May 21, 1940. K. J. GERMESHAUSEN 2,201,166

ELECTRIC CIRCUIT

Filed March 9, 1937 2 Sheets-Sheet 1

Fig. 1.

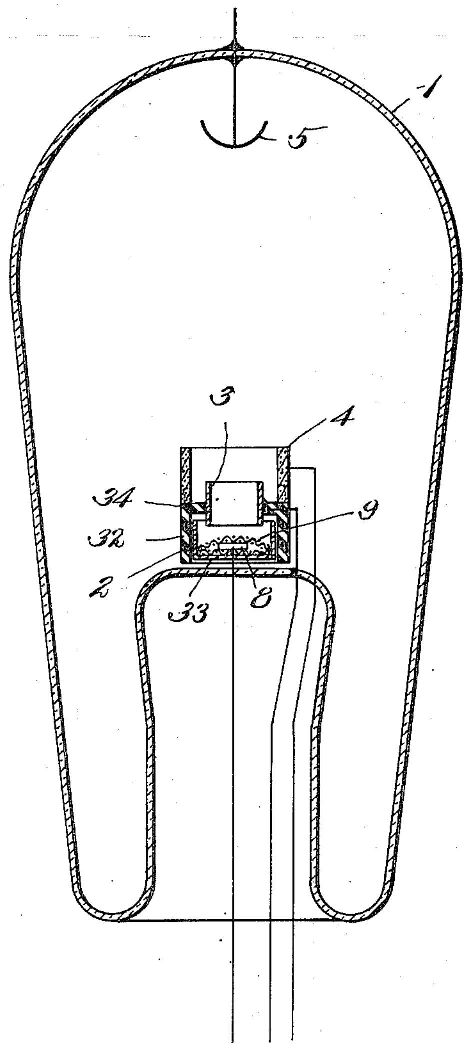

Fig. 2.

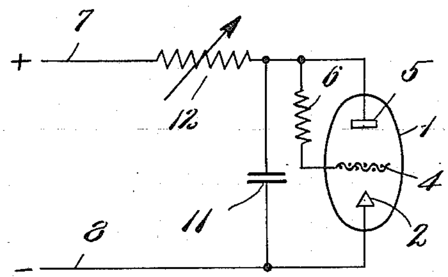

Fig. 3.

