the electrodes, and in general it makes the process of evacuation considerably more difficult.

In my device the cathode is not heated and I find that small traces of gas which might not have been removed or which might have become set free while the tube is in use, do not cause the same disturbances in the functioning of the tube as it does in the case of glowing cathode tubes.

The Coolidge tube is based upon the principle that in an extreme vacuum a pure electronic discharge is obtainable from a heated filament, and this discharge is then focused upon a small area upon the anticathode by means of an electrostatic focusing device. This focusing device consists of a cylinder placed over the filament and which, when charged with a negative potential, causes the electrons to escape through the center of this tube. The same object may be attained by placing a spirally shaped metallic member, a metallic cylinder or a metallic hemisphere, so arranged as to serve as a shield which, when charged, develops an electrostatic force, and this force causes the electrons to converge and to fall upon a relatively small area, on the anti-cathode.

While my improved vacuum tube can be operated as either a tube containing a small but appreciable residuum of gas or as con-

taining an extremely high vacuum and thus adapted for a pure electronic discharge, it is preferably used with an extreme vacuum. Therefore the vacuum tubes which I show and describe may be considered as each containing a very high vacuum and as adapted for a pure electronic discharge.

It may sometimes be advantageous either for radiographic, therapeutic, or fluoroscopic work, not to allow the entire current phase of the alternating current impulse, either rectified or non-rectified, to pass through the tube. This is because the soft rays, which are produced when the low voltage part of the curve passes, is bound to cause injury to the skin, in consequence of the stronger effect of the soft rays upon the skin. With my improved vacuum tube this same object can be accomplished even when the entire current phase is passed through the tube; or, any desired part of the curve can be prevented from passing through the tube. This is done by so producing ultra-violet light as to render the latter intermittent, so that the ultra-violet rays are produced at the precise moment when it is desired that the fraction of the impulse should pass. This action is similar to that in the audion tube, as used in accordance with my invention. It is possible also, in the case of X-ray tubes and valve tubes to select for passage through the tube the particular part of the impulse applied, as may be desired. This is accomplished by merely causing the ignition current for the source of ultra-violet light to be in synchronism and of proper duration, so as to take place and to persist at the precise moment, and such moment only, when the impulse should pass.

A valuable feature of my type of tube is the absence from it of any electrostatic focusing device. The illumination of the inner surface of a uniformly curved cathode prevents the formation of any discharge from the rear of this cathode, and consequently no cathode shield or any other sort of focusing device is necessary to afford any desired focal area.

Reference is here made to the fact that the ultra-violet rays are as far as practicable thrown directly upon the cathode, and prevented as far as practicable from falling directly upon the anode.

In many instances I seek to render the ultra-violet rays as nearly pure as possible—that is, free from the rays of the visible spectrum and from heat rays, as well as from nondescript rays of other kinds. By thus rendering the ultra-violet rays pure, I seek to intensify their functions, and by so doing to prevent various disturbing effects due to the presence of undesirable rays of other kinds. I particularly wish to avoid the use of heat rays, because they tend to elevate the temperature of the cathode and rendering the tube resistance irregular as well as in many other ways interfering with the electric discharge.

I have made the discovery that under the various conditions above-mentioned, if the ultra-violet rays reach the metallic surface by irradiation, or by reflection, or in such other manner as to greatly reduce the number of heat rays accompanying them, the action of the ultra-violet rays actually reaching the metallic surface is rendered more pronounced, more reliable, and by far more easily controlled than it may be when the rays last-mentioned are allowed to pass directly to the metallic surface from a hot body disposed in close proximity thereto.

I have made the further discovery that for the purpose of causing the cathode to discharge electrons, the ultra-violet rays may be rendered very intense and very effective if they are derived from a powerful source of ultra-violet light, located extraneous to the tube but in close proximity thereto.

I have also discovered that the action of the ultra-violet rays may produce exceptionally good effects if the source of the rays be located within the tube, provided the rays when formed are accompanied by a minimum quantity of heat rays, or that after being formed they are by reflection or otherwise, freed in great measure from the heat rays.

