Nov. 23, 1926. 1,608,268

C. G. FOUND ET AL

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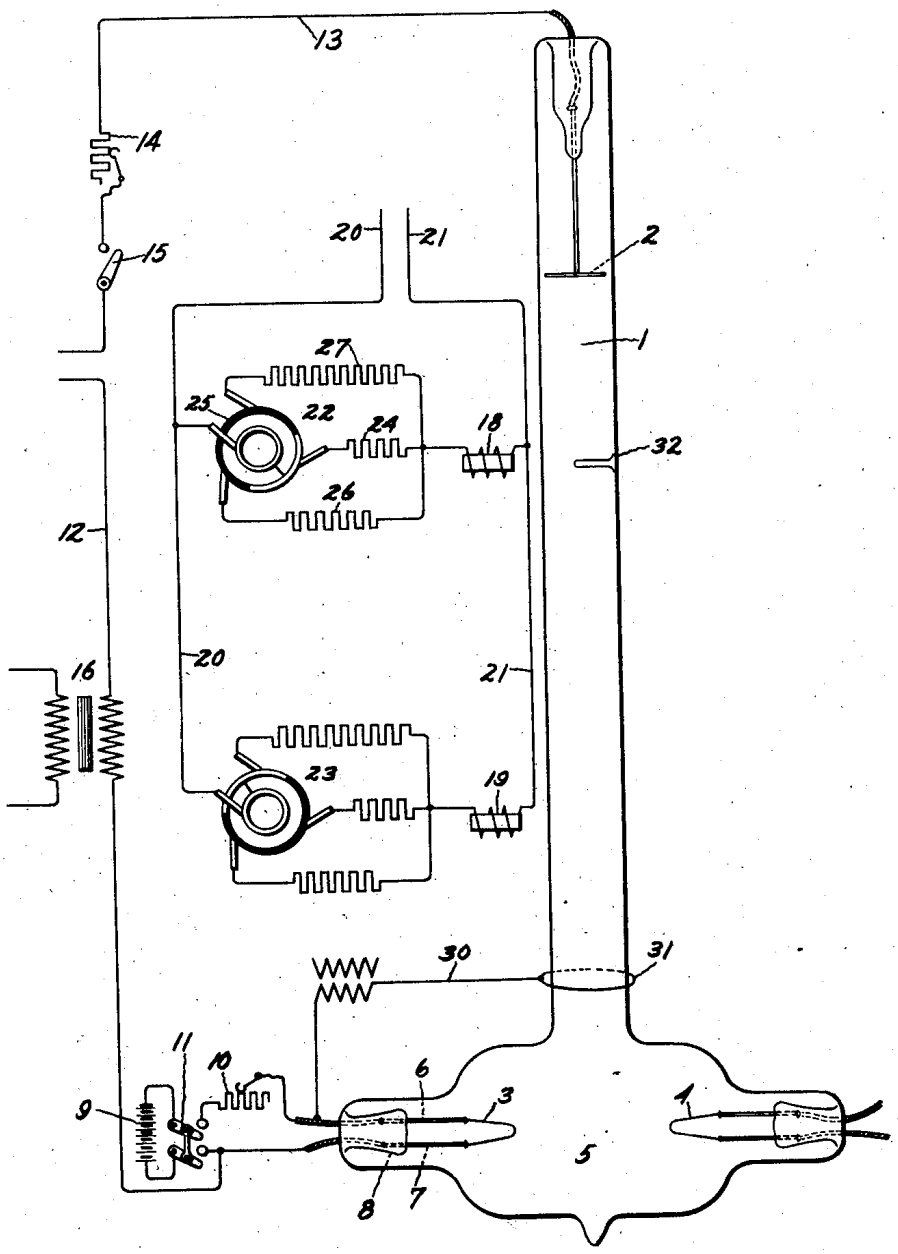
Filed Sept. 18, 1924



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Patented Nov. 23, 1926. 1,608,268

UNITED STATES PATENT OFFICE.

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ELECTRICAL DISCHARGE DEVICE AND METHOD OF OPERATION.

Application filed September 18, 1924. Serial No. 738,519.

The present invention comprises a new device for producing electric glow discharges which is operable by the ionization of a gas giving a discontinuous spectrum, but which in addition is provided with means for producing simultaneously a luminous discharge having a continuous spectrum. The invention further comprises a method of producing a continuous spectrum in a gaseous glow discharge. In the device embodying our invention various spectacular luminous electrical effects can be obtained, thus rendering the device useful as a lighting source for display purposes.

As will be later explained luminous streamers can be produced in our new device which have a wave form characteristic of the wave form of an impressed variable current. This characteristic of our device may be utilized as in an oscillograph for the investigation of electrical phenomena.