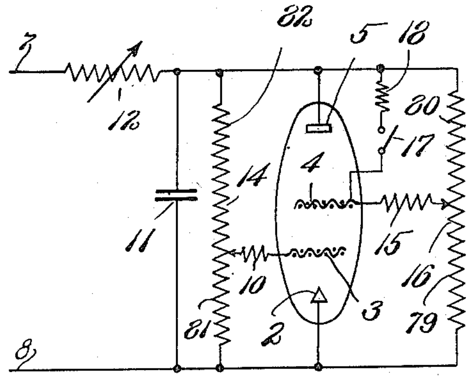

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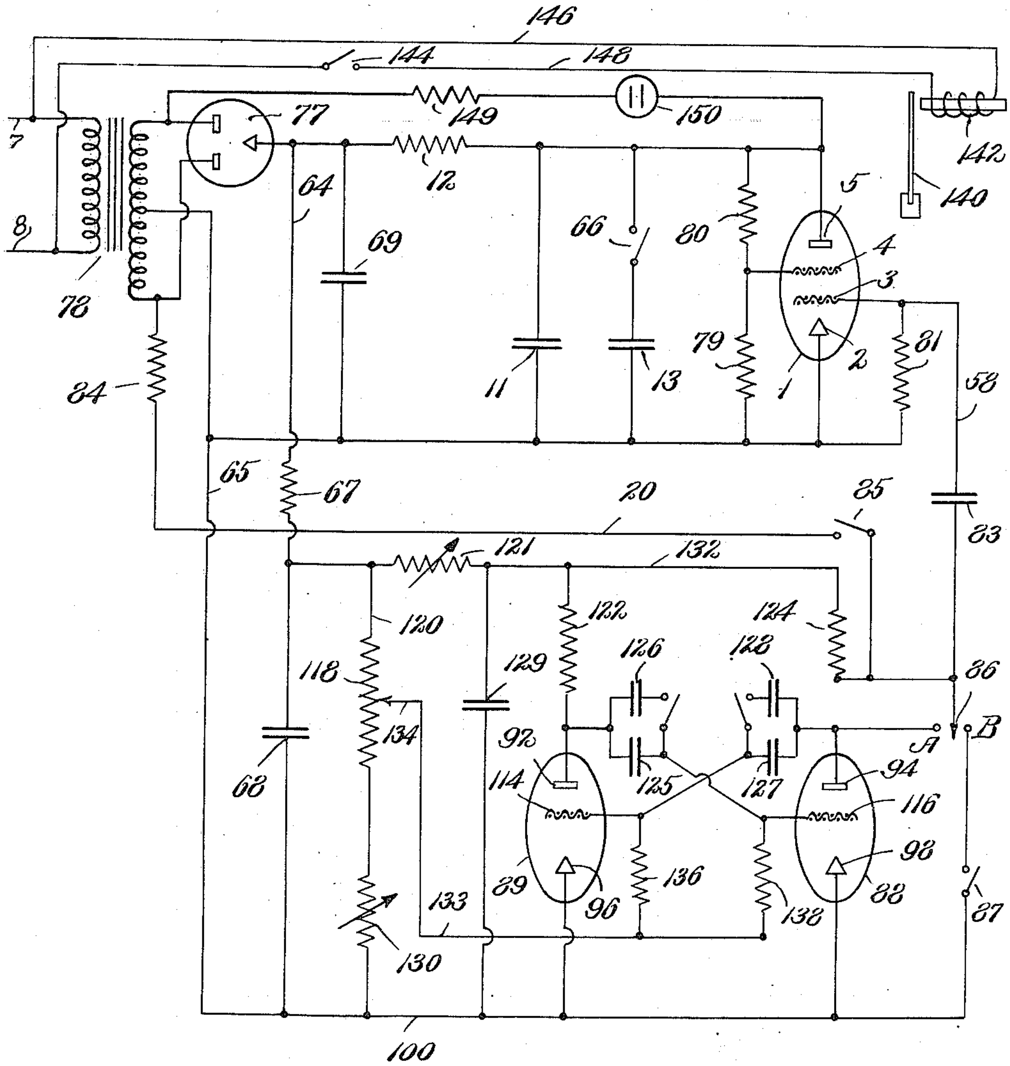
Fig. 4.



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2,201,166

ELECTRIC CIRCUIT

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Application March 9, 1937, Serial No. 129,837

35 Claims. (Cl. 176—124)

The present invention relates to electric circuits, and more particularly to circuits particularly adapted for uses requiring large peak currents, with relatively small average currents.

An object of the present invention is to provide a novel electric circuit embodying a cold-cathode gaseous-discharge device of the character described in Letters Patent 2,185,189, granted January 2, 1940, and application, Serial No. 129,838, filed March 9, 1937, particularly circuits requiring intermittent or occasional operation. The invention is of broad and general utility, such as for stroboscopic and relay purposes and power control.

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 drawings, Fig. 1 is a longitudinal section of a preferred gaseous-discharge tube that may be connected into circuit in accordance with my invention; Fig. 2 is a simple stroboscope circuit embodying a discharge lamp of the above-described character with a single control grid; Fig. 3 is a circuit embodying a lamp of the above-described character with two grids; and Fig. 4 illustrates a preferred complete stroboscope circuit embodying the invention.

The tube employed in the circuits embodying the present invention may be of the type illustrated in the said Letters Patent, or a modification of the same, illustrated in Fig. 1 and described more at length in the said copending application, Serial No. 129,838. It comprises 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, the grid **3** may, in normal use, by 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 coating or layer of the caesium or other material of low work-function is thus maintained on the grid **3** during the normal operation of the tube. As illustrated in Fig. 1, however, and as explained in the said application, Serial No. 129,838, the grid **3** may, under some circumstances, be precoated.

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.

The advantages of tubes of the above-described character are very clearly shown by their use as intermittent light sources in the illustrated circuits.

In the circuit of Fig. 2, a tube **1** is illustrated having but a single grid **4**. 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**, which may be a resistor, or a combination of resistance and inductance. 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), direct-current generators (not shown), thermionic or gaseous-discharge rectifiers for producing direct current from alternating current, as illustrated in Fig. 4, or any other source of direct current. The grid **4** is connected through a resistance or other impedance **6** to the anode **5**.