It is impracticable for me to illustrate and describe all of the varied forms and uses of my invention, as this would involve an endless amount of detail. However, I will illustrate and describe a few specimens of apparatus in which my invention is incorporated in such manner as to be of advantage in the various arts.

Reference is made to the accompanying drawings forming a part of this specification, and in which like reference characters indicate like part throughout the several figures.

Figure 1 is a longitudinal section of a vacuum tube used as a valve rectifier, and shows one way in which the cathode terminal may be illuminated by ultra-violet light reaching it from a source which, while practically located within the tube, is not inside the vacuum thereof.

Figure 2 is a diagram showing how the tube shown in Figure 1 may be energized by aid of a transformer.

Figure 3 is a longitudinal section through a vacuum tube used as a valve rectifier, and shows one way in which the cathode terminal may be illuminated by ultra-violet light from a source extraneous to the tube, the light in this instance being admitted through a prismoidal solid body and being reflected internally thereof.

Figure 4 is a longitudinal section through

a vacuum tube used as a valve rectifier, and shows another way in which the cathode terminal may be illuminated by ultra-violet light reaching it through a solid body and by internal reflection within said solid body, the source of light being extraneous to the tube.

Figure 5 is a longitudinal section through a vacuum tube used as a valve rectifier, the ultra-violet light being generated within the tube by means of a type of mercury lamp.

Figure 6 is a longitudinal section through a vacuum tube used as an X-ray tube, the ultra-violet light being made by an arc lamp located within the vacuum tube.

Figure 7 is a longitudinal section through a vacuum tube used as a valve rectifier, the ultra-violet light being radiated by an incandescent filament, and reaching the cathode directly and mainly by reflection.

Figure 8 is a longitudinal section through a vacuum tube used as an X-ray tube, in which the ultra-violet rays are thrown upon the cathode by reflection.

Figure 9 is a diagram of a transformer and various parts associated therewith along with their connection, as used for energizing the tube shown in Figure 8.

Figure 10 is a longitudinal section through a vacuum tube used as an X-ray tube, the ultra-violet rays being generated within the tube or in close proximity thereto, and by irradiation transmitted to the cathode.

Figure 11 is a longitudinal section through a vacuum tube used after the manner of the kenatron, the pliotron, the oscillion and various other valve tubes, and in which the ultra-violet rays are generated by a miniature mercury lamp located within the tube.

Figure 12 is a section through a valve tube provided with a grid and adapted for use in wireless telephony, the ultra-violet rays in this instance being generated by a small mercury lamp located within the tube.

Figure 13 is a longitudinal section through an oscillation valve, in which the ultra-violet rays are produced by a mercury vapor tube located within the wall of the oscillation valve.

In the vacuum tube rectifier shown in Figure 1 and embodying one form of my invention, the vacuum tube appears at 14 and is provided with a neck portion 15. This neck portion supports the anode which appears at 16 and has the form of a flat plate, mounted upon a terminal rod 17. The cathode appears as 18, and has an approximately hemispherical form. This gives it the advantage of a large surface, all portions of which are favorably disposed relatively to the position occupied by the anode. A terminal wire 19 is connected with the cathode, and the cathode is supported upon posts or lugs 20, carried by the vacuum tube. This vacuum tube is provided with a neck portion 21, and with this neck portion is made of glass. Mounted upon this neck portion 21, and secured thereto by fusion or otherwise, is a tubular member 22, of quartz glass or other material through which the ultra-violet light rays can readily pass. The tubular member 22 is preferably connected to the neck portion 21 by a joint 23 formed by slightly fusing the abutting edges together.

A pair of metallic conductors, 24 and 25, are provided respectively with portions 26, 27, of suitable form to produce an arc when a suitable current is passed through these parts; the arc thus produced being, of course, located within tubular member 22. The conductors 24, 25, are spaced apart and mounted in position by being secured to a spacing block 28 of insulating material, by means of screws 29 or other appropriate fastenings. A band 30 of rubber or other appropriate insulating material, serves as a bushing for the conductors 24, 25, and parts in immediate contact therewith.

