May 21, 1940. K. J. GERMESHAUSEN 2,201,167

GASEOUS-DISCHARGE DEVICE

Filed March 9, 1937

Fig. 1.

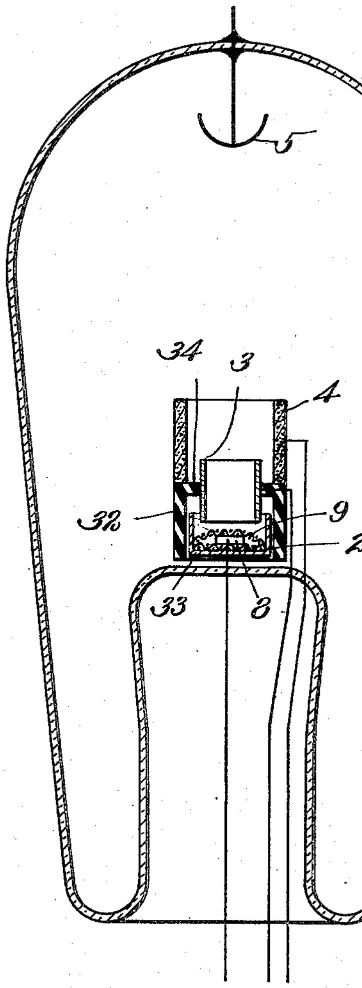
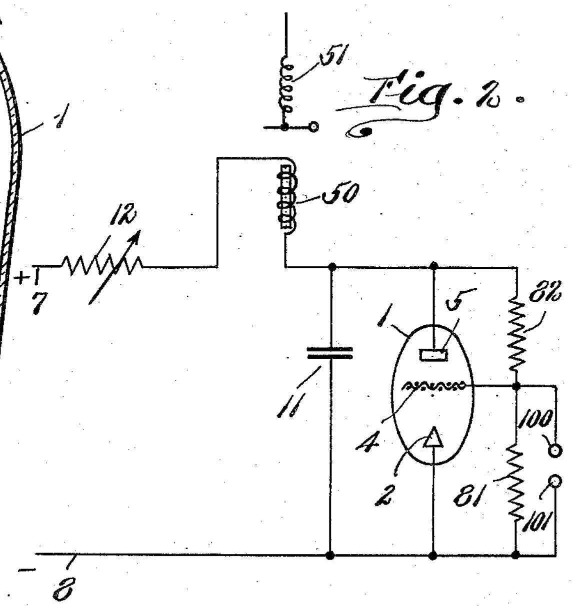


Fig. 2.



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GASEOUS-DISCHARGE DEVICE

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17 Claims. (Cl. 250—27.5)

The present invention relates to gaseous discharge devices.

An object of the present invention is to provide a new and improved cold-cathode gaseous-discharge device of the character described in Letters Patent 2,185,189, granted January 2, 1940, that shall operate immediately, without continuous consumption of cathode-heating power, and without a time delay to heat the cathode. Reference is made to the said Letters Patent for matters not more fully disclosed herein.

Another object of the invention is to provide a new and improved gaseous discharge device of the above-described character for controlling very large instantaneous amounts of power and current in response to the application of very small amounts of power.

A further object is to provide a new and improved grid-controlled gaseous-discharge device of the above-described character that shall be adapted to control very large surges of current in response to a very small current applied to its grid.

Other objects will be explained hereinafter and will be particularly pointed out in the appended claims.

For a consideration of what I believe to be novel and my invention, attention is directed to the accompanying description and the claims appended thereto.

In the accompanying drawing, Fig. 1 is a longitudinal section of a gaseous-discharge tube embodying the present invention; and Fig. 2 is a circuit diagram containing a tube of the above-described character, showing one use to which this tube may be put.

The tube illustrated in Fig. 1 may comprise an evacuated glass envelope 1, filled with a suitable gas, such as neon, or any of the other noble gases, such as argon or helium. The pressure of the gas in the tube may vary, the usual pressure being from one to two centimeters. The tube contains several electrodes, namely, a solid cathode 2, an anode or plate 5, and one or more grids, inner and outer grids being shown at 3 and 4 between the anode and the cathode. The source of the electrons is a bright cathode spot on the surface of the cathode. Either grid may be used as the control grid, depending upon the polarity and the magnitude of the control voltage.