In the operation of the circuit, the condenser **11** starts to become charged from the direct-current source through the impedance **12**, the tube being nonconductive. When the voltage across the condenser **11** reaches the required value, say 110 volts, however, the voltage between the grid **4** and the cathode **2** exceeds the breakdown value and the tube becomes conducting.

Because of the glow discharge thus formed 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**. The values of this impedance and of 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**, 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. If the pill 8 is constituted of caesium chloride and aluminum, as before described, for example, the action of the cathode spot causes the caesium chloride to break down, aluminum being substituted for the caesium and forming aluminum chloride. In addition to the material of low-work function produced by the reaction of the cathode spot on the material of the cathode, there may be produced also various unwanted gaseous products which may be detrimental to the operation. If the material contains an oxide, for example, an unwanted gas may be oxygen. These unwanted gases may be absorbed by the aluminum or by magnesium. 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 blow 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 operation of the circuit described above is similar to that of the well-known relaxation-oscillator circuit using a glow tube. Due, however, to the special tube employed, the circuit oscillates more readily, without tending to hold into a steady glow, it can handle a large average power, and it is capable of producing very large momentary currents. Typical values for the constants of the circuit in Fig. 2 may be as follows:

Supply voltage________________volts D. C.__	400
Resistance 12______________________ohms__	3000
Capacity 11 ________________microfarads__	4
Average current____________milliamperes__	40
Maximum current in the tube___amperes__	300

The voltage at which the glow discharge from the grid to the cathode begins and that of the arc drop in the tube are so nearly constant that the light flashes from the tube occur at substantially constant frequency. They may, therefore, be used for stroboscopic purposes. The rate at which the flashes occur can be controlled by changing the variable resistance 12, the supply voltage, or the capacity 11. The lamp is particularly adapted for use as a stroboscope, because the moment that the discharge stops, the illumination also stops. The glow does not persist and the cathode 2, being a cold cathode, gives off no light itself, the light being produced by the discharge between the cathode 2 and the anode 5. As the discharge between the cathode 2 and the anode 5 is under the control of the grid 4, it is possible, by suitably energizing and deenergizing the grid 4 at rapid intervals, therefore, to send discontinuous current surges rapidly through the vapor of the tube.

In Fig. 3, potentiometers 14 and 16 are shown connected across the condenser 11. The grid 3 is shown connected to a movable arm of the potentiometer 14 through the resistor or other impedance 10. This movable arm divides the potentiometer 14 into parts 81 and 82, the former of which is connected between the cathode 2 and the grid 3, and the latter between the grid 3 and the plate 5. The grid 4 is connected through a resistance 15 to the movable arm of the potentiometer 16. As the resistance of the potentiometers is large, they require very little current. The last-named movable arm divides the potentiometer 16 into parts 79 and 80, the former of which is connected between the cathode 2 and the grid 4 and the latter between the grid 4 and the plate 5. The condenser 11 is thus connected to the impedances of the parts 81 and 82 of the potentiometer 14, connected in series, and to the impedances of the parts 79 and 80 of the potentiometer 16, likewise connected in series. The potentiometers are normally set by the said movable arms 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.

By properly setting the potentiometers, it is possible to have the voltage between the anode 5 and the cathode 2 much greater than the voltage required to cause a glow discharge between the grid 4 and the grid 3 and hence make the tube conducting.

The operation of the circuit shown in Fig. 3 is similar to that of Fig. 2. In this case, however, the glow discharge starts between the grids 3 and 4 in response to a voltage applied between them, and then transfers to the anode-cathode circuit.

The voltage applied between the grids 3 and 4 should be sufficient to cause an initiating glow discharge between the cylinder 4 and the coating on the cylinder 3. The voltage at which this discharge takes place is low and substantially constant, due to the fact that the grids 3 and 4 shield the field between the grids from charges on the glass. The grids 3 and 4 also provide a restricted passage for the arc discharge, which results in substantially constant tube drop. 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 discharge between the grids. To start the blow discharge between the grids may require a voltage of only about a hundred volts and a current of only a fraction of a milliampere, so very little power is required.

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 11 is limited and the bias on the grids so adjusted that the voltage between the grids does not exceed the breakdown voltage.

