Nov. 2, 1926. 1,605,001

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VACUUM VALVE WITH GLOW DISCHARGE

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Fig. 1

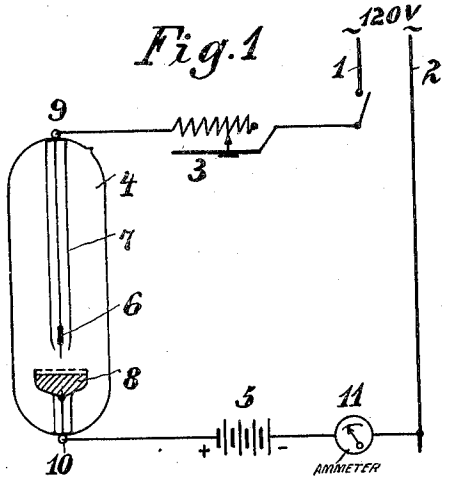


Fig. 2

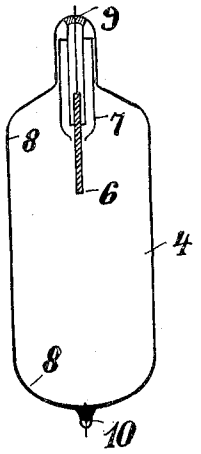


Fig. 3

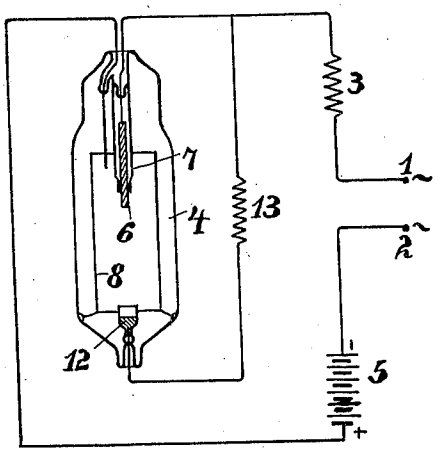
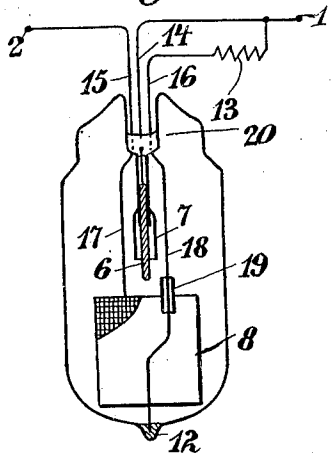


Fig. 4



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UNITED STATES PATENT OFFICE.

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VACUUM VALVE WITH GLOW DISCHARGE.

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The present invention relates to a discharge tube, put in a circuit as a valve and filled with rare gases under reduced pressure, and it consists of that kind of discharge tubes, in which the discharge has the characteristic of a glow discharge so that the main part of its consumption of voltage lies in the Crookes' dark space directly on a relatively cold cathode. By this feature the tube is distinguished from other tubes filled with rare gases, in which the discharge takes place in the form of an arc, and it is also distinguished from such tubes, in which the ionization is caused by a cathode, working at a high temperature and thereby emitting electrons, thereby rendering the discharge possible. The tube according to the invention is especially adapted to rectify alternating current, but it is not confined to such use. Thus, for an example, it may as well be used as a valve for reducing the voltage, i. e. a valve, which absorbs a part of a given voltage, in other words, chokes the same like a reducing valve. When employed for this purpose, the tubes according to the invention may serve for taking from a supplying circuit of higher voltage such, for instance, as 110 or 220 volts currents of a reduced voltage for operating bells, signaling apparatus in telephone plants, or the like. In case the supplying circuit is charged with alternating current, as shall be assumed in the statements following hereafter, then the two effects i. e. the rectifying—as well as the choking—effect are simultaneously utilized in that, for instance, a battery of moderate voltage, which serves for operating some signaling apparatus in a telephone plant, is charged with direct current from the alternating current supplying circuit, the voltage, acting in the circuit, being at the same time reduced by an amount corresponding to that absorbed in the discharge tube. This latter effect occurs even if the intensity of current becomes very reduced and approaches zero, as even then the discharge tube, quite contrary to the ohmic resistances, as, for instance, metallic resistances, absorbs a high percentage of supplying circuit voltage between its electrodes when supplying a current capable of being measured.