The novel features of our invention will be set forth with particularity in the appended claims. Briefly described, our device operates by the ionization of an attenuated gas in the presence of particles of refractory material, as for example, tungsten in a state of extremely fine subdivision, such as produced by electric sputtering.

The accompanying drawing shows somewhat diagrammatically an embodiment of our invention, organized mainly as an electrical display device, but also including the electrical connections whereby the wave form of the voltage in the electrical circuit may be indicated in a visible way.

A glow discharge may be produced in accordance with our invention in a device comprising an elongated or tubular envelope 1, as shown in the drawing, which is provided with a plate-shaped anode 2, consisting of molybdenum, tungsten or other suitable conducting material, and a cathode 3, constituted by a small incandescent lighting filament consisting of tungsten, tantalum, molybdenum or other suitable refractory material. A second filament 4 has been shown in the drawing as located in the opposite end of the enlargement 5, formed at one end of the envelope 1, but this second filament is not an essential element in our new device. It may be used as a spare cathode, or may be used to start the discharge between the main electrodes 2 and 3, or to furnish luminosity-producing material, all as later explained. The filament 3 is connected as usual to leading-in conductors 6, 7 which are sealed into a glass stem 8, and are connected externally to any suitable source of current, as represented by a battery 9. In series with the battery 9 is a regulating resistance 10 and an electric switch 11. The electrodes 2, 3 are connected by the conductors 12, 13 to a source of direct current (not shown in the drawing) in series with the regulating resistance 14 and a switch 15. Included in the circuit 12 is a secondary of a transformer 16 whereby an alternating voltage may be superimposed upon the unidirectional voltage in order to vary the character of the electrical discharge in the device, or, if the device is to be used in the manner of an oscillograph, to superimpose upon the operating voltage a variable voltage the wave form of which is to be recorded or observed.

Spaced along the tube 1 in which the discharge is produced are electromagnets 18 and 19 which are provided with a mechanism whereby the strength of the magnetic field may be varied. Any desired number of such magnets may be used for varying the luminous effect in the device, as will be later explained, only two having been shown to render the drawing simple. The current for operating the magnets is derived by the conductors 20, 21 from a source of current (not shown), which preferably is direct current. In series with the magnets are circuit switching devices or commutators 22, 23 whereby resistances of different values are connected in series with each of the electromagnets in order to vary their strength. For example in series with the magnet 18 the commutator 22 has in the position indicated in the drawing completed the circuit of the magnet 18 through a resistance 24. Upon further rotation of the commutator in a clockwise direction the non-conducting segment 25, indicated by the full black line, would open-circuit the resistance 24 and the commutator will introduce a higher resistance 26 in the circuit. Still further rotation of the commutator will introduce the resistance 27 into the circuit which being still higher, will further weaken the magnet 18. As later explained these variations of the magnetic field acting on the discharge vary the luminous effects.

The tubular envelope 1 is evacuated and

freed from water vapor in the usual way and the metal parts are rendered gas-free. A gas then is introduced through which a luminous electric discharge may be produced. For example one of the rare gases, such as argon, or a mixture of these gases may be used at a pressure varying from about 2 to 5 mm. of mercury.

A luminous glow discharge with a discontinuous spectrum may be started between the main electrodes 2, 3 from a source of direct current at a voltage of about 250 volts, the switch 15 being closed; by impressing a high frequency field upon the gaseous discharge path, as indicated by the high frequency circuit 30 which includes a conductor 31 surrounding the tube 1 and being connected to the cathode 3. The color of this luminous discharge will depend on the character of the gas used, for example, in the case of argon a purplish glow is produced.

With the filament 3 operating at a temperature of about 2500° C. the current value of the discharge is limited by the series resistance 14. With about 225 ohms resistance the current will be about 1 ampere and the voltage drop between the electrodes 2 and 3 will be about 25 volts, the rest of the voltage being mainly consumed in the series resistance 14. If now very finely refractory metal particles are introduced into the discharge as by disintegration of some of the cathode material, then brilliant light effects are produced. For example some of the material from the cathode 3 may be electrically disintegrated or sputtered, as by opening the cathode circuit through the switch 11 for a short time, thereby reducing the temperature of the cathode, which limits the current to a lower value by the reduction of electron emission. At this lower current the voltage drop in the resistance 14 is lowered and a greater voltage is impressed mainly at the cathode. This increased cathode drop between the electrodes 2 and 3 causes disintegration of the cathode by positive ion bombardment. The presence of this disintegrated metal in the discharge path causes first the production of brilliant flashes of blue, bluish-green and sometimes yellowish-green light in the lower part of the bulb, the flashes forming a distinct luminous column which usually is well defined and which elongates with lateral writhing and twisting movements, moving progressively upwards to the anode 2. This new luminous effect produced by the metal vapor has a continuous spectrum as though due to the incandescence of the metal particles.