When the contactor 17 is closed, the condenser 11 being fully charged, the positive bias on the grid 4 is increased by means of current conducted through the resistor 18. If the resistors 15 and 18 are properly proportioned, the extra voltage applied to the grid 4 will cause the voltage between the grids 3 and 4 to exceed the breakdown voltage and the tube will become conducting.

Fig. 4 illustrates a complete stroboscope circuit, with a conventional power supply to furnish direct current from the alternating-current mains, a separate oscillator to drive the stroboscopic lamp so as to cause the lamp to flash at the desired frequency, a means for calibrating the oscillator, a means for operating the lamp so as to cause it to flash at the frequency of the alternating-current supply-voltage from the line, and a contactor device for controlling the flashing rate.

In this circuit, a transformer 78, a double-anode rectifier tube 77 and a condenser 69 form a conventional power supply to give any desired direct-current voltage, say, 300 volts, from the 110-volt alternating-current mains. It is understood that any source of direct current of about 300 volts can be substituted for the power supply shown in the drawings.

The stroboscope circuit of Fig. 4 is in many respects similar to that of Fig. 3. The impedances 79 and 80 are, however, shown connected between the cathode 2 and the grid 4, and between the grid 4 and the anode 5, respectively; the impedance 81 is shown connected between the cathode 2 and the grid 3; and the impedance 82 is omitted, together with the impedance 18 and the contactor 17, their function being performed by other elements, as will hereinafter appear. The bias is so adjusted on the grid 4 by means of these impedances, and the supply voltage is so adjusted, that it is possible to have the voltage between the anode 5 and the cathode 2 much greater than the voltage required to cause a glow discharge between the grid 4 and the grid 3, and the tube will thus stay in a non-conducting state when the condenser 11 is fully charged. The discharge condenser 11, connected across the conventionally shown power supply through the impedance 12 in the manner before described, is used for high-frequency operation of the stroboscope circuit; for low-frequency operation, a condenser 13 is connected in parallel with the condenser 11 by means of a switch 66.

Current is also supplied from the power supply to the conductors 100 and 132. The conductor 132 is connected, through a resistor 124, to a switch 86, adapted to occupy two positions A and B. The conductor 100 is connected, by a contactor device 87, to a contact member with which the switch 86 is adapted to contact in position B. The circuits of the hereinafter-described multivibrator are open when the switch 86 occupies the position B. The switch 86 is connected by a conductor 58, through a condenser 83, to the grid 3. The switch 86 is connected also to the alternating current, by way of a conductor 20, and through a resistor 84, by a switch 85. The contactor 87 may be periodically opened and closed in any-desired manner; this is not shown in order to simplify the drawings.

The lamp circuit comprises the said two discharge condensers 11 and 13, the said current-limiting resistor 12 and the three resistors 81, 80, 79.

With the switch 86 in position B, and the switch 85 open, the lamp 1 can be triggered at the desired instant by means of the contactor device 87, which causes a momentary surge through the condenser 83. When the contactor device 87 closes, therefore, the grid 3 is given a negative voltage pulse equal to the voltage existing between the conductors 100 and 132. The condenser 83 then discharges through the resistor 81 and the grid 3 to the cathode 2, allowing the voltage of the grid 3 to return to zero. The discharge circuit extends from one side of the condenser 83, through the resistor 81 and the grid 3 and the cathode 2, in parallel, by way of the conductors 8, 65 and 100, and through the switches 87 and 86, the latter in the position B, to the other side of the condenser 83. Once the contactor 87 becomes closed, it may remain closed without the stroboscope flashing on again when the condensers 11 and 13 build up their voltages. The operation is independent of the length of time that the contactor 87 remains closed, the complete function being performed at the moment it first becomes closed. The contactor 87, therefore, gives only one impulse of voltage at each closing, and the length of time the contactor 87 remains closed does not affect the operation of the tube.

The negative voltage pulse applied to the grid 3 starts a glow discharge between the grid 3 and the grid 4, causing the tube 1 to become conducting, as described in connection with Fig. 3. This permits condenser 11 or 13 (or both) to discharge through the tube, giving a brilliant flash of light, lasting but a few microseconds. The tube then extinguishes and the condensers 11 and 13 recharge.

