Jan. 1, 1929. 1,697,210

L. SZILARD

DISCHARGE TUBE

Filed April 20, 1925

Fig. 1.

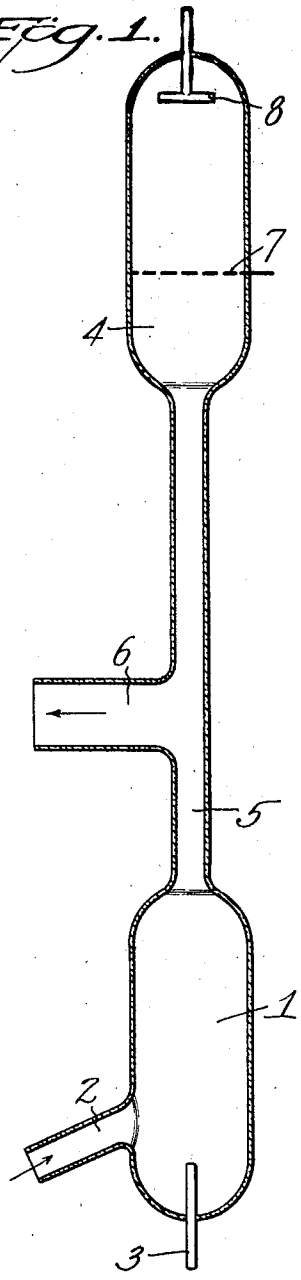
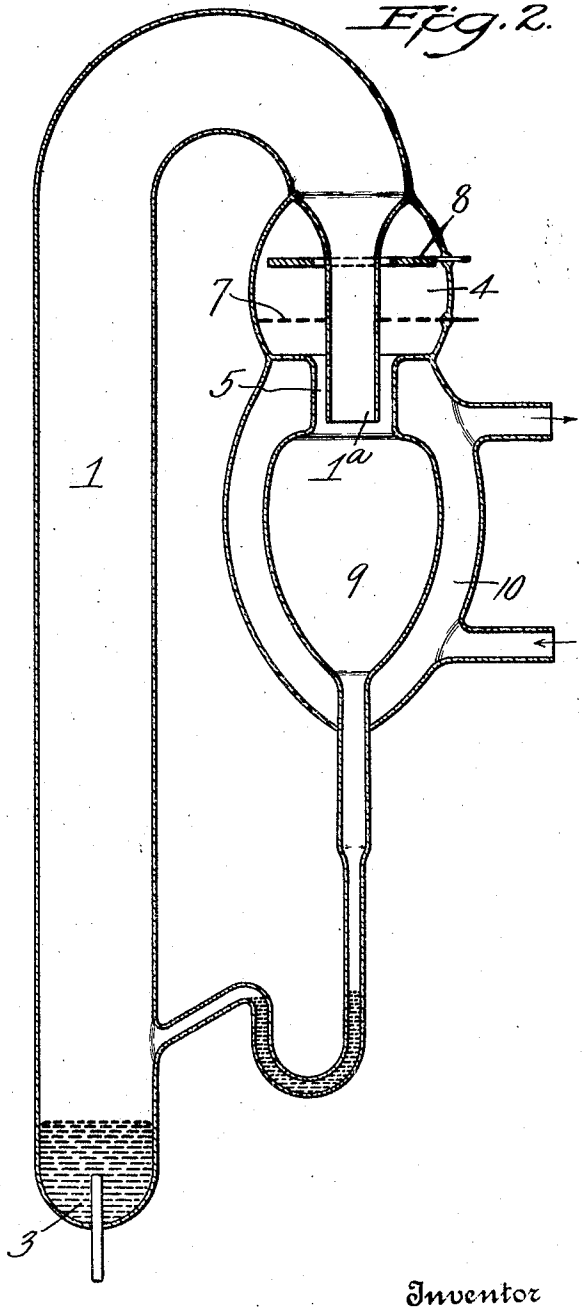


Fig. 2.



Inventor
LEO SZILARD

WITNESS
Olive A. Holmes

By his Attorneys
Muir & Muir.

Patented Jan. 1, 1929. 1,697,210

UNITED STATES PATENT OFFICE.

LEO SZILARD, OF BERLIN, GERMANY, ASSIGNOR TO SIEMENS-SCHUCKERTWERKE AKTIENGESELLSCHAFT, OF BERLIN-SIEMENSSTADT, GERMANY, A CORPORATION OF GERMANY.

DISCHARGE TUBE.

Application filed April 20, 1925, Serial No. 24,575, and in Germany September 3, 1924.

This invention refers to a novel form of electronic discharge tube which allows of obtaining intense electronic currents in a high vacuum by comparatively simple means.