The operation of the machinism shown in Figure 1 is as follows: An arc being started and maintained between portions 26, 27, of electrodes 24, 25, the ultra-violet rays from this arc pass out through the adjacent wall of the tubular member 22 and strike the inner surface of the cathode 18. From this cathode the electrons are focused directly upon the anode 16 as indicated by broken lines in Figure 1. The portion 27 of the conductor 25 is enlarged, so as to prevent the ultra-violet rays and other rays of the arc from passing directly to the anode 16. That is to say, the portion 26 serves as a shield for preventing the rays from reaching the anode.

In order to produce both the currents required for operating the arc and the discharges which are to pass between the anode and cathode, I use the mechanism shown diagrammatically in Figure 2. The conductor 25 is connected to a wire 31 and the conductor 24 is similarly connected to a wire 32. The wires 31 and 32 lead to a secondary winding 33 carried by and forming a part of a transformer 34. This transformer is provided with a secondary winding 35 having a larger number of turns than the secondary winding 33, and thus producing currents of much higher voltage than those produced by the secondary winding 33. A wire 36 leads from the winding 35 to the electrode 17, and a wire 37 leads from the secondary winding 35 to the electrode 19. The transformer 34 is provided with a primary winding 38 whereby it is energized. For this purpose the primary winding 38 is connected to wires 39, 40, which are energized

by alternating currents from any suitable source.

Thus the transformer, 34, when energized through its primary winding 38, supplies low voltage currents for the arc and also high potential currents for obtaining a discharge between the cathode and the anode. Thus a one-way discharge takes place through the tube 14, but no discharge can take place between the electrodes 24, 25 and any part located within the vacuum of the tube 14.

It will be noted here that the source of ultra-violet light, while for all practical purposes located within the vacuum tube, is not within the vacuum, and is really extraneous to the vacuum tube, in so far as the action of the device is concerned. The ultra-violet rays which actually reach the cathode are comparatively pure, and have very little tendency to elevate the temperature of the cathode or of any part immediately adjacent thereto. The ionizing action of this form of cathode, operated under the conditions here contemplated, is very great. The result is, that the rectifying action of the vacuum tube is exceptionally good.

In the form of my device shown in Figure 3, the vacuum tube appears at 41 and is provided with neck portions 42, 43. The neck portion 42 carries an inwardly extending reverting portion 42A. The anode appears at 44 and is supported by a conductor 45 which serves as a tube terminal. Mounted within the reverting portion 42A of the neck 42, is a prismoidal rod 46, made of quartz, and provided with a concave platinized surface 47, thus serving the purpose of an internal reflector. The cathode appears at 48, and is made of non-sputtering metal. It has generally the form of a reflector, and secured to it is a terminal rod 49. The cathode is supported upon rods one of which shown at 50. An arc lamp 51 is disposed in axial alinement with the quartz rod 46, and is in this instance used as a source of ultra-violet rays. These rays pass through the quartz rod 46, in the general direction of the length thereof, and are reflected by the platinized surface 47 so as to fall upon the cathode 48.

The tube thus described has a valve action, in that discharges taking place between the cathode and the anode all pass in a single or unitary direction.

Except as otherwise indicated, the action of the device shown in Figure 3 is similar to that appearing in Figure 1.

In the form shown in Figure 4 the vacuum tube appears at 52, the anode at 53, and the anode terminal at 54. The cathode appears at 55, and has, as before, the form of a hemisphere. It is supported upon a cathode terminal rod 56.

The wall of the vacuum tube 52 is provided with a neck 57 extending internally, and extending through this neck is a prismoidal member 58 having the form of a short rod and made of quartz. This rod has two surfaces 59, 60, the surface 59 being concave and the surface 60 being convex. The surface 59 is preferably surfaced with platinum or with some other bright metal so as to render it capable of reflecting ultra-violet rays internally of the member. These rays pass out through the surface 60 and strike the cathode. The surface 59 is located in or near the focus of the reflecting surface 55, so that the ultra-violet rays from the surface 59 are diffused as nearly as practicable uniformly in relation to the surface 60.