This process of charging the condenser 11 from the source of energy, and discharging it through the vapor of the tube 1, is repeated many times a second, in synchronism with the opening and closing of the contactor 87. The use of the controlling oscillator, for impressing its oscillations upon the grid 3, makes it possible to operate the stroboscope without any moving parts.

The controlling oscillator for impressing its oscillations upon the grid 3 may be of any type, but the multi-vibrator oscillator is preferred, because of its simplicity, cheapness, constancy of frequency irrespective of variations in applied voltage, abrupt wave form, and its comparatively high voltage output.

The illustrated oscillator, therefore, is of the conventional multi-vibrator type, except for a novel method of controlling the frequency, as will be hereinafter described. The direct-current power supply for the oscillator is obtained from the power supply for the stroboscope circuit through the conductors 64 and 65 and the resistor 67. A filter condenser 68 is provided to remove any slight alternating-current ripple in the direct-current voltage.

The oscillator circuit comprises the vacuum triodes 88 and 89, the plate resistors or other impedances 122 and 124, the grid resistors 136 and 138 that are connected to the grids 114 and 116 of the triodes 89 and 88, the grid condensers 125, 126, 127 and 128, and the condenser 129. The frequency-control circuit of the said oscillator comprises the variable, calibrating resistors or other impedances 121 and 130 and the potentiometer 118. The set of electrodes of the vacuum triode 89, comprising the filament or cathode 96, the grid 114 and the anode 92, and the set of electrodes of the vacuum triode 88, comprising the filament or cathode 98, the grid 116 and the anode 94, may be in separate envelopes, or in a single envelope. It is usually more convenient to combine the two in a single tube. The voltage from the voltage source is applied to the oscillator by way of the conductors 100 and 132, between which the oscillator is connected. The calibrating resistor 121 is connected between resistor 67 and conductor 132. The second calibrating resistor 130 is connected, in series with the potentiometer 118, to the conductor 100. The potentiometer 118 is thus connected between the calibrating resistors 121 and 130. The cathodes of the oscillator tubes 88 and 89 are connected to the conductor 100. The anodes of the oscillator tubes are connected to the conductor 132 and the resistor 121 through the resistors 122 and 124. The switch 86 is connected, in position A, to the anode 94 of the triode 88. The anodes 92 and 94 are thus connected to one side of the source of voltage by the conductor 132, through the resistances 122 and 124. The cathodes 96 and 98 of these respective triodes are connected to the other side of the voltage source by the conductor 100. The slider 134 of the potentiometer 118 is connected to the two resistors or other impedances 136 and 138 by a conductor 133.

The input circuit of the triode 89 may be traced from the filament 96, by way of the conductor 100, through the calibrating resistor 130, the lower portion of the potentiometer 118, and the adjustable arm 134, and by way of the conductor 133, through the resistor 136, to the grid 114. The input circuit of the triode 88 may similarly be traced from the filament 98, by way of the conductor 100, through the calibrating resistor 130, the lower portion of the potentiometer 118, and the adjustable arm 134, and by way of the conductor 133, through the resistor 138, to the grid 116. The output circuit of the triode 89 may be traced from the filament 96, by way of the conductor 100, through the calibrating resistor 130, the potentiometer 118, and the calibrating resistor 121 and, by way of the conductor 132, through the resistor 122, to the anode 92. The output circuit of the triode 88 may similarly be traced from the filament 98, by way of the conductor 100, through the calibrating resistor 130, the potentiometer 118 and the calibrating resistor 121 and, by way of the conductor 132, through the resistor 124, to the anode 94. The condenser 125 is connected between the grid 116 and the anode 92, and the condenser 126 may be connected in parallel therewith. The condenser 127 is similarly connected between the grid 114 and the anode 94, and the condenser 128 may be connected in parallel therewith.

With the switch 86 in the position A, the output of the oscillator, taken from the plate of one of the triodes, is connected to the stroboscopic lamp 1 through the coupling condenser 83 and the conductor 58.

The principles of operation of the oscillator are well understood in the art and hence will not be gone into here.

As explained in a divisional application, Serial No. 167,618, filed October 6, 1937, to which reference may be made for further details, the frequency may be controlled by adjusting the slider 134 back and forth on the potentiometer 118 to vary the positive bias on the grids of the triodes 88 and 89. This yields both a linear frequency scale and a wide frequency range,—as much as six to one. The potentiometer 118 is calibrated in flashes per minute of the stroboscope lamp, with the aid of a vibrating reed 140, driven by means of a solenoid 142, and the calibrating resistors 121 and 130.