As regards construction the glow discharge tube according to the invention is distinguished from those tubes, filled with rare gases and working with an arc or with a discharge emanating from an incandescent cathode, by the fact, that a non-incandescent metal of large area, uniformly covered with a layer of glowing gas, is used as a cathode. Quite the contrary appears when the discharge has the form of an arc in which case the whole discharge is concentrated at a single incandescent point of the total surface of the cathode, on which a vivid vaporization takes place. The formation of such an incandescent point on the cathode and the reversal of the glow discharge characteristic to the arc, is obviated with the tube according to the present invention by making the surface of the cathode so large in relation to the maximum strength of current to be passed through the tube, that the cathode metal cannot be superheated by the current escaping on all parts with constant density.

The electrodes of the tube are located so close to each other that, at a filling with rare gases under a reduced pressure, for instance, with argon from 1 to 7 mm. or a mixture of neon and helium of 3 to 10 or with mixtures of the gases before-mentioned of 3 to 20 mm. mercury, the discharge is automatically started by the voltage of the supplying circuit. In order to render possible an independent passage of the discharge between the electrodes and in turn a proper working of the device without further auxiliary means, even at the low voltage of 100 to 150 volts, one of the electrodes of the tube, or both, but the cathode in any case, should consist of an alkaline metal, such, for instance, as potassium, sodium, lithium or the like, or another strongly electro-positive metal such, for instance, as calcium, barium, magnesium or the like, or of alloys or compounds of such metals one with another or with other metals, such, for instance, as zinc, aluminium, mercury, thallium, lead or the like. By the effect of the alkaline metal contents of the cathode the voltage drop in the Crookes' dark space is diminished so that the discharge may take place with less voltage and the absorption of energy by the discharge tube is reduced so that the duration of life of the tube is increased. Furthermore, the strongly electro-positive metal as above-mentioned in-

creases the efficiency of the transformation of the alternating current more effectively than by other less electro-positive metals (such as iron, tungsten and the like), of which the cathode might be formed. The alkaline metal, or to speak more generally, the strongly electro-positive metal may form the cathode or both electrodes bodily or it may be used as a coating on conductors of any other substance. When both electrodes consist of the strongly electro-positive metal the advantage is attained that, on account of the smaller anode drop of such metals, the consumption of voltage across the terminals of the tube and also the starting potential will be reduced. Likewise, receptacles of insulating substance within the discharge tube may be filled with the said metal in such a manner that the surface of the metal filled in acts as an electrode and a metallic conductor properly contacts with the metal filled in.

Further features of the invention are disclosed by the embodiments of discharge tubes and their connections in relation to the weak current apparatus hereafter described.

In order to render my invention more easily intelligible reference is had to the accompanying drawings in which Figs. 1 to 4 illustrate several forms of embodiment of the vacuum valve with glow discharge.

Referring to the drawings Fig. 1 illustrates the embodiment and electric connections of the discharge tube, by means of which the current of an alternating voltage supply circuit of 120 volts is to be rectified and a battery to be charged with the direct current of less voltage thus obtained. By establishing a connection by means of a switch, current is taken from the conductors 1 and 2. The resistance 3 limits the strength of the current and is preferably made variable as shown. The glow discharge tube 4 is filled with rare gas under reduced pressure and preferably made of glass, and 5 is the battery. An ammeter 11 for measuring the current is connected in series with the circuit. The current enters the discharge tube 4 through the terminal 9 and leaves it through terminal 10. The anode 6 may be of any desirable conductive material, such, for instance, as tungsten, carbon, iron, nickel and the like. In case such discharge tubes are used as choking valves in a direct current circuit, the anode may consist of the same substance as the cathode or may be provided with coatings of such substance. The rectifiying efficiency of the alternating current is increased by a mantle tube 7 or the like, which narrowly encases the anode without touching it, and thereby prevents the formation of cathodic glow layers. By such an arrangement it is effected that as small a quantity of current as possible flows in the opposite direction.

The cathode 8 has the shape of a cup or pan consisting of insulating material, such as glass, quartz, porcelain, magnesia or the like, and filled with the electro-positive material. Current is supplied through a wire entering the cup from below and connected up with the lead 10. The electro-positive metal, as alkaline metal and its alloys, is preferably fed to the cup in a molten state through a pipe, to which the metal is admitted from a heated projection of the tube. A finely pointed projection forming a continuation of the anode facilitates the discharge in case alternating current is used. If direct current is used the pointed projection must be attached to the cathode. Owing to the small cathode voltage drop of the electro-positive metal the discharge is started automatically, even at a voltage below 100 volts, as soon as the electric connection is established. No current can pass in the opposite direction since the given voltage of 120 volts would not suffice for starting the discharge owing to the fact that the electrode 6 acting as cathode in this case would not allow the current to pass at so low a voltage. Weak currents may flow in this direction, if the battery 5 comprises a considerable number of cells and thus has a higher voltage. However, owing to the current being impeded by the small free surface of the electrode 6 and by the insulating tube 7, it will always remain small in comparison to that flowing in opposite direction, in which 8 acts as cathode. Consequently the total current in the circuit possesses always a considerable direct current component.