If the cathode circuit is closed after a short interval and the magnets 18 and 19 are not energized, the luminous flashes in the tube would soon die down and the tube would continue to operate with the gaseous glow discharge with a discontinuous spectrum. The magnetic field, however, causes the luminous effect to continue, varying in accordance with the variation of strength of the magnetic field, to give very beautiful and brilliant lighting effect in form of streamers and luminous clouds.

The discharge sometimes acts as though the luminous streamers which have a continuous spectrum, were derived from a skin or surface of the glow discharge column which is pushed inwardly from the exterior by the magnetic field acting as though this surface layer had a marked surface tension. By manipulation of the magnetic field this surface layer may be forced as little droplets from the exterior into the center of the column, these droplets being perhaps less than 0.1 mm. in size, moving slowly enough to be easily followed by the eye. These droplets have a yellowish-white brilliancy and show a continuous spectrum. When the surface of the envelope has a discontinuity such as represented by the projection 32 in the figure, the droplets can be more easily caused to leave the inner surface of the envelope from this surface layer which bends around the projection without touching the projection. Apparently the streamers and clouds in the device are made up of these droplets coming from the surface layer so close together as to be indistinguishable in many cases to the eye.

When a variable or alternating current is applied to the primary of the transformer 16 and thus superimposed upon the operating voltage, the luminous streamers in the discharge have a wave form corresponding to the wave form thus superimposed.

Our invention is not limited to the introduction of the metal vapor by positive ion bombardment of an incandescent cathode which constitutes one of the main electrodes in the device. Even with such an arrangement the device would have a long useful life as the electrode material is vaporized only for short periods. The luminous effect will persist for as long as twenty-four hours when the metal vapor is introduced by opening the switch 11, as above described, for a period of less than a second. The sputtering operation can be repeated many thousands of times with the same filament. The metal vapor may be introduced from an independent electrode 4, which is either made a cathode of a discharge operating therefrom to either the electrodes 2 or 3 as anode when the electrode 4 is heated by passage of current. The vapor may be produced from the electrode without a heating current passing through the electrode when a sufficiently high potential is impressed between the electrode 3 and 4, the latter being negative. In this case the electrode 4 may consist of a more massive piece of tungsten or other metal, for example, of a disk or rod.

What we claim as new and desire to secure by Letters Patent of the United States, is,—

1. The method of producing an electric discharge having a continuous spectrum in a gaseous glow discharge which consists in vaporizing a refractory material in the presence of said discharge.

2. The method of producing highly luminous discharges having a continuous spectrum in a gaseous glow device constructed to operate with an electric discharge having a discontinuous spectrum which consists in producing in said device the vapor of a highly refractory metal.

3. An electric discharge device comprising means for producing a luminous discharge having a discontinuous spectrum and means for supplying to said discharge the vapor of a highly refractory material.

4. An electrical discharge device comprising an envelope, a gas therein at a pressure of at least several millimeters of mercury, a cathode adapted to be heated by passage of current, an anode and means for electrically disintegrating a solid material in said envelope.

5. An electric discharge device comprising an envelope, electrodes therein, a gaseous filling and means for electrically sputtering the material of one of said electrodes.

6. An electric discharge device comprising an envelope, a filamentary cathode therein consisting of tungsten, a cooperating anode, a filling of gas at a pressure of about several millimeters, and means for subjecting said cathode to positive ion bombardment at voltages at which electrical disintegration occurs.

7. An electric discharge device comprising means for producing a luminous discharge having a discontinuous spectrum, means for supplying to said discharge the vapor of a refractory material and means for subjecting said discharge to a magnetic field.

8. An electric lighting device comprising an envelope, electrodes therein, one of which is adapted to be operated by passage of current, a charge of argon gas at a pressure of about several millimeters of mercury, means for sputtering some of the material of said filament, and means for impressing a variable magnetic field upon the discharge path between said electrodes.

9. An electric descharge device comprising an envelope filled with a rare gas at a substantial pressure, a pair of electrodes within the envelope, means whereby a potential may be applied to the electrodes to produce a luminous discharge therebetween, said discharge having a discontinuous spectrum, and means for electrically disintegrating a solid material within said envelope to thereby vary the spectrum produced by the discharge between said electrodes.

In witness whereof, Clifton G. Found has hereunto set his hand this 16th day of September, 1924, and Irving Langmuir has hereunto set his hand this the seventeenth day of September, 1924.

CLIFTON G. FOUND.
IRVING LANGMUIR.