To this end, the solenoid 142 is connected in circuit with a switch 144 and conductors 146 and 148 across the alternating-current supply.

The said divisional application describes also an alternative method of checking the calibration by means of a glow lamp 150 and a resistor 149.

By closing the switch 85, an alternating-current voltage is applied to the oscillator from transformer 78 through resistance 84 and the conductor 20. This causes the oscillator to run at the frequency of the line voltage and in exact synchronism therewith. This is useful in certain applications of the stroboscope.

The light produced by this stroboscope, obtained from a 115-volt, 60-cycle alternating-current source, is sufficient to permit good stroboscopic observation of mechanisms, particularly when the light is concentrated by means of a parabolic reflector. Because of the calibrated frequency scale, the stroboscope is particularly useful in measuring the speed of rotating or vibrating mechanisms.

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. In an electric circuit, a gaseous-discharge tube comprising an anode and a cold 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 means for subjecting the cathode and the anode to energy sufficient in character and amount to form a cathode spot on the cathode but without supplying sufficient heat to the cathode to cause destruction of the cathode by heat.

2. In an electric circuit, a gaseous-discharge tube comprising an anode, a cold 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 grid disposed between the anode and the cathode, and means for subjecting the cathode and the anode to energy sufficient in character and amount to form a cathode spot on the cathode but without supplying sufficient heat to the cathode to cause destruction of the cathode by heat.

3. In an electric circuit, 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 disposed between the anode and the cathode and a grid disposed between the cathode and the first-named grid, and means for subjecting the cathode and the anode to energy sufficient in character and amount to form a cathode spot on the cathode but without supplying sufficient heat to the cathode to cause destruction of the cathode by heat.

4. In an electric circuit, a condenser arranged to be charged from a source of energy, a gaseous-discharge tube comprising an anode and a cathode comprising a mixture of a caesium salt and a metal which will displace the caesium in the salt under the action of a cathode spot, the cathode being adapted to form a cathode spot thereon, and means for connecting the condenser to the anode and the cathode to cause the con-

denser to discharge through the tube to form a cathode spot on the cathode.

5. In an electric circuit, a condenser arranged to be charged from a source of energy, a gaseous-discharge tube comprising an anode and a cathode having a material from the group comprising the first and second groups of the periodic table of elements and the rare earths, the cathode being adapted to form a cathode spot thereon, and means for connecting the condenser to the anode and the cathode to cause the condenser to discharge through the tube to form a cathode spot on the cathode.

6. An electric circuit having, in combination, a gaseous-discharge device comprising an envelope containing gas and having an anode and a solid cold cathode, the cathode being constituted of a material having a relatively low work-function and that does not combine chemically with the gas in the envelope, means for applying a voltage between the anode and the cathode, and means comprising the first-named means for passing an electrical discharge between the anode and the cathode through the gas in the envelope to produce a cathode spot on the cathode.

7. An electric circuit having, in combination, a gaseous-discharge device comprising an envelope containing gas and having an anode and a solid cold cathode, the cathode being constituted of a material having a relatively low work-function and that does not combine chemically with the gas in the envelope, a condenser, means connecting the condenser to the anode and the cathode, means for periodically charging the condenser, and means for periodically discharging the condenser between the anode and the cathode to pass an electrical discharge between them through the gas in the envelope to produce a cathode spot on the cathode.

8. An electric circuit having, in combination, a gaseous-discharge device comprising an envelope containing gas and having an anode, a solid cold cathode, and a grid, the cathode being constituted of a material having a relatively low work-function and that does not combine chemically with the gas in the envelope, an impedance connected between the anode and the grid, a condenser, means connecting the condenser to the anode and the cathode, means for periodically charging the condenser, and means for periodically discharging the condenser between the anode and the cathode to pass an electrical discharge between them through the gas in the envelope to produce a cathode spot on the cathode.