The life of such valve tubes with glow discharge is very considerable, owing to the uniform distribution of the heat generated over the whole cathode surface, no parts of the same are in any way superheated. Furthermore, the alkaline metals offer the advantage that the rare gases are not occluded by the discharge, as this is the case with other discharge tubes. Finally, by this combination the advantage is offered that gaseous impurities mixed with the rare gas filling are easily removed by the strongly reactive, electro-positive substances.

In case the full wave of the alternating current is used to obtain direct current, the electrical connections indicated in Fig. 1, which allows the utilization of but one phase, must be modified in the manner well known in mercury rectifiers i. e. a tube with two anodes and one cathode must be employed, the anodes of which are connected to the two ends of the winding of a transformer or reactance coil, the mid-point of the winding being connected to the cathode. This electrical connection is shown, for instance, in British patents to Weintraub No. 7065/1904 or 7067/1904 Figure 1.

The embodiment of the discharge tube explained with reference to Fig. 1 is especially suitable for weak currents up to about 3 milliamperes per square centimeter of cathode-surface. In case stronger currents are to be obtained, all the cathode substance would be soon carried away from its original place owing to the heat generated on the cathode at the discharge, partly by vaporization and partly by disintegration of the cathode. In order to obviate this drawback in tubes of relatively high capacity, the cathode substance is used as a coating or lining placed upon the inner wall of the tube, which, on account of the external cooling, forms the portion having the lowest working temperature. The anode is so arranged and dimensioned that owing to the influence of the heat of the current there will be a drop of temperature in direction from the anode to the cathode, so that accordingly all the metal particles escaping off the cathode are always forced to return to the place of the lowest temperature i. e. to their place of origin. This arrangement is shown in Fig. 2. The glow discharge tube 4 is filled with rare gas under reduced pressure. The anode 6 consists of the same substances as set forth with reference to Fig. 1. 7 indicates the protecting tube for increasing the safety of the rectifying effect. The surface of 6, as far as it projects out of the protecting tube 7, is so small that a temperature is imparted to the metal, which is higher than that which may be taken up by the cathode-surface at the desired current strength. Thereby the temperature drop directed towards the wall of the tube is produced. 9 and 10 indicate, in the same manner as in Fig. 1, the two terminals. The cathode-substance 8 is uniformly distributed over the entire inner wall of the tube, and this uniform distribution must be such that the layer coating or lining is of sufficient density to ensure an equally small drop of cathode voltage, as would be the case on places of greater thickness of the layer, so that the current density of the discharge is thoroughly a uniform one. It will do, when manufacturing the tube, if at the beginning only a part of the inner wall is covered with the cathode substance, and this because, owing to the arising differences of temperature, the discharge itself will distribute the electro-positive cathode material gradually over the entire inner wall of the tube.

The distribution of the cathode substance upon the inner wall of the tube 4 is effected by coating in a purely mechanical or thermic way, by means of cathodic disintegration or in any other suitable manner as, for instance, galvanically or chemically. It is preferable to provide a metallic blanket, which is connected to the current supply and at the same time protects the tube material against being attacked by the strongly reactive cathode substance, and which may be used in form of sheet metal, fabric or a galvanically or chemically produced coating, for instance, a silver layer, which is arranged upon the inner wall. The blanket should preferably be of a metal or alloy to which the cathode substance adheres effectively, or with which it is easily alloyed or chemically combined. Such a metallic blanket prevents the cathode substance chemically attacking the tube material, consisting generally of glass, and is partly responsible for heat dissipation since it equalizes any differences in temperature that may occur at same portions of the wall. The cooling of the tube wall is, in the presence of stronger currents, assisted by a black coating or paint on the outer side, which increases the radiation of heat.

