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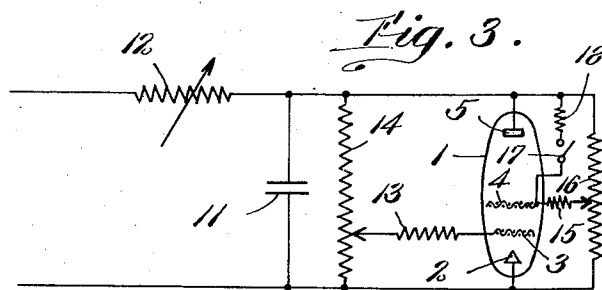
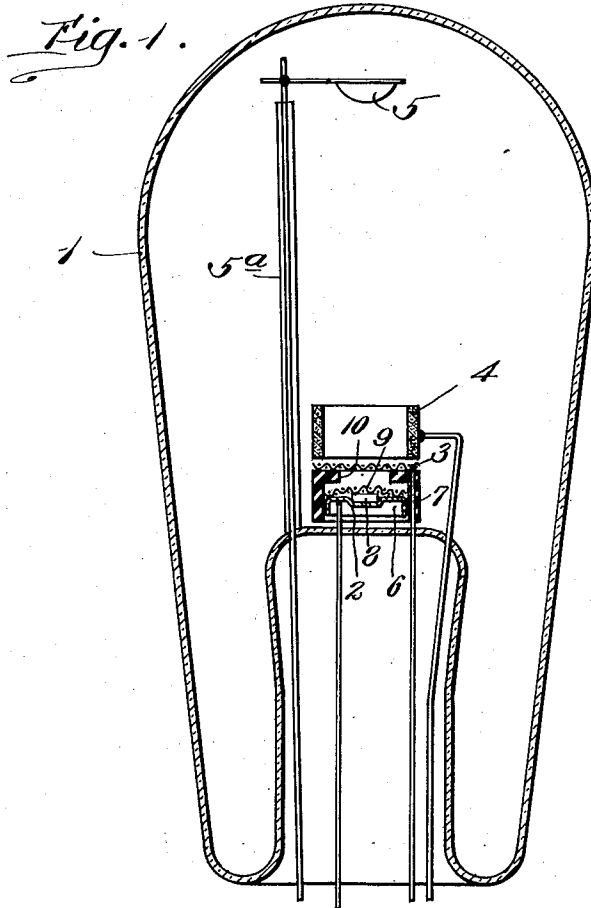
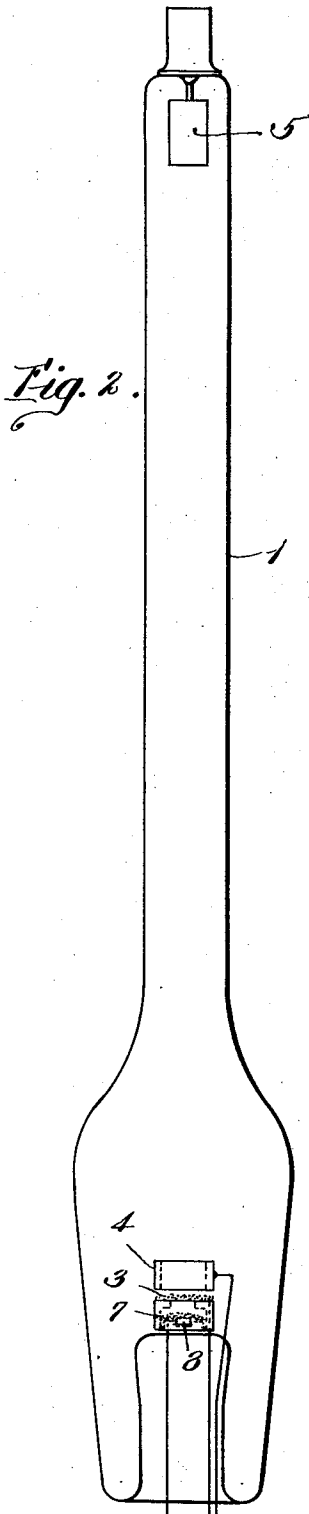
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2,185,189

GASEOUS DISCHARGE TUBE

Filed Nov. 7, 1935

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 4.