9. An electric circuit having, in combination, a gaseous-discharge device comprising an envelope containing gas and having an anode, a solid cold cathode, and a grid, the cathode being constituted of a material having a relatively low work-function and that does not combine chemically with the gas in the envelope, an impedance connected between the anode and the grid, an impedance connected between the cathode and the grid, a condenser, means connecting the condenser to the anode and the cathode in parallel to the impedances connected in series, means for periodically charging the condenser, and means for periodically discharging the condenser between the anode and the cathode to pass an electrical discharge between them through the gas in the envelope to produce a cathode spot on the cathode.

10. An electric circuit having, in combination, a gaseous-discharge device comprising an envelope containing gas and having an anode, a solid cold cathode, a grid disposed between the anode and the cathode, and a grid disposed between the cathode and the first-named grid, the cathode being constituted of a material having a relatively low work-function and that does not combine chemically with the gas in the envelope, an impedance connected between the anode and the first-named grid, an impedance connected between the cathode and the first-named grid, a condenser, means connecting the condenser to the anode and the cathode in parallel to the impedances connected in series, an impedance connected between the cathode and the second-named grid, means for periodically charging the condenser, and means for periodically discharging the condenser between the anode and the cathode to pass an electrical discharge between them through the gas in the envelope to produce a cathode spot on the cathode.

11. An electric circuit having, in combination, a gaseous-discharge device comprising an envelope containing gas and having an anode, a solid cold cathode, and a grid, the cathode being constituted of a material having a relatively low work-function and that does not combine chemically with the gas in the envelope, an impedance connected between the anode and the grid, a condenser, means connecting the condenser to the anode and the cathode, means for periodically charging the condenser, and means for periodically discharging the condenser between the anode and the cathode to pass an electrical discharge between them through the gas in the envelope to produce a cathode spot on the cathode, and the impedance being so proportioned that, when the voltage across the condenser reaches a predetermined value, a discharge will take place between the cathode and the grid and, therefore, between the cathode and the anode.

12. An electric circuit having, in combination, a gaseous-discharge device comprising an envelope containing gas and having electrodes comprising an anode and a solid cold cathode, the cathode being constituted of a material having a relatively low work-function and that does not combine chemically with the gas in the envelope, means for applying a voltage between the anode and the cathode, an oscillator, and means for impressing the oscillations of the oscillator upon one of the electrodes to cause an electrical discharge to be passed between the anode and the cathode through the gas in the envelope to produce a cathode spot on the cathode.

13. An electric circuit having, in combination, a gaseous-discharge device comprising an envelope containing gas and having an anode, a solid cold cathode, a grid disposed between the anode and the cathode, and a grid disposed between the cathode and the first-named grid, an impedance connected between the anode and the first-named grid, an impedance connected between the cathode and the first-named grid, a condenser, means connecting the condenser to the anode and the cathode in parallel to the impedances connected in series, an impedance connected between the cathode and the second-named grid, an oscillator, and means for impressing the oscillations of the oscillator upon the second-named grid to cause discharges to take place periodically between the grids and, therefore, between the cathode and the anode.

14. An electric circuit having, in combination, a gaseous-discharge device comprising an envelope containing gas and having an anode, a solid cold cathode, and a grid, the cathode being con-

stituted of a material having a relatively low work-function and that does not combine chemically with the gas in the envelope, means for applying a voltage to the grid, a condenser, means connecting the condenser to the anode and the cathode, means for periodically charging the condenser, and means for periodically discharging the condenser between the anode and the cathode to pass an electrical discharge between them through the gas in the envelope to produce a cathode spot on the cathode.

15. In an electric circuit, 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, means for causing a continuous glow discharge in the tube, a grid for preventing conduction between the anode and cathode, and means changing the bias on the grid for causing an arc discharge between the anode and the cathode.

16. In an electric circuit, a gaseous-discharge tube comprising an anode, a cathode comprising a mixture of a caesium salt and a metal which will displace the caesium in the salt under the action of a cathode spot and form a surface coating thereon of a metal of low work-function, means for causing a continuous glow discharge in the tube, a grid for preventing conduction between the anode and cathode, and means changing the bias on the grid for causing an arc discharge between the anode and the cathode.

17. In an electric circuit, a gaseous-discharge tube comprising an anode, a caesium-containing cathode on which a cathode spot can be formed by a glow discharge to the cathode to form a surface coating thereon of a metal of low work-function, means for causing a continuous glow discharge in the tube, a grid for preventing conduction between the anode and cathode, and means changing the bias on the grid for causing an arc discharge between the anode and the cathode.