The source of ultra-violet rays is in this instance an arc lamp 61, which is disposed in axial alinement with the member 58.

This device, like the ones already described, has a valve action, in that the discharges take place through the tube in a unitary direction.

Owing to the curvature of the surfaces 59 and 60, the ultra-violet rays upon leaving the member 58 through the surface 60 ar irradiated so as far as practicable they are projected upon the inner or concave surface of the cathode, but do not illuminate any other parts, and do not reach the anode.

In the form of my device shown in Figure 5, the vacuum tube appears at 62 and is provided with an anode 63, supported upon an anode terminal 64. In this instance, as in the others above mentioned, the anode has the form of a flat plate.

The cathode is shown at 65, and has as before the form of a reflector. It is made of metal and preferably bright. Connected with this cathode is a cathode terminal 66, mating the anode terminal 64 of the tube. Located within the vacuum tube 62 is a mercury lamp 67 having the general form of a mutilated sphere made of quartz and provided with a flat reflector 68, opaque to ultra-violet light. For the purpose of energizing the lamp 67, I employ a pair of conductors 69, 70, having in this instance the form of stout insulated wires. These wires are provided with portions 71, 72, which carry small electrodes 73, 74, located within the mercury lamp. A volume of liquid mercury 67a, is located within the lamp, and is vaporized when a current is sent through the mercury lamp by aid of the electrodes 69, 70. This current may be direct, alternating or pulsating, depending upon the use to which the vacuum tube is to be applied.

The vacuum tube thus described has a rectifying or valve action, and generally speaking may be employed for any purpose requiring such a rectifying or valve action tube.

In the form of my device appearing in Figure 6 the vacuum tube is shown at 75,

and is provided with two necks 76, 77, the neck 76 having a somewhat greater internal diameter than that of neck 77, in order to serve as a housing for various parts. Located within the neck 76 and extending diametrically across the same, is a bridge 78. This bridge supports a pair of electrodes, 79, 80, of such form and so arranged as to be capable of service as an arc lamp. A cathode is shown at 81, and has the form of a concave reflector. It is made as before, of bright metal. Connected with the cathode 81 is a cathode terminal 82, having the form of a rod. This rod like rods 79 and 80 is secured to the bridge 78 and supported mainly thereby. Connected with the rods 79, 80, 81 are terminal wires 83, 84, 85, the terminal wire 85 being the one in communication with the cathode. The rods 79 and 80 do not touch the cathode, as they extend through a slot $81^a$ therein.

The anode is shown at 86, and is carried upon an anode terminal rod, 87. Connected with this anode terminal rod is a wire 88, mating the wire 85, and used for supplying high tension current to the tube.

The operation of the device shown in Figure 6 may readily be understood from the foregoing description. An arc being formed between the rods 79 and 80, ultra-violet rays are emitted by this arc and strike the internal surface of the cathode 81.

In other respects the vacuum tube shown in Figure 6 is similar to those above described. This form of vacuum tube is well adapted for X-ray work. The portion of the rod 79 immediately adjacent the end portion of the rod 80, is enlarged so as to serve as a screen and thus prevent the ultra-violet rays of the arc from passing directly to the anode.

In the form of my device shown in Figure 7, the vacuum tube appears at 89 and is provided with two necks 90, 91. The anode is shown at 92, and has in this instance the form of a flat plate made of bright metal. It is carried upon a rod 93, extending through the neck 90, and serving as an anode terminal.

The cathode appears at 94, and is connected with a rod, 95, by aid whereof it is supported, and which serves as the cathode terminal of the tube. Located adjacent the cathode, and facing the same, is a metallic member 96 bent to form a concave reflector and supported upon a rod 97. Located adjacent this rod and disposed parallel thereto is another rod 98. A filament 99 extends from the rod 98 to the rod 97, this filament being disposed adjacent the member 96 serving as a reflector. The rods 97, 98 serve as terminals for the filament 99. This filament need not be located in the principal focus of the reflector 96. The relative arrangement of all of these parts is such that, as far as practicable, all ultra-violet rays proceeding from the filament 99 are so reflected as to reach the cathode 94 directly or by reflection.