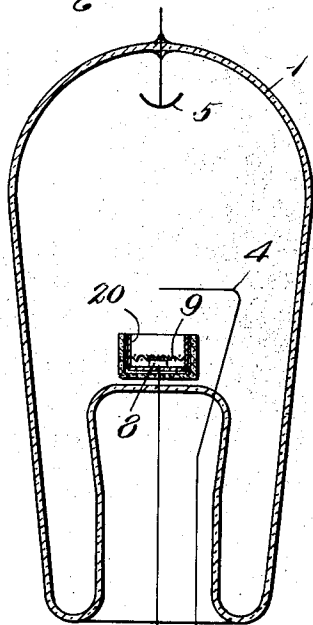


Fig. 5.

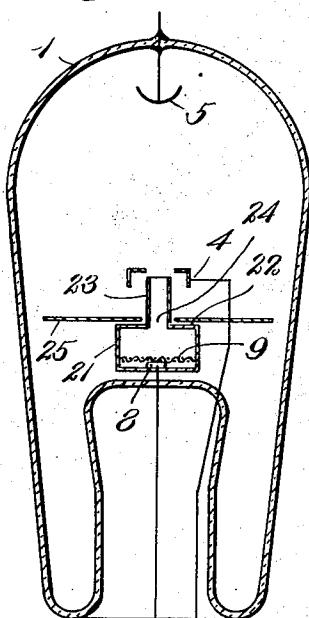


Fig. 6.

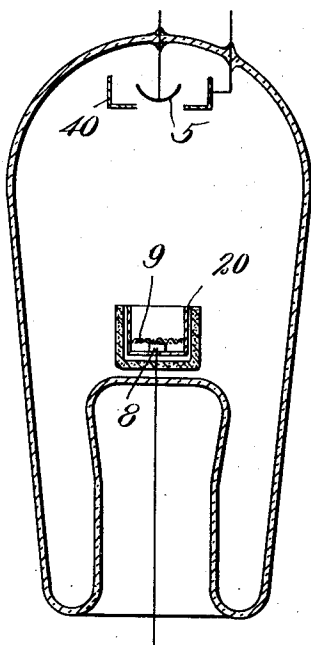
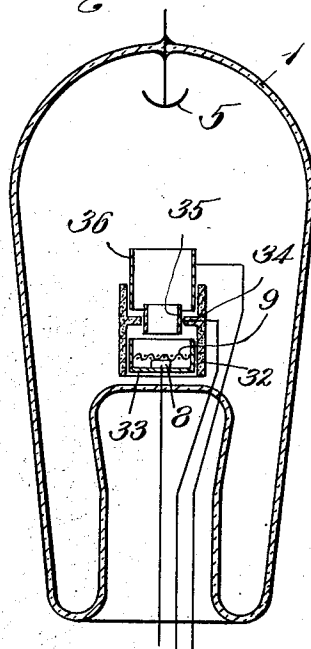


Fig. 7.

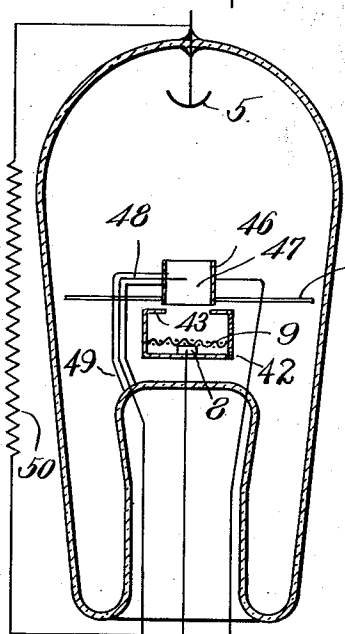


Fig. 8.

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UNITED STATES PATENT OFFICE

2,185,189

GASEOUS DISCHARGE TUBE

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Application November 7, 1935, Serial No. 48,669

13 Claims. (Cl. 176—122)

The present invention relates to cold-cathode, gaseous-discharge tubes of the type in which the source of electrons is a bright spot on the surface of the cathode material, called a cathode spot.

5 In one well-known tube of this type, the cathode is a pool of mercury. This tube can pass very high currents, and serves as a good light source. It has some disadvantages, which are common to most cold-cathode tubes, among which are that
10 the cathode spot is difficult to form and requires complicated equipment to start it, and that the operating characteristics and the light emission of the tube vary with the operating temperature. Further, the tube cannot be inverted without displacing the mercury.