18. In an electric circuit, 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 means causing a glow discharge to form a cathode spot on the cathode.

19. In an electric circuit, a gaseous-discharge tube comprising an anode, a solid cathode on which a cathode spot can be formed by a glow discharge, and means for continually but interruptedly passing current between the anode and the cathode 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 at low average temperature and to produce a fall of cathode potential lower than that occurring to a glow discharge, and sufficiently low so that the root-mean-square value of this current shall be low enough so that the average temperature applied thereby to the cathode shall be less than the temperature at which substantially incandescent cathode emission is produced, thereby continually but interruptedly to form a cathode spot on the cathode.

20. In an electric circuit, a gaseous-discharge tube comprising an anode, a cathode of a material that will break down under the action of a cathode spot and form a surface coating of a material of low work-function thereon, and means for continually but interruptedly passing current between the anode and the cathode 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 at low average temperature and to produce a fall of cathode potential lower than that occurring in a glow discharge, and sufficiently low so that the root-mean-square value of this current shall be low enough so that the average temperature applied thereby to the cathode shall be less than the temperature at which substantially incandescent cathode emission is produced, thereby continually but interruptedly to form a cathode spot on the cathode.

21. In an electric circuit, a gaseous-discharge tube having an anode, a cathode comprising a mixture of a caesium salt and a metal which will displace the caesium in the salt under the action of a cathode spot, and means for continually but interruptedly passing current between the anode and the cathode 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 at low average temperature and to produce a fall of cathode potential lower than that occurring in a glow discharge, and sufficiently low so that the root-mean-square value of this current shall be low enough so that the average temperature applied thereby to the cathode shall be less than the temperature at which substantially incandescent cathode emission is produced, thereby continually but interruptedly to form a cathode spot on the cathode.

22. In an electric circuit, a gaseous-discharge device comprising an anode, a solid cathode on which a cathode spot can be formed by a glow discharge, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

23. In an electric circuit, a gaseous-discharge device comprising an anode, a cathode 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 low work-function, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

24. In an electric circuit, a gaseous-discharge device comprising an anode, a solid cathode on which a cathode spot can be formed by a glow discharge, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shall be less than the temperature at which substantially incandescent cathode emission is produced, thereby continually but interruptedly to form a cathode spot on the cathode.

25. In an electric circuit, a gaseous-discharge device comprising an anode, a 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, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

26. In an electric circuit, a gaseous-discharge device comprising an anode, a caesium-containing cathode, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals betwen the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

27. In an electric circuit, a gaseous-discharge device comprising an anode, a barium-containing cathode, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

28. In an electric circuit, a gaseous-discharge device comprising an anode, a cathode containing barium and a metal that wil displace the barium under the action of a cathode spot, means for continually setting up discharges of arc characteristic betwen the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shal be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

29. In an electric circuit, a gaseous-discharge device comprising an anode, a cathode comprising a mixture of a caesium salt and a metal that will displace the caesium in the salt under the action of a cathode spot, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals betwen the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

30. In an electric circuit, a gaseous-discharge device comprising an anode, a cathode comprising a mixture of a caesium salt and aluminum, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

31. In an electric circuit, a gaseous-discharge device comprising an anode, a cathode comprising a mixture of a caesium salt and cadmium, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

32. In an electric circuit, a gaseous-discharge device comprising an anode, a cathode comprising a mixture of caesium chloride and a metal that will displace the caesium in the caesium chloride under the action of a cathode spot, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

33. In an electric circuit, a gaseous-discharge device comprising an anode, a cathode comprising a mixture of caesium chloride and aluminum, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

34. In an electric circuit, a gaseous-discharge device comprising an anode, a cathode comprising an open enclosure and a reactive mixture therein of a material that will break down under the action of a cathode spot and form a surface coating thereon of a material of low work-function, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode.

35. In an electric circuit, a gaseous-discharge device comprising an anode, a cathode 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 low work-function, means for continually setting up discharges of arc characteristic between the cathode and the anode, and means for providing intervals between the discharges sufficiently large so that the average temperature of the cathode shall be low enough to prevent rapid disintegration of the cathode, thereby continually but interruptedly to form a cathode spot on the cathode, the device being provided with means for absorbing gaseous products that may result from the reaction of the cathode spot on the said material.

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