Figs. 3 and 4 illustrate other embodiments of discharge tubes filled with rare gases according to this invention, and these have for their objects to use as small quantities as possible of the strongly reactive cathode material and to render the operation of the tube constant and safe. For this purpose the electro-positive substance forms a special electrode, for instance, an auxiliary electrode, charged with low current density. From this electrode small quantities of the electro-positive substance are by means of the discharge permanently carried to the cathode surface proper. Referring to Fig. 3, 1 and 2 designate the connection to an alternating current supply circuit, 3 a current limiting resistance, 4 the discharge tube with the anode 6, protected by the insulator 7; and 5 the battery to be charged by the direct current generated. The electro-positive substance is placed within a special electrode receptacle 12. In the circuit of this electrode a resistance 13 is interposed, which keeps down the current strength, so that a slow volatilization of the substance of 12 takes place. The volatilized metal particles are deposited as a layer upon the cylindrical electrode 8, which consists of any desired metal, for instance iron, nickel or copper. This deposit forms a cathode with a large area and a small cathode voltage drop. In the electrical connections shown the auxiliary electrode 12 has the same polarity as the anode 6. The resistance 13 may also be so arranged that it establishes connection between the terminals of the electrodes 8 and 12. This is immaterial as regards the efficiency of the auxiliary electrode. In both cases the starting of the discharge in the tube is facilitated by the auxiliary electrode 12. The resistance of 13 must be so high that the branch current passing over 12, remains always small enough, in comparison to the current passing between 6 and 8, to maintain a sufficient efficiency of the device.

Another embodiment is shown in Fig. 4. Here the current is supplied to the three electrodes through a common seal 20, which resembles the press of an incandescent electric lamp, and in which the leading-in wires of the three conductors 14, 15, 16 are sealed. The lead 14 is connected to the anode 6, which in turn is provided with an insulator 7. The auxiliary electrode 12, located on the bottom of the tube and consisting of a very small amount of the electro-positive substance is connected to the lead wire 16. The wire 15 continues within the interior of the tube as a conductor 17, which is connected to the cathode 8, having a large area and being of screen or net-like construction. This cathode may be made of perforated sheet metal, metal-fabric or the like. The conductor 18, which establishes connection between the wire 16 and the auxiliary electrode 12, is prevented from contacting with cathode 8 by means of an insulator 19. The branch current emanating from 12 carries small quantities of electro-positive substance to the cathode 8, in the meshes of which such particles are retained. The speed of admitting effective material to the cathode depends on the degree of the heating of the cathode, for, owing to such heating, 8 loses small quantities of its electro-positive coating, which must be replaced by the auxiliary electrode 12. This electrode may be connected with the anode 6 or with the cathode 8 by means of a sufficiently high resistance 13, such, for instance, as referred to in Fig. 3. In the first mentioned arrangement the discharge in the tube is especially facilitated.

I do not wish to confine myself to the embodiments shown and, therefore, the arrangements are merely to be considered as examples of the manner in which my invention may be carried into effect It is also to be understood that in place of the battery shown, other weak current apparatus, such as relays, bells, telephones, and the like, may be included in the circuit of the tube.

I claim as my invention:—

1. Improved vacuum valve with glow discharge comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode of strongly electro-positive metal, an anode, said anode and cathode being spaced apart by a relatively small unobstructed gap so that the voltage of ordinary supplying circuits allows an automatic discharge in the receptacle, and means for supplying current to the said cathode and anode.

2. Improved vacuum valve with glow discharge comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode, and an anode having a smaller area than said cathode, said anode and cathode being separated by a relatively small unobstructed gap and means for supplying current to the said cathode and anode both located within said receptacle.

3. Improved vacuum valve with glow discharge comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode, and an anode having a smaller area than said cathode, the anode consisting of a less electro-positive metal than the cathode, said anode and cathode being separated by a relatively small unobstructed gap and means for supplying current to the said cathode and anode.

4. Improved vacuum valve with glow discharge comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode, an anode having a smaller area than said cathode, the anode consisting of a less electro-positive metal than the cathode, an insulator encasing the anode for diminishing its free surface, and means for supplying current to the said cathode and anode.

5. Improved vacuum valve with glow discharge, comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode embodying an alkaline metal such, for instance, as potassium, sodium, lithium and the like, an anode, said anode and cathode being separated by a relatively small unobstructed gap whereby the voltage of ordinary supplying currents allows an automatic discharge in the said receptacle, and means for supplying current to the said cathode and anode.

6. Improved vacuum valve with glow discharge, comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode of a strongly electro-positive metal alloyed with other metals such, for instance, as zinc, mercury, lead, thallium and the like, and an anode, both arranged within said receptacle in such a manner and at so small a distance apart that the voltage of ordinary supplying currents allows an automatic discharge in the said receptacle, and means for supplying current to the said cathode and anode.