15 An object of my invention is to provide an improved, cold-cathode tube among the advantages of which are relatively easy, cathode-spot formation; stability of operating characteristics
20 under changes of temperature, stray fields, changes of load, etc.; simplicity of control; a solid cathode construction which permits operation of the tube in any position; and excellent light emission. Other objects will be explained
25 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.

30 In the accompanying drawings, Fig. 1 is a longitudinal section of a gaseous discharge tube embodying my invention; Fig. 2 is an elevation of another tube embodying my invention; Fig. 3
35 is a circuit showing one manner of using the tube; Fig. 4 is a sectional elevation of a modification of the tube; Figs. 5 and 6 show modifications of the cathode and grid structures; Fig. 7 shows a modification of the tube in which the
40 grid is adjacent the anode; and Fig. 8 shows a tube in which there is a continuous glow discharge to the cathode and in which the start of the current flow from the anode is controlled by a grid.

45 Referring to the drawings, the tube shown in Fig. 1 comprises an evacuated glass envelope 1 filled with a suitable gas such as neon, and containing a cathode 2, an inner grid 3, an outer grid 4 and an anode 5.

50 The cathode comprises a metal disc 6 secured within and closing the lower end of a cylinder 7 of insulating material. On the upper side of the disc is a depression in which is a pill 8 of compressed caesium chloride and aluminum filings
55 or powder which is held in place by a wire mesh

screen 9. The pill forms the active material of the cathode. During the manufacture of the tube, the cathode is heated so that it evolves a small quantity of caesium. The upper end of the cylinder 7 has an inwardly projecting flange
5 10 on which rests a wire-mesh screen which forms the grid 3. The grid 3 is placed with reference to the cathode so that a coating of caesium is continually formed thereon during the operation of the tube. The grid 4 is a cylinder
10 of carbon concentric with the cathode. The lead to the anode is enclosed by insulation 5a.

15 In the operation of the tube, a voltage is applied between the grid 4 and the grid 3 which is sufficient to cause a glow discharge between these electrodes. The voltage at which this discharge takes place is low, due to the coating of caesium on the grid 3 and the close spacing of the grids. This voltage is also substantially constant, due
20 to the caesium-coated surface of the grid 3 and the shape of the grids, which makes the operation independent of charges on the glass and stray fields. The grid 3 shields the cathode from the grid 4 so that changes in the surface of the cathode do not affect the starting of the glow
25 discharge between the grids. To start the glow discharge between the grids requires a voltage of about a hundred volts and a current of a fraction of a milliampere, so very little power is required.

30 Immediately after the glow discharge starts between the grids, current flows to the cathode in the form of a glow discharge. When this current flow reaches sufficient density at the surface of the cathode, a cathode spot is formed on the surface of the pill 8, causing an arc-characteristic
35 discharge to the cathode. The action of the cathode spot causes the caesium chloride to break down, aluminum being substituted for the caesium and forming aluminum chloride. This reaction results in the formation of a thin surface
40 layer or coating of caesium on the pill which has a great tendency to adhere to the surface. It is on this layer that the cathode spot is formed.

45 The current passes between the anode and the cathode continually but interruptedly to set up continual 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
50 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 said current is nevertheless relatively low. It is
55

sufficiently low, indeed, so that its root-mean-square value 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 a 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 caesium is continuously 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. Under the action of the continually but interruptedly produced cathode spot, the surface of the pill 8 undergoes changes and there is some sputtering of caesium particles or boiling of caesium vapor, but most of this condenses on the grid 3 and on the screen 9. The adherence of the layer of caesium decreases the sputtering. There is very little condensation of caesium on the surface of the carbon grid 4 because the caesium does not stick readily to carbon or because the caesium is absorbed into the carbon.

The material of the pill 8, which provides the active material of the cathode, furnishes enough free caesium so that advantage can be taken of the ease of spot formation on caesium, which is a material of low work-function. If the pill 8 furnished too much free caesium, or if it were made of pure caesium, or if the arc discharge between the cathode and the anode were non-intermittent, the cathode spot could be formed, but the caesium would be quickly sputtered and evaporated over the tube and the cathode would have very short life. As a matter of fact, the 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. Viewed from one aspect, 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 the glow discharge. If the screen 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 cathode will hold over in a glow discharge. Due to the high cathode drop in glow discharges, the current flow is limited. The form of the screen 9 is not critical as far as the operation of the tube is concerned.