Hitherto considerable currents could only be obtained in a highly evacuated tube, such as for instance a triode by means of incandescent cathodes, requiring very large heating currents. On the other hand an electron discharge produced in a less high vacuum for instance by a mercury vapor arc while allowing large currents to pass, cannot be controlled by grids or similar means in a way which is possible with discharges in high vacuum triode tubes. For instance if a grid is interposed between cathode and anode of a mercury vapor rectifier it is possible to retard or to prevent the starting of the discharge by bringing the grid to a sufficiently high negative potential but it is impossible to influence or to suppress the arc once produced.

The present invention comprises a vacuum discharge tube divided into two main parts which are connected by a narrow communication path. In one part which contains the cathode a sufficiently high gas pressure is maintained so as to obtain an arc discharge. The electrons discharged in this part of the tube pass through the communication path to the other part of the tube where a high vacuum is maintained. The electron current can be influenced and interrupted in this part of the tube by means of grids charged at suitable potentials or by magnets much the same as in the well known, vacuum tubes.

In the annexed drawing the subject matter of the invention is represented in two embodiments. Figure 1 shows diagrammatically the simplest form, and Figure 2 shows another embodiment.

Referring to Figure 1, 1 is the first compartment of the tube containing gas at fairly low pressure, suitable to maintain an arc; 2 is a small tube through which small quantities of gas are continually admitted into compartment 1; 3 is a cathode; 4 is a second compartment; 5 is a communicating passage way between compartments 1 and 4; 6 is an outlet connected to a high vacuum pump (not shown); 7 is a grid set up in compartment 4; and 8 is an anode arranged in compartment 4.

This arrangement allows a small gas pressure to be maintained in compartment 1 and at the same time a high vacuum in compartment 4. If a discharge is caused between electrodes 3 and 8, this discharge will exhibit in compartment 1 the character of an arc according to the prevailing gas pressure; it will then by passing through communication 5 gradually change into a pure electronic current. This current can be controlled in compartment 4 by means of the grid 7 much the same as in an ordinary triode.

Another embodiment of the invention is shown in Fig. 2. It consists of a mercury vapor jet high vacuum pump of a well known type. Here again 1 represents the compartment having suitable low pressure for maintaining an arc discharge and the mercury pool 3 of which is used as a cathode. Compartment 1 discharges the vapor in a jet through nozzle 1^a, into condenser 9 which is cooled by a cooling jacket 10. 4 is the high vacuum compartment in which the vacuum is maintained by the well-known action of mercury jet pumps. The narrow throat formed between nozzle 1^a and the jacket wall forms the small communicating passage 5, equivalent to passage 5 in Figure 1 for the discharge between compartments 1 and 4. The latter contains grid 7 and anode 8.

When the pump is working the pressure of mercury vapor in compartment 1 and in the stream of the vapor is high enough to allow of an arc discharge, while in compartment 4 a very high vacuum can be obtained. The arc discharge passing from the low pressure compartment through the gap 5 into compartment 4 now assumes the character of an electronic current and can then be controlled by the grid 7 as effectively as in a triode. If a suitable negative potential with respect to the cathode is applied to the grid, the current can be reduced to any value or be even stopped. The grid current will be small at the same time.

In the arrangement described above it is essential that the mercury vapor be prevented from entering the high vacuum part. In order to obtain this effect the width of the cooled gap should be of the same order or less than the width of the mean free path of the mercury molecules under the prevailing conditions. This is essential in order to obtain a sufficiently low mercury vapor pressure in the high vacuum part of the pump. Similar restrictive devices are used in every type of mercury vapor pump. Indeed any type of mercury vapor pump different in its detail

arrangement from that shown can be fitted with electrodes according to the principle shown and be used for the purpose of the invention.

It is not necessary, in order to exercise the invention to use a mercury pump device as electronic discharge tube. Any mercury vapor tube may be used, provided the communication between the tube portion containing the cathode and that containing the electron controlling element is barred for the mercury vapor by cooled surfaces, the width of the passage along the cooled surface being at one point at least of the same order of dimension as the mean free path of the mercury molecules at that point. It is preferable to use a bent communication path such as would result for instance from an arrangement shown in Figure 2 in order to prevent molecules from flying in a straight line through the cooled passage without striking the walls. At any rate it is preferable to use a pump device; any gases will be removed then with certainty from the high vacuum chamber.

The vapor pressure in the high vacuum part of the tube is essentially equal to the saturation pressure of the mercury at the temperature of the cooled surfaces. By using other suitable cooling liquids instead of water and a cooling device connected to a small refrigerating machine, temperatures much below zero can be maintained. By choosing the right temperature one can arrive at any suitable vapor pressure in the high vacuum compartment. This vapor pressure can be chosen so that it is sufficiently low to permit the interruption of the current by means of a suitably charged grid and that there still will be left enough vapor there to supply enough positive ions to compensate the negative space charged.

