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G. M. J. MACKAY  
ELECTRICAL GLOW DEVICE

Filed Jan. 26, 1920

Fig. 1.

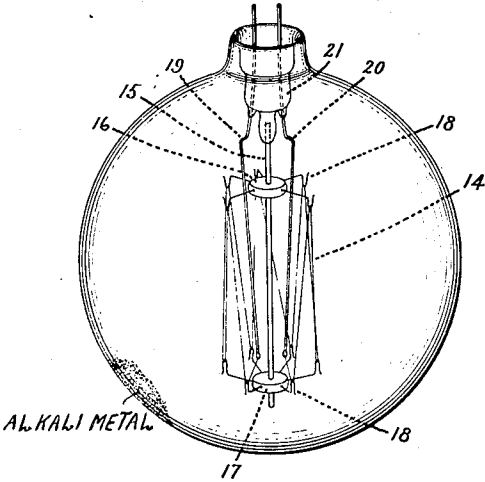


Fig. 2.

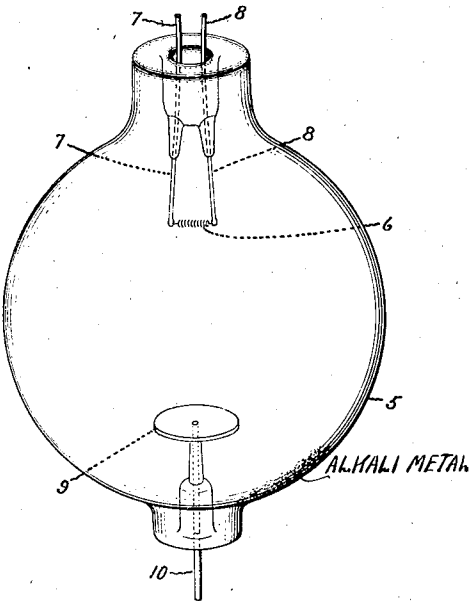


Fig. 3.

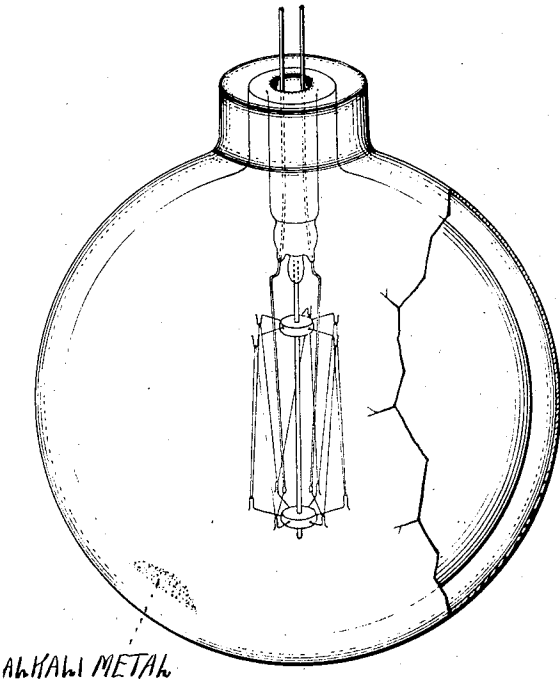
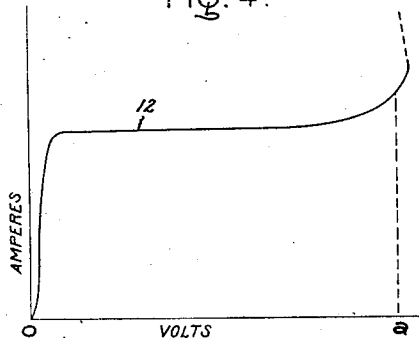


Fig. 4.



Inventor:  
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## UNITED STATES PATENT OFFICE.

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## ELECTRICAL GLOW DEVICE.

Application filed January 26, 1920. Serial No. 354,195.

*To all whom it may concern:*

Be it known that I, GEORGE M. J. MACKAY, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Electrical Glow Devices, of which the following is a specification.

The present invention relates to electrical glow devices and comprises a means and a method of producing an electrical discharge having new and technically useful characteristics.

My invention in one of its aspects is an electric lamp of higher efficiency than heretofore attainable.

I have discovered that an electric discharge from an incandescent cathode in the vapor of an alkali metal at pressures below about fifty microns of mercury (0.05 mm. Hg.) and preferably within a range of vapor pressure corresponding to temperatures between about 200° to 300° C. does not cause the cathode to disintegrate or sputter. What is still more remarkable, the cathode does not disintegrate even when the discharge is operated at commercial voltages, that is, over one hundred volts and with relatively large currents, say, over 100 milliamperes. The discharge has a stable volt-ampere characteristic when the applied voltage is within this range and the current is relatively large. The current increases with a rising voltage up to a limiting value, and thereafter remains substantially constant over a relatively wide range of voltage. This discharge has a high luminous efficiency, a large part of the energy being emitted in the visible portion of the spectrum. It does not require an energy-consuming, steady resistance, and therefore may be operated in shunt to an incandescent filament to constitute a lamp of high efficiency.

These and other novel features of my invention will be pointed out with particularity in the appended claims. For a complete understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawings.

Figs. 1 and 2 illustrate somewhat diagrammatically two embodiments of my invention; Fig. 3 is a modification having a

double-walled container to reduce heat dissipation, and Fig. 4 is a diagram of the volt-ampere characteristics of thermionic discharges in sodium vapor.

The device illustrated by Fig. 2 comprises a sealed envelope 5 consisting of a suitable material not readily