The screen 9 may itself serve as a cathode when a certain amount of caesium has been sputtered on its surface. After the cathode spot has formed on the coating on the screen, the caesium is consumed, and the cathode spot subsequently forms on the pill 8. The action of the cathode is therefore self regulating, and the operation is not endangered by the sputtering of the caesium.

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 chimney or restricted passage for the arc discharge provided by the grid 4 and the cylinder 7 makes the voltage drop of the arc stream more constant and, therefore, increases the stability of the operation of the tube.

There is 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 is prevented by the cylinder 7. This tendency is further resisted by placing the active material of the cathode at the bottom of a 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 grid 3 is purposely placed so that caesium will sputter on its surface during the operation of the tube, and maintain the coating on the grid. The reason for this is that a glow discharge to a cathode surface of low work-function starts at a lower voltage. The grid 4 is placed so that caesium will not be sputtered on its surface. If caesium did sputter on its surface, the breakdown voltage of the tube would be lowered, due to a tendency of a glow discharge to start between the anode and the grid 4.

Still further to insure that caesium shall not be sputtered on the grid 4, it is made of carbon, a material to which the caesium will not readily adhere. By making the grid 4 of carbon, the voltage at which a glow discharge will start between the grids depends on the polarity. This is useful in tubes controlled by alternating current.

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.

The pressure of the gas in the tube may vary. When the tube is used for illumination, pressures of from 3 to 20 millimeters of neon are suitable.

The tube shown in Fig. 2 is identical with the tube shown in Fig. 1, except that it is provided with a long, restricted passage for the arc discharge. This tube is adapted for higher power applications, and particularly for uses which require a large amount of light emission.

The advantages of tubes embodying my invention are very clearly shown by its application in the circuit, shown in Fig. 3, as an intermittent light source for stroboscopic use.

In this circuit the anode 5 and the cathode 2 of the tube are connected across a condenser 11, which is continuously charged, from a suitable source, through a variable resistance 12. The grid 3 is connected, through resistance 13, to a tap on a resistance 14, connected across the condenser. The grid 4 is connected, through resistance 15, to a tap on a resistance 16, connected across the condenser. The resistances 13, 14, 15 and 16 are large and, therefore, require very little current. The taps on resistances 14 and 16 are proportioned so that the grid 3 is positive with respect to the cathode 2, and the grid 4 is positive with respect to the grid 3.

In the use of the circuit, the condenser is connected to a suitable source of direct current and immediately starts to become charged. While the condenser is being charged, the tube is non-conductive. When the condenser reaches the required voltage, the voltage between the grid 3 and the grid 4 becomes high enough to cause a glow discharge between the grids. This removes the shielding effect of the grids, and causes a glow discharge to start between the anode and the cathode, which forms a cathode spot on the cathode and causes an arc discharge. The discharge of the condenser causes a current of a few hundred or more amperes to flow through the tube, producing a bright flash of light, which lasts a few microseconds. The resistance 12 does not permit the flow of sufficient current to maintain the arc discharge; after the discharge of the condenser, therefore, the arc is extinguished and the tube becomes non-conducting. The voltage at which this glow discharge between the grids takes place, and the voltage drop in the arc discharge, are so nearly constant that the light flashes from the tube occur at substantially constant frequency, and can be used for stroboscopic purposes. The rate at which the tube flashes can be controlled by changing the variable resistance 12 or by changing the biasing voltage of either grid.

In order to illustrate the possibilities of the tube, the following figures are given for a tube having the external dimensions of a small radio tube:

Condenser discharge voltage-----	300 volts
Peak discharge current-----	500 amps.
Voltage between grids required to start glow discharge between grids	100 volts
Current flow in glow discharge between grids.	Less than 1 milliamp.

The numerical values vary, of course, with the size and the construction of the tubes; but they do show the ease of control of the tube, and its ability to handle large currents, compared to tubes of similar dimensions.

If desired, the flashing of the tube can be controlled by a contactor 17, connected to the positive side of the condenser, through a resistance

18. In this case, the maximum voltage of the condenser is limited to a value below the breakdown voltage of the tube, or the bias of the grids is adjusted so that the tube will not become conducting.

The grid-controlled, cold-cathode, gas-filled, arc-discharge tube that is herein described has many other uses than as a stroboscope. Its unique properties can be applied to a number of applications where the ability of the tube to pass large currents, to act as a rectifier, to stand ready to operate instantly without requiring cathode-power or cathode-heating time, and to act as a sensitive grid-controlled relay, are important. Those skilled in the art will appreciate that the tube described herein can be used in practically all of the circuits in which grid-controlled, hot-cathode, gas-filled tubes, such as "thyratrons" "grid-glow" tubes, are now used.