Mercury vapor discharge tubes provided with grids are already known. In some of these tubes the vacuum in the neighborhood of the grid is higher than close to the cathode. However, the designers could not have intended to obtain in such devices a high vacuum close to the grid, such as is required for the purpose of the present invention, for the reason that even if one would cool the walls of such a prior art tube very intensely one would not obtain a sufficiently high vacuum in the neighborhood of the grid, for in these prior art devices the path open for the vapor to reach the grid is a very broad one. One would get in consequence a very large grid current if attempts were made to stop the electron current by imposing upon the grid a negative potential with respect to the cathode. This current is caused by the positive ions which are supplied by the vapor in large quantities and which make it impossible to control direct current effectively with mercury vapor tubes of the types suggested by others in the past.

In the tubes according to the present invention the mean free path of the molecules is (in the controlling part) of the order of centimeters. Therefore velocity of the positive ions is given by the formula

$$v = \sqrt{\frac{efl}{m}}$$

a homogeneous electrical field being presumed and collisions being neglected. (e is the charge of the ion, f is the field intensity, m the mass and l the length of the path.) As the mass of the mercury ion is 400,000 times as large as that of an electron the positive ions will transport $\frac{1}{600}$ part of the total current if the concentration of the positive ions and of the electrons is equal. This will occur at a certain critical vapour pressure. If the pressure is higher than this critical value the positive ions will prevail and there will result a positive space charge. If the pressure is lower than this critical value the electrons will prevail and there will result a negative space charge. In order to keep the potential drop between anode and cathode at a small value one should chose the vapour pressure above this critical value so as to avoid the negative space charge. It is, however, advisable to choose the vapour pressure at least so low that the grid current (caused by the positive ions which are supplied by the vapour) shall not exceed 10% of the main current. Such a vacuum is easily obtained in the controlling part of the discharge tubes according to the present invention.

I claim:

1. An electronic vacuum discharge tube having a compartment containing gas at a pressure to sustain an arc discharge, a cathode in said compartment, a second compartment, a communicating passage-way between said compartments, means for producing a high vacuum in said second compartment sufficient to allow control of the electron current due to the arc discharge in the said first compartment and controlling means to influence said electron current in said second compartment.

2. An electronic vacuum discharge tube having a compartment containing gas at a pressure to sustain an arc discharge, a cathode in said compartment, a second compartment, a communicating passage-way between said two compartments for directing the electron stream due to said arc discharge into said second compartment, cooling means operatively disposed relatively to said passage-way and designed to prevent vapors produced by said arc discharge from passing through said passage-way into said second compartment, means for producing a high vacuum in said second compartment sufficient to allow control of the electron current produced in said first compartment, and

controlling means to influence the electron current in said second compartment.

3. An electronic vacuum discharge tube having a compartment containing gas at a pressure to sustain an arc discharge, a cathode in said compartment, a second compartment, a communicating passage-way between said two compartments for directing the electron stream due to said arc discharge into said second compartment, cooling means operatively disposed relatively to said passage-way and designed to prevent vapors produced by said arc discharge from passing through said passage-way into said second compartment, means for producing a high vacuum in said second compartment sufficient to allow control of the electron current produced in said first compartment, and a grid element for controlling the electron current in said second compartment.

4. An electronic vacuum discharge tube having a compartment containing gas at a pressure to sustain an arc discharge, a cathode in said compartment, a second compartment containing an anode, a suitably restricted communicating passage-way between said two compartments for directing the electron current due to said discharge between said cathode and anode, cooling means operatively disposed relatively to said passage-way and designed to prevent vapors produced by said arc discharge from passing through said passage-way into said second compartment, means for producing a high vacuum in said second compartment sufficient to allow control of the electron current produced in said first compartment, and a grid element disposed in said second compartment between the cathode and anode for controlling the electron current flowing to the anode.

5. An electronic vacuum discharge tube comprising a mercury vapor jet vacuum pump having at least a vapor generating compartment, a high vacuum compartment and a vapor condensing compartment, all suitably connected with each other, said vapor compartment containing a cathode and vapor at a pressure to sustain an arc discharge, said vacuum compartment designed to receive the electron current due to said arc discharge and having a high vacuum, means for controlling said electron current in said vacuum compartment and means for preventing vapor molecules from entering said vacuum compartment.

6. An electronic vacuum discharge tube comprising a mercury vapor jet vacuum pump having at least a vapor generating compartment, a high vacuum compartment and a vapor condensing compartment, all suitably connected with each other, said vapor compartment containing a cathode and vapor at a pressure to sustain an arc discharge, said vacuum compartment designed to receive the electron current due to said arc discharge and having a high vacuum, an anode and a grid in said vacuum compartment for electrostatically controlling the electron current flowing between the cathode and anode, and means for preventing vapor molecules from entering said vacuum compartment.

In testimony whereof I have signed my name to this specification.

LEO SZILARD.