As illustrated in Fig. 1, the cathode may comprise a metal cup 33 secured within and closing the lower end of a ceramic insulating cylinder 32. In the cup is a pill 8 that may be constituted of a mixture of materials that can react chemically to produce a substance of relatively low work-function, and that do not combine chemically with the gas in the envelope 1. A pill of compressed caesium chloride and aluminum filings or powder answers to this description. The pill forms the active material of the cathode and is held in place by a wire-mesh screen 9. The cylinder 32 prevents the discharge from forming on the outside of the cup.

The grids may also be supported by the insulating cylinder 32. To this end, the cylinder 32 may be provided with an inwardly projecting flange 34, on the inner side of which is secured a metal cylinder which serves as the grid 3. The other grid 4 comprises a carbon cylinder which is secured to, or rests upon, the upper end of the cylinder 32. The cylinder 4 is placed so that caesium does not sputter on its surface.

As explained in the said Letters Patent, this grid 3 may, in normal use, be placed close to the cathode 2, say, not more than a few millimeters from the cathode, and may be of such shape that the cathode will sputter a thin surface layer or coating of a material of low work-function, such as caesium, on the grid surface. A thin surface layer of caesium or other material of low work-function is thus maintained on the grid 3 during the normal operation of the tube. A feature of the present invention is to provide a gaseous-discharge device of the type described and claimed in the said Letters Patent, but having constructional features not covered by the claims thereof. According to another feature of the present invention, however, the coating of low work-function may be provided on the grid 3 by other means than sputtering from the cathode 2. The grid 3 may then be placed some distance from the cathode, as it will then be no longer necessary to depend on the cathode sputtering to coat the grid 3.

The grid 3 may be precoated in any desired way, but a preferred method is as follows:

Previous to assembly of the tube, the grid 3 is coated with a material of low work-function, or that can be reduced to a material of low work-function after the tube is evacuated. In the claims, both of these will be generically referred to under the terminology "comprising a material of low work-function" or its equivalent. A material of this nature that has proven satisfactory is barium nitrate. The barium nitrate may be very finely powdered, and carried by means of a suitable medium, such as collodion. After assembly, the tube is evacuated and baked at 400 degrees centigrade for 10 to 15 minutes, the oven is then removed, and the tube is allowed to cool. About 1 centimeter pressure of a suitable gas, such as neon, is then added to the tube, and a discharge is passed between the grid **3** and the grid **4**. The current should be sufficient to heat the grid **3** to a dull red heat in about 30 seconds. This decomposes the barium nitrate to barium oxide. A discharge current of about 100 milliamperes at 60 cycles arternating current is suitable. As soon as the grid **3** has reached a dull red heat, the current is shut off and the tube is evacuated. The tube is then refilled with the desired gas at an appropriate pressure and sealed off. The tube is now aged by placing it in a condenser-discharge circuit such as that illustrated in Fig. 2; after a few minutes of operation, it will be found that the barium oxide has formed a uniform surface of low work-function. The surface so formed is stable in character and of long life.

It is understood that other methods may be employed to coat the grid **3**, such as the use of barium azide, which is reducible to barium, or barium or other metals of low work-function may be evaporated onto the grid **3** from a suitable source of the metal, such as a reaction mixture placed on the grid **4** or on the anode and heated to evolve the desired material, such as barium.

The hereinafter-described cathode spot is more easily formed on the pill of caesium chloride and aluminum than on pure caesium. This is due to the fact that the caesium chloride and aluminum are in effect surface impurities or irregularities. If the pill **8** were made of pure caesium, furthermore, or for other reasons furnished too much free caesium, or if the arc discharge between the cathode and the anode were non-intermittent, the caesium would be quickly sputtered and evaporated over the tube and the cathode would have very short life.

Viewed from one aspect, therefore, the pill **8** is composed of a chemical compound of caesium which is slowly broken down under the action of the cathode spot, liberating free caesium. Viewed from another aspect, the pill is composed of a mixture of caesium with a material which retards the vaporization of the caesium under the action of the cathode spot.