In Figure 8, I show a form of my device in which the invention is applied to an X-ray tube. A vacuum tube appears at 100, and is provided with two necks 101, 102. The anode appears at 103, and is supported upon a rod 104 serving as the anode terminal. The cathode is shown at 105, and has the substantially hemispherical above described. Extending through a hole in the cathode is a small mercury lamp 108, having the general form of a tube and provided with a reflector 109. Encircling the tube just mentioned is a winding 110, and connected with this winding are two wires, 111, 112, serving as the terminal wires of the mercury lamp 108. The lamp 108 contains a small quantity of mercury and is exhausted, being thus filled with attenuated mercury vapor. When the lamp is energized by means of the high frequency currents flowing through the winding 110, the vapor becomes luminous, as in the case of other mercury lamps heretofore used. The light emitted by this lamp is rich in ultra-violet rays. The reflector 109 being opaque, none of the ultra-violet rays can pass through it, and such ultra-violet rays as impinge upon the reflector are reflected to the left according to Figures 8 and 9, and at the same time diffused and caused to impinge upon the inner surface of the concave reflector 105, which as above explained is the cathode, and cause it to discharge electrons.

The X-ray tube just described is energized by either alternating currents or pulsating currents, as the case may be but in any event, only discharges of unitary direction can possibly take place through the tube. By means of the lamp 108, ultra-violet rays are emitted. These for the most part strike the cathode directly and are thence reflected upon the anode. Such of them as strike the reflector 109, are of course reflected and practically all of the rays thus reflected strike the cathode. The lamp 108 is preferably energized synchronously with the alternations of potential applied to the main discharge terminal.

In Figure 9 I show a transformer and various other parts especially arranged and adapted for energizing all parts of the X-ray tube shown in Figure 8. A transformer 113. of the so-called closed-core type is provided with a primary winding 114 whereby it is energized, and connected with this winding are wires 115, 116 through which alternating current is supplied. The transformer is provided with a secondary winding 117, and from the latter a wire 118 leads to the anode terminal 104 of the X-ray tube. From the secondary winding 117 another

wire 119 leads to the cathode terminal 107. Thus the anode and cathode of the X-ray tube are subjected directly to the potential of the secondary winding 117. On this account I designate the winding 117 as the main secondary winding of the transformer. Another secondary winding 120 is provided for the transformer, and this secondary winding is by a wire 121 connected with a condenser 122. The secondary winding 120 is by means of another wire 123, connected with another condenser 124. Connected with the condensers 122 and 124 are wires 125, 126 and connected with these wires are two other wires, 127, 128, which leads to a spark gap 129, the latter being thus bridged across from the wire 125 to the wire 126.

A wire 130 is connected with the wires 125 and 127. Similarly a wire 131 is connected with the wires 126 and 128. The wires 130 and 131 lead to and are connected with a pancake spiral 132. Mating this spiral, and in inductive relation thereto is another pancake spiral 133, the latter being connected to the wires 111, 112 for the purpose of energizing the lamp 108 above described, and with which the X-ray tube is provided.

The winding 120 energizes the condensers 122 and 124; these condensers energize the pancake spiral 132; this spiral acts inductively upon the pancake spiral 133, and thus within the latter are generated oscillating currents which energize the lamp 108. This lamp thereupon produces ultra-violet rays which strike the cathode reflector 105. From here on the action of the device is similar to that above described with reference to Figure 8.

In the arrangement shown in Figure 9, like that appearing in Figure 2, a single transformer is used to supply current for the main discharge through the X-ray tube, and also to supply current for energizing the miniature lamp 108, forming virtually a part of the X-ray tube.