7. Improved vacuum valve with glow discharge, comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode of strongly electro-positive metal chemically combined with other metals such, for instance, as mercury and the like, and an anode, both arranged within said receptacle in such a manner and at so small a distance apart that the voltage of ordinary supplying currents allows an automatic discharge in the said receptacle, and means for supplying current to the said cathode and anode.

8. Improved vacuum valve with glow discharge, comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode consisting of any suitable substance being coated with a strongly electro-positive metal, and an anode, both arranged within said receptacle in such a manner and at so small a distance apart that the voltage of ordinary supplying circuits allows an automatic discharge in the said receptacle, and means for supplying current to the said cathode and anode.

9. Improved vacuum valve with glow discharge, comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode and an anode within said receptacle, arranged in such a manner and at so small a distance apart that the voltage of ordinary supplying circuits allows an automatic discharge in the receptacle, an auxiliary electrode of strongly electro-positive metal, a branch circuit for causing particles of said metal to be carried from said auxiliary electrode to the cathode surface proper, said branch circuit including a resistance to reduce the cathode voltage drop, and means for supplying current to the said cathode and anode.

10. Improved vacuum valve with glow discharge, comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode and an anode, both arranged within said receptacle in such a manner and at so small a distance apart that the voltage of ordinary supplying circuits allows an automatic discharge in the receptacle, an auxiliary electrode of strongly electro-positive metal, means for causing particles of said metal to be carried from said auxiliary electrode to the cathode surface proper, said means including a resistance, to reduce the cathode voltage drop, and means for supplying current to the said cathode and anode.

11. Improved vacuum valve glow discharge comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode and an anode within said receptacle, arranged in such a manner and at so small a distance apart that the voltage of ordinary supplying circuits allows an automatic discharge in the receptacle, an auxiliary electrode of strongly electro-positive metal, a branch circuit for causing particles of said metal to be carried from said auxiliary electrode to the cathode surface proper, said branch circuit including a resistance, to reduce the cathode voltage drop, a high resistance connecting the auxiliary electrode with said anode, and means for supplying current to the cathode and anode aforesaid.

12. Improved vacuum valve with glow discharge, comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode and an anode within said receptacle, arranged in such a manner and at so small a distance apart that the voltage of ordinary supplying circuits allows an automatic discharge in the receptacle, an auxiliary electrode of strongly electro-positive metal, a branch circuit for causing particles of said metal to be carried from said auxiliary electrode to the cathode surface proper, said branch circuit including a resistance, to reduce the cathode voltage drop, the auxiliary electrode being connected with the anode, and means for supplying current to the said cathode and anode.

13. Improved vacuum valve with glow discharge, comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode containing electro-positive metal within said receptacle, said cathode consisting of a perforated body of large area, and an anode within said receptacle, said cathode and anode being arranged at so small a distance apart and in such a manner that the voltage of ordinary supplying circuits allows an automatic discharge in the receptacle, an auxiliary electrode of strongly electro-positive metal, a branch circuit for causing particles of this metal to be carried from said auxiliary electrode to the cathode surface proper, said branch circuit including a resistance, to reduce the cathode voltage drop, means for supplying current to the said cathode and anode, and weak current apparatus in the circuit of the main electrodes.

14. Improved vacuum valve with glow discharge, comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a coating of strongly electro-positive metal uniformly distributed upon the inner wall of the receptacle and acting as a cathode, an anode arranged within said receptacle so that its temperature exceeds that of the cathode surface, a protecting tube for said anode, and means for supplying current to said cathode and anode.

15. Improved vacuum valve with glow discharge, comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode formed of conductive material covering the inner wall of said receptacle and coated with electro-positive metal, an anode arranged within said receptacle, a protecting tube for said anode, and means for supplying current to said cathode and anode.

16. Improved vacuum valve with glow discharge, comprising a receptacle, a filling of rare gas within said receptacle under a reduced pressure, a non-incandescent cathode within said receptacle, an anode within the said receptacle, the surface of the cath-

ode being so dimensioned in relation to the discharge current strength and kept at so low a temperature, that the reversal of the glow discharge characteristic to the arc characteristic is obviated.

17. A glow discharge device comprising an evacuated vessel, a rare gas therein under reduced pressure, a non-incandescent cathode, an anode, said cathode and anode being arranged at so small a distance apart that the voltage of ordinary supply circuits allows an automatic discharge in said vessel, an auxiliary electrode of electro-positive metal, and means for causing particles of said metal to be carried from said auxiliary electrode to said cathode.

In testimony whereof I have affixed my signature.

FRITZ SCHRÖTER.