Other materials than caesium chloride and aluminum may be used for the pill **8**; for example, mixtures of caesium chloride and cadmium or zinc, and mixtures of caesium chloride and rubidium chloride and aluminum, cadmium or zinc. Other metals than caesium, such as the alkali-metals, the alkali earth metals, or the rare-earth metals, may be used to provide the active material of the cathode. Examples of these are mixtures of sodium chloride and lead; mixtures of barium chloride and aluminum or zinc; barium oxide; strontium oxide; and misch metal. All tests have shown the caesium compounds to be most satisfactory.

In general, a chemical compound of one of the alkali, alkali-earth, or rare-earth, metals mixed with a metal which will displace the combined metal, or a mixture of one of the alkali, alkali-earth, or rare-earth, metals with a substance which will retard the vaporization of the metal, will be satisfactory and will provide a cathode on which the cathode spot may be readily formed. The action of the cathode spot should evolve a material of low work-function, so that advantage can be taken of the ease of cathode-spot formation on these materials.

The screen **9** facilitates the formation of a cathode spot on the pill by providing a number of points for the concentration, at the surface of the cathode, of the glow-discharge current from the anode which precedes the arc discharge. Irregularities and impurities on the surface of the cathode also assist in concentrating and localizing the electrical glow discharge on the cathode to produce the cathode spot on the cathode, and thereby render the electrical discharge an arc discharge. If the screen **9** is omitted, the local current density at the cathode may not become high enough to cause the formation of a cathode spot, and the discharge between the anode and the cathode would then hold over in a glow discharge.

The form of the arc stream between the anode and the cathode is a column of small diameter which has high intrinsic brilliance, with substantially all the light emitted from the concentrated arc stream. This discharge is easily distinguished from a glow discharge, which occupies substantially the whole interior of the tube, with a discharge of low intrinsic brilliance, the greatest brilliance being at the surface of the cathode.

The grids **3** and **4** and the cylinder **32** constitute a chimney or restricted passage for the arc discharge, rendering the voltage drop of the arc stream more constant and, therefore, increasing the stability of the operation of the tube.

The cylinder **32**, furthermore, overcomes some tendency for the discharge between the anode and the cathode to become a glow discharge between the outside of the cathode and the anode. This tendency is further resisted by placing the active material of the cathode at the bottom of the cup or cylinder, since there is a greater tendency for a cathode spot to form on an inner surface, such as the bottom of a depression, or in a corner, than there is for the cathode spot to form on an outer surface.

The anode is so placed that caesium is not sputtered on its surface during the operation of the tube. As an additional precaution, it also might be made of a material, such as carbon, to which the caesium does not readily adhere.

In the circuit of Fig. 2, a tube is illustrated having but a single grid **4**. Circuits embodying a two-grid tube are illustrated and described in the said Letters Patent and in application Serial No. 129,837, filed March 9, 1937. The anode **5** and the cathode **2** of the tube are shown connected across a condenser **11**, which is continuously charged, by way of conducting wires **7** and **8**, from a suitable direct-current source (not shown) of, say, 300 to 400 volts, connected through a variable current-limiting impedance **12** and an output element, such as a counter or other device **51**. The impedance **12** may be a resistor, or a combination of resistance and inductance. The relay **51** is shown provided with a relay coil **50**. The wire **7** is shown as the positive conducting lead, and the wire **8** as the negative lead. The source may be one or more batteries (not shown), thermionic or gaseous-discharge rectifiers (not shown) for producing direct current from alternating current, or any other source of direct current. The grid **4** is connected to the junction of resistors **81** and **82**, thus providing a positive bias for the grid **4**.

In the operation of the circuit, the condenser **11** starts to become charged from the direct-current source, through the impedance **12** and the relay coil **50**, the tube being non-conductive. When the voltage across the condenser **11** is equal to the voltage of the direct-current supply, the current ceases to flow. The grid bias of the tube

1 is adjusted so that the voltage across the resistor 81 normally does not exceed the breakdown voltage between the grid 4 and the cathode 2. The tube 1 does not, therefore, normally become conducting, even when the condenser 11 is fully charged. If, however, a control voltage of sufficient magnitude, from any suitable source, such as an oscillator, a contactor device, a photocell, an amplifier, etc., is now applied between the terminals 100 and 101 connected to the opposite ends of the resistor 81, with the terminal 100 positive, the potential of the grid 4 will momentarily be raised so that the breakdown voltage between the grid and the cathode will then be exceeded, the tube will become conducting, and a glow discharge will consequently take place between the grid and the cathode.