Figs. 4 to 8 inclusive show modifications of the structure of the tube. In the tube shown in Fig. 4, the cathode 2 comprises a metal cup 20, at the bottom of which is the pill 8 and the screen 9. The outside of the cup 20 is coated with insulating material, which prevents glow discharge to the outside of the cup in the same manner as the cylinder 7 of insulating material shown in Fig. 1. One of the grids is omitted in this tube, and the grid 4 is merely a wire above the end of the cup 20. In the operation of this tube, the glow discharge starts between the grid 4 and the cathode. This causes a glow discharge between the anode 5 and the cup 20, which reaches sufficient local current density on the surface of the pill 8 to form a cathode spot and start the arc discharge between the anode and the cathode. In other respects, the operation of the tube is substantially the same as the tube shown in Fig. 1. The glow discharge which starts the operation of this tube may be formed between the grid 4 and the upper edge of the cup 20, between the grid and the caesium coating which is sputtered on the inside of the cup 20 during the operation of the tube, or between the grid and the surface of the pill 8. Since the cathode is subject to violent, surface changes under the action of the cathode spot, the voltage at which this glow discharge from the grid starts is not so constant as in the tube shown in Fig. 1. If the cup 20 is deep, the side walls of the cup act as a shield, and the glow discharge from the grid is not likely to form between the grid and the surface of the pill 8. When the grid 4 is in the form of a wire, furthermore, the field between the grid and the cathode, or the metal cup 20, is not so effectively shielded from charges which may accumulate on the glass envelope, and these charges may affect the voltage required to start the glow discharge from the grid. The operation of this tube is, therefore, subject to two variable factors; the surface of the pill 8, and the effect of charges which accumulate on the glass.

In certain applications, the grid 4 may be completely eliminated. In this case, the initial discharge in the tube is a glow discharge between the anode and the cathode, which is followed by an arc discharge. This tube is still further affected by charges on the glass, so that the voltage at which the tube becomes conducting is not constant.

In the construction shown in Fig. 5, the pill 8 is held by the screen 9 on the bottom of a metal cup 21. Across the upper end of the cup is a metal disc 22, having a cylinder 23 secured in an opening 24 in its center. A disc 25 of insulat-

ing material surrounds the cylinder 23 and prevents glow discharge to the outside of the cup 21. The grid 4 is in the form of an annular ring having a depending flange on its outer edge, and closely spaced from the upper end of the cylinder 23. The operation of this tube is similar to that of the tubes shown in Figs. 1, 2 and 4. The initiating glow discharge starts between grid 4 and the cylinder 23. The grid 4 shields the cylinder 23 from the charges on the glass, so that the voltage at which the glow discharge from the grid starts is relatively constant. The cylinder 23 provides a restricted opening to the cup 21, and thereby tends to confine the sputtering of the free caesium of the cathode to the inner surface of the cup 21 and the disc 22. The cylinder 23 also provides a restricted passage for the arc stream, which makes the tube drop more constant.

In the construction shown in Fig. 6, the cathode and the grids are supported by a cylinder 32 of insulating material. The cathode comprises a metal cup 33, secured in the lower end of the tube, and having a pill 8 held in the bottom thereof by the screen 9. The cylinder 32 is provided with an inwardly projecting flange 34, on the inner side of which is secured a metal cylinder 35, which serves as a grid. This cylinder is placed so that caesium will sputter on its surface during the operation of the tube. The other grid comprises a metal cylinder 36, which is secured in the upper end of the cylinder 32. The cylinder 36 is placed so that caesium does not sputter on its surface. In the operation of this construction, the initiating glow discharge takes place between the cylinder 36 and the coating on the cylinder 35. The voltage at which this glow discharge takes place is substantially constant, due to the fact that the grids 35 and 36 shield the field between the grids from charges on the glass. The grids 35 and 36 also provide a restricted passage for the arc discharge which results in substantially constant tube drop.

The tube shown in Fig. 7 is a modification of the tube shown in Fig. 4, in which the grid 40 is near the anode. The grid 40 has, at its center, an opening 41, through which the arc discharge passes. The grid 40 shields the field between it and the anode from the effect of charges on the glass. In the operation of this tube, the initiating glow discharge takes place between the grid 40 and the anode, and subsequent operation of the tube is the same as in the previously described tubes.