In Figure 10, I show still another form of my device and in this form I apply the principle of my invention to an X-ray tube of the so-called Lilienfeld type. That is to say, the principal is here applied to an X-ray tube of the type illustrated in Figure 1 of patent dated March 6, 1917, No. 1,218,423, to J. E. Lilienfeld. A vacuum tube 134 is provided with two necks 135, 136. The anode appears at 137, and is connected with a terminal wire 138. A cathode appears at 139 and has a slight curvature, or in other words, is slightly concave. The cathode is provided with a supporting neck 140, made of metal. Connected with this neck is a terminal wire 141 which extends out of the tube, through a hollow projection 142. The cathode terminal wire 141 and the anode terminal wire 138 are connected with the end of a secondary winding 143, with which a transformer 144 is provided. Thus the secondary winding 143 supplies the potential and current for the main discharge through the X-ray tube. Located within the neck 135 is a tubulere 145, upon which the supporting neck 140 of the cathode is mounted. The tubulere 145 is provided with a closed end 144. A miniature mercury lamp 146 is located within the tubulere 145 and carries a winding 147 whereby the mercury lamp is energized. This winding is connected to two wires, 148 and 149 which lead to a secondary winding 150, with which the transformer 144 is provided. The cathode 139 is provided with openings 151 through which ultra-violet light from the mercury lamp 146 can pass. The rays of ultra-violet light, in passing through the openings 151 and striking the cathode 139, serve to perform the office known in this art as ignition of the tube, for the purpose of controlling the main discharge thereof.

Except in the particulars just stated, the X-ray tube shown in Figure 10 acts like the other X-ray tubes above described.

The miniature mercury lamp 146 may be merely an exhaustive capsule, containing a small drop of mercury in a vacuum. The capsule may be made of quartz, fluorite or other material transparent to ultra-violet rays. It may be cemented or otherwise secured in position, but its mounting should always be such as not to interfere with the maintenance of a suitable vacuum within the tube. For purposes of maintaining the vacuum within the tube, the winding 147 should either be fused into position, or else embedded within the material of the capsule.

It will be understood, of course, that when the transformer 144 is energized, the windings 143 and 150 are energized in the same phase. Hence the action of the mercury lamp 146 is most intense at the particular instant when the potential between the cathode and the anode of the X-ray tube is at its maximum. The evacuation of the tube is of such degree that no discharge whatever can take place within the tube except when the mercury lamp is in action, and when its action is most intense. Therefore no discharge can take place through the tube except when the terminals thereof are at their proximate maximum potential. In this way, the X-ray tube as a whole selectively picks out the peaks and the peaks only of the current waves, the residual portions of the current waves being utterly unable to pass through the tube. The discharges through the tube are of course, of unitary direction.

In Figure 11 I show my invention as applied to a vacuum tube, for use in relation analogous to those of the kenatron, the pliotron, the oscillion, and various other types

of valve tubes, used mainly for purposes of wireless telegraphy and telephony.

That is to say, my device shown in Figure 11 is well adapted for amplifying current variations which are under the control of sound waves, or at least which are varied in intensity in accordance with sound waves. The vacuum tube is shown at 152, and contains a positive plate or anode 153 and a negative plate or cathode 154. The cathode 154 is supported upon a rod 155, ending in a terminal 156. The anode 153 is supported upon a metallic rod 157, ending in a terminal 158. Thus the terminals 156 and 158 are the main terminals. A miniature mercury lamp 159, of the kind above described, is mounted upon a glass stem 160, and extends into a central opening 161 with which the plate 153 is provided. It may be connected with any suitable source of alternating current, and for this purpose, is provided with a winding 162 and connected with the ends of this winding are wires 163, 164, leading to terminals 165, 166.

The mercury lamp, 159 may be energized synchronously with the anode 153 and cathode 154 or not, depending upon the particular use for which the device is employed.

Where the parts just mentioned are energized synchronously, the device can be used for detecting the presence of electric oscillations of a predetermined frequency. This is done by subjecting both the mercury lamp and the electrodes of the tube, to continuous oscillations of a predetermined frequency. The terminals 156 and 158 may be connected with either a telephonic line wire or an antenna to be energized by the oscillation which are to be selectively picked out or detected. Thus when the line wire or the antenna, as the case may be, is energized by oscillations of the predetermined frequency, and not otherwise, there are corresponding increases in the current passing through the vacuum tube, which thus respond to the incoming oscillations of the predetermined frequency. Again, by varying the frequency with which the device is continuously energized, and measuring or otherwise noting the variations of current which pass through the tube, the device can be used to determine the frequency of oscillations controlled from a distance. Further, the main terminals 156 and 158 may be subjected to a constant and uniform difference of potential, and the lamp terminals 165 and 166 may be subjected to potential variations of constant and predetermined frequency, or to potential variations of varying frequency, as the case may be, the quantity of current passing through the tube, being measured or otherwise noted in order to enable the operator to determine when the incoming oscillations have a predetermined frequency, or to determine the frequency of the oscillations thus controlled from a distance.

In addition, the terminals 156 and 158 may be subjected to a constant difference of potential and by connecting the terminals 165 and 166 with a sound control microphone, or an aerial, an audion, or the like, variations may be set up in the flow of current from the anode 153 to the cathode 154. In this manner the device performs the function of an audion, a pliotron, an oscillion, a kenatron, or the like, depending upon the particular purpose for which the device is used.

In the form of my device appearing in Figure 12, the principles just described with reference to Figure 11 may be utilized, but in Figure 12 I show a grid, in addition to the other parts as hereinafter described.

The vacuum tube is shown at 168, the cathode at 169, the grid at 170, and the anode at 171. The anode is in the form of a plate and is provided with an opening 173. A mercury lamp 174, having the general form of a capsule as above described, extends through this opening. The lamp 174 is provided with a winding 175, and connected with the ends of this winding are stout wires 176, 177. The cathode 169 is provided with a terminal 178 and the anode 171 is similarly provided with a terminal 179. The wires 176, 177 are provided with terminals 181, 182.

The device, as a whole, is closely analogous to an audion, a pliotron, an oscillion or the like, which is provided with a grid. The grid is used in the manner conventional for devices of this kind. For instance, if the device is used in connection with an aerial for the purpose of receiving wireless communications, the terminal 180 is connected with the aerial. Except as just described, the device is similar in its action to the one already described with reference to Figure 11.

The action of ultra-violet light upon the grid for the purpose of ridding the grid of the charges of negative electricity otherwise tending to accumulate upon it and thus to impair the action of the vacuum tube, is above set forth at length.

In the form of my device shown in Figure 13, the cathode has the form of a tube terminating in a hemispherical end, and the source of ultra-violet light is an ordinary mercury tube.

The vacuum tube appears at 183, the cathode at 184, the cathode being of the form above described. It is provided with an opening 185 and is mounted upon a rod 186 serving as the cathode terminal of the tube. The anode appears at 187, and is a flat plate of metal supported upon a metallic rod 188, serving the purpose of the anode terminal.

Located within the cathode 184, is a mercury vapor tube 189, containing a volume 190 of free mercury. The tube 189 is provided with terminals 191, 192. A wire 193 leads from the terminal 192 through the opening 185 and out through the wall of the tube. A wire 194 is connected with the terminal 191, and leads therefrom out through the wall of the tube. Thus the wires 193, 194 serve as terminals for the purpose of energizing the mercury tube 189 and the terminals 186, 188 are the main terminals of the tube.

The mercury tube 189 when energized by means of a source of electricity extrinsic to the vacuum tube and suitable for the purpose, throws off large quantities of ultra-violet rays, which strike the anode 187.

Except as just described the action of the device shown in Figure 13 is similar to that of the other forms of my device.

In each of the various vacuum tubes above described the main discharge through the tube, from the cathode to the anode, is proportional to the intensity of the ultra-violet rays. The quantity of the discharge therefore depends upon the ultra-violet light, while the penetration of the X-ray depends upon the voltage applied to the terminals of the electrodes.

The discharge is entirely under the control of the operator, and no discharges take place from the cathode except from the area which is illuminated by the ultra-violet rays.

In instances where my device is employed as an X-ray tube or in connection therewith, the focus of the reflecting cathode can be adjusted, if desired, in a manner similar to that heretofore employed for adjusting the focus of a gas tube. While, therefore, the focus is converging, it can be adjusted to be either fine, medium, or broad, according to requirements.

My method of producing cathode discharges differs from the thermionic method in that I do not expose the anode to radiation directly from a hot body, and do not necessarily have a heated body in the vacuum tube. I thus accomplish the release of electrons entirely by means of light of relatively short wave length. These are true photo-ionic discharges.

In my system the discharge from the illuminated surface can be directed as desired, and discharges take place from the surface which is directly illuminated, and not from any other surface.

Because of the many different sources from which ultra-violet light is obtainable, the precise form in which the light is supplied may be varied within wide limits.

I do not limit myself to the precise mechanism here shown and described, as variations may be made therein without departing from my invention, the scope of which is commensurate with my claims.

I claim:—

1. An electrical vacuum device comprising an evacuated envelope, an anode and a cathode located therein, means for subjecting said cathode to the action of ultra-violet rays, means for varying the intensity of said ultra-violet rays, and means for preventing electrons emitted from the surface of the cathode from falling upon any other part of the device, except the anode.

2. A device of the character described comprising a highly evacuated vessel, an anti-cathode and a cathode located within said vessel, said cathode being concave and being focused upon said anti-cathode, means for subjecting said cathode and said anti-cathode to high potential current, a source of ultra-violet light so positioned as to prevent the rays thereof from reaching said anti-cathode, and means for causing ultra-violet rays from said source to fall upon the inner surface of said cathode, so as to set up a cathode ray discharge for the production of X-rays.

3. A device of the character described, for the production of X-rays, comprising a hollow vessel evacuated to the highest possible degree, an anti-cathode and a cathode located within said vessel, said cathode being concave and being focused upon said anti-cathode, a source of ultra-violet light, so located relatively to the cathode that ultra-violet rays from said source can fall upon the inner surface only of the cathode, mechanism for regulating the intensity of the ultra-violet rays, means for energizing said source of ultra-violet rays, and connections for subjecting said cathode and said anti-cathode to high tension current.

4. In an X-ray tube the combination of an anti-cathode serving as a target, a cathode, a source of ultra-violet light for illuminating said cathode, and mechanism located within the tube for preventing the ultra-violet light from reaching the anti-cathode.

5. In an X-ray tube the combination of a vessel evacuated to an extreme degree, an anode and a cathode located within said vessel, said anode serving as a target, a source of ultra-violet light for illuminating said cathode, and a screening member located within said evacuated vessel for the purpose of preventing ultra-violet rays from the source of ultra-violet light from reaching said anode.

6. In a device of the character described the combination of a vessel evacuated to an extreme degree, a cathode, and an anti-cathode located within said vessel a source of ultra-violet light mounted within said vessel and favorably located therein for the purpose of throwing ultra-violet light upon

said cathode, and a screening member located within said vessel and in proximity to said source of ultra-violet light for the purpose of preventing ultra-violet rays from reaching said anti-cathode.

7. In an X-ray apparatus the combination of a vessel evacuated to an extreme degree, a cathode and an anti-cathode located within said vessel, an electrically operated source of ultra-violet light located within said vessel. for the purpose of subjecting said cathode to the action of ultra-violet light, a transformer provided with a primary winding and with a plurality of secondary windings, connections from one of said secondary windings to said cathode and said anti-cathode for energizing the same, and connections from another of said secondary windings to said electrically operated source of ultra-violet light, for the purpose of energizing the same.

8. In an X-ray apparatus the combination of a vessel evacuated to an extreme degree, a cathode and an anti-cathode mounted within said vessel, the anti-cathode serving as a target, an electrically operated source of ultra-violet light located within said vessel and disposed in close proximity to said cathode, a screening member located between said source of ultra-violet light and said anti-cathode for the purpose of screening said anti-cathode from ultra-violet rays, a transformer provided with a primary winding whereby it may be energized, said transformer being further provided with a pair of secondary windings, connections from one of said secondary windings to said cathode and said anti-cathode for the purpose of causing a discharge to take place from said anti-cathode to said cathode, connections from the other of said secondary windings to said electrically operated source of ultra-violet light, and condensers and a pancake transformer included within said last-mentioned connections.

ARTHUR MUTSCHELLER.