Because of this glow discharge between the grid and the cathode, an electrical discharge will start between the anode and the cathode through the gas in the envelope 1. If the impedance in the circuit comprising the condenser, the anode and the cathode is low, the current will instantly rise to a value sufficient to start a cathode spot. This results in a low-drop arc discharge in the tube. The current rises to a very high value (say, 300 amperes) and the tube emits a brilliant flash of light. The low impedance of the discharge path permits the condenser to discharge almost instantly, the current and flash of light lasting a few microseconds. When the voltage across the condenser has fallen to a value approximately equal to the arc drop, the tube current is maintained only by the flow through the charging impedance 12 and the relay coil 50. The values of this impedance and the direct current supply must be such that the residual current is too small to maintain the cathode spot. When this is the case, the tube drop must rise to that necessary to maintain a glow discharge, which is some ten times that necessary to maintain the arc. By the time the voltage of the condenser has risen to this value, the tube has had time to extinguish and return to its normal non-conducting state and will remain so until the grid voltage has again reached the value necessary to cause breakdown of the tube.

The arc through the tube 11 is not maintained, because of the action of the impedance 12 with the impedance of the relay coil 50, which limits the current flow to such an extent that the arc is extinguished.

The fact that the condenser, together with the leads to the electrodes of the tube, forms an oscillatory circuit further assists in the extinguishing of the tube, tending to cause the voltage across the tube to fall to a value lower than the arc drop of the tube, or even to reverse polarity.

The condenser 11 is thus periodically charged from the source of voltage supply and then discharged through the tube 1, from the anode to the cathode.

The impedance of the discharge circuit comprising the condenser 11 and the tube 1 should be sufficiently low so that the current will rise to the value necessary to start the cathode spot (say, 5 amperes). Unless this is so, the circuit will not operate properly and the tube 1 may "hold over" into a continuous glow discharge.

The current passes between the anode and the cathode continually but interruptedly to set up continually discharges of arc characteristic between the cathode and the anode. It is of amperage sufficiently high to produce a potential gradient on a relatively small area only of the cathode high enough to extract electrons from the cathode while the cathode remains "cold," at low average temperature, and to produce a fall of cathode potential lower than that occurring in a glow discharge. The average value of the said current is nevertheless relatively low. It is sufficiently low, indeed, so that its root-mean-square value, that is, the heating current, through the tube, is low enough so that the average temperature applied by the current to the cathode is less than the temperature at which substantially incandescent cathode emission is produced. The reaction takes place, therefore, at relatively low temperature, and is not progressive or explosive, and the cathode spot is formed on the cathode continually but interruptedly. The result is that the layer of the material of low work-function, such as caesium, is continually replaced during the operation of the tube. The intervals between the discharges are sufficiently large so that the average temperature of the cathode remains low enough to prevent rapid disintegration of the cathode. If the heating current were great enough to cause the cathode to become overheated, the reaction mixture in the cathode would completely react, and the caesium would all become displaced from its salt, so as to become evaporated onto the surface of the bulb. An approximate value of root-mean-square current for a small tube is 50 milliamperes.

If a glow discharge is maintained in the tube, the permissible root-mean-square current will be less than 50 milliamperes, since the cathode voltage drop is higher, and hence the heating effect at the cathode will be greater for a given current.

The current required to charge the condenser 11 again is used to operate the relay or counter 51. If the relay, counter or other electrical device has sufficient impedance, the resistor 12 may be omitted.

It is apparent that, for each pulse of voltage applied to the control terminals 100 and 101, of sufficient magnitude to start the tube 1, there is a resulting pulse of current in the relay circuit. The tube 1 and the control terminals 100 and 101 constitute, in effect, a relay or switch. The magnitude and duration of the current in the relay circuit is independent of the control pulse and is determined by the supply voltage, the impedance 12, the impedance of the relay, and the condenser 11. This is important in many applications, especially where the duration of the controlling-voltage pulse is extremely short.

An application of this circuit that has resulted in a very considerable reduction in apparatus and complexity over previous circuits is the counting of cosmic rays detected by means of a Geiger counter. The output of the Geiger counter can be placed directly in the grid circuit of the tube 1. Although the power output of the counter is extremely small, and its voltage pulse of very short duration, it is sufficient to start the tube 1, which then operates an appropriate mechanical counter, which may be represented by the output element 50.

Further modifications will occur to persons skilled in the art and all such are considered to fall within the scope and spirit of the invention.

What is claimed is:

1. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a material that will break down under the action of a cathode spot

to form on the cathode a surface coating of a material of a low work-function, and the grid comprising a material that is reducible to a material of low work-function.

2. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a material that will break down under the action of a cathode spot to form on the cathode a surface coating of a material of a low work-function, and the grid comprising a material of low work-function.

3. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a material that will break down under the action of a cathode spot to form on the cathode a surface coating of a material of a low work-function, the grid comprising a material that is reducible to a material of low work-function, and a second grid between the first-named grid and the anode.

4. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a material that will break down under the action of a cathode spot to form on the cathode a surface coating of a material of a low work-function, the grid comprising a material of low work-function, and a second grid between the first-named grid and the anode.

5. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a material that will break down under the action of a cathode spot to form on the cathode a surface coating of a material of a low work-function, and the grid having a barium coating.

6. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a material that will break down under the action of a cathode spot to form on the cathode a surface coating of a material of a low work-function, the grid having a barium coating, and a second grid between the first-named grid and the anode.

7. A gaseous-discharge tube comprising an anode, an insulating cylinder provided with an inwardly projecting flange, a cathode in the cylinder of a material which will break down under the action of a cathode spot and form a surface coating thereon of a metal of low work-function, and a cylinder held by the flange and constituting a grid.

8. A gaseous-discharge tube comprising an anode, an insulating cylinder provided with an inwardly projecting flange, a cup in the cylinder, a cathode in the cup of a material which will break down under the action of a cathode spot and form a surface coating thereon of a metal of low work function, and a cylinder held by the flange and constituting a grid.

9. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a first substance and also a compound containing a second substance of a low work-function, the compound being a material that will break down under the action of a cathode spot to form on the cathode a surface coating of the second substance, the first substance being a material that will replace the second substance in the compound, whereby the coating will continually break down under the action of the cathode spot to form the said surface coating on the cathode and the first substance will continually replace the second substance in the compound during the continual breaking down of the compound under the action of the cathode spot, and the grid comprising a material of low work-function.

10. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, an insulating cylinder at the lower end of which the cathode is disposed and at the upper end of which the grid is disposed, the cathode comprising a material that will break down under the action of a cathode spot to form on the cathode a surface coating of a material of a low work-function, and the grid comprising a material of low work-function.

11. A gaseous-discharge device comprising an anode, a cathode and an inner grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a material that will break down under the action of a cathode spot to form on the cathode a surface coating of a material of a low work-function, the grid comprising a material that is reducible to a material of low-work-function, and an outer grid of carbon between the inner grid and the anode.

12. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a material that will break down under the action of a cathode spot to form on the cathode a surface coating of a material of a low work-function, the grid comprising a material of low work-function and cylindrical means for restricting the arc discharge.

13. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a mixture of a caesium salt and aluminum, the grid having a coating comprising a material of low work-function.

14. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a mixture of caesium chloride and aluminum, the grid having a coating comprising a material of low work-function.

15. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a mixture of a caesium salt and cadmium, the grid having a coating comprising a material of low work-function.

16. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathide, the cathode comprising a mixture of caesium chloride and cadmium, the grid having a coating comprising a material of low work-function.

17. A gaseous-discharge device comprising an anode, a cathode and a grid disposed adjacent to the cathode between the anode and the cathode, the cathode comprising a compressed pill of a material that will break down under the action of a cathode spot to form on the cathode a surface coating of a material of a low-work-function, a support for the cathode pill the grid comprising a material of low work-function, and a screen for holding the pill on the support and for facilitating the formation of a cathode spot.

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