In the tube shown in Fig. 8, the cathode comprises a metal cup 42, having the pill 8 held in the bottom thereof by the screen 9. A metal disc 43, having an opening 44 at its center, is secured across the upper edges of the cup. Above the disc 43, is a disc 45 of insulating material, having a metal cylinder 46, projecting through an opening 47 in its center. Projecting through the side of the metal cylinder 46, is an electrode 48, which is surrounded by insulation 49. The electrode 48 is connected to the anode through a resistance 50, and the potential between the electrode 48 and the cathode is such that a continuous glow discharge is formed between these electrodes. The cylinder 46 serves as a grid and is normally biased, so that discharge between the anode and cathode is prevented. When the bias on the control grid 46 is changed to the proper value, a glow discharge takes place between the anode and the cathode, which results in the formation of a cathode spot, and thereby produces an arc discharge between the anode and the cathode. The opera-

tion of this tube is likewise unaffected by charges on the glass due to the shielding effect of the metal cylinder 46. In a tube of this construction, it is satisfactory to have a continuous glow discharge between any two electrodes, with some form of shielding to prevent discharge between the anode and the cathode.

Having now described my invention, I claim:

1. A gaseous-discharge tube comprising an anode, a cathode of a material which will break down under the action of a cathode spot and form a surface coating thereon of a material of low work-function, and a screen over the cathode material for providing points at which a glow discharge to the cathode may concentrate on the surface of the cathode, whereby the formation of a cathode spot on the cathode is facilitated.

2. A gaseous-discharge tube comprising an anode, a cathode of a material which will break down under the action of a cathode spot and form a surface coating thereon of a material of low work-function, a grid, and a surface adjacent said grid, said grid and said surface being arranged so that the field therebetween is shielded from stray fields, and a glow discharge initiated between the anode and cathode by a glow discharge between the grid and the surface being effective to form a cathode spot on the cathode.

3. A gaseous-discharge tube comprising an anode, a cathode of a material which will break down under the action of a cathode spot and form a surface coating thereon of a material of low work-function, a surface arranged so that the material of low work-function on the surface of the cathode will be sputtered thereon during the operation of the tube, and a surface adjacent said first surface, a glow discharge between said surfaces being adapted to cause an arc discharge between the anode and the cathode.

4. A gaseous-discharge tube comprising an anode, a cathode 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, an outer grid, and an inner grid arranged to shield the field between the outer grid and the cathode, a glow discharge between said grids being adapted to initiate an arc discharge between the anode and the cathode.

5. A gaseous-discharge tube comprising an anode, a cathode 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, an outer grid of carbon, and an inner grid arranged so that the metal of low work-function will be sputtered thereon during the operation of the tube, and means causing a glow discharge between said grids being adapted to initiate an arc discharge in the tube.

6. A gaseous-discharge tube comprising an envelope provided with an anode, a cathode of a material which will break down under the action of the cathode spot and form a surface coating thereon of a metal of low work-function, means in the envelope providing a restricted passage extending from the cathode toward, but not as far as the anode, the cathode occupying a relatively small area in the restricted passage at some distance away from the end of the passage nearest the anode, and a glow discharge between the anode and the cathode being adapted to form a cathode spot on the cathode.

7. 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 and on the grid surface coatings of the material of a low work-function.

8. A gaseous-discharge device comprising an anode, a cathode and a grid, 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, and the first substance being a material that will replace the second substance in the compound, whereby the compound 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.

9. A gaseous-discharge device comprising an envelope, an anode, a caesium-containing cathode, an inner grid disposed between the anode and the cathode, and an outer grid of carbon disposed between the anode and the inner grid.

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 and the grid surface coatings of a material of a low work-function.

11. A gaseous-discharge device comprising an anode, a cathode, a grid disposed 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 low work-function, and cylindrical means for restricting the arc discharge.

12. In a gaseous-discharge device, an insulating cylinder, a metal disc closing the lower end thereof and provided with a depression in its upper side, a pill of compressed caesium chloride and aluminum filings or powder in the depression, and a wire-mesh screen covering the pill, the pill constituting a cathode.

13. In a gaseous-discharge device, an insulating cylinder, an anode, a metal disc closing the lower end of the cylinder and provided with a depression in its upper side, a pill of compressed caesium chloride and aluminum filings or powder in the depression, and a wire-mesh screen covering the pill, the pill constituting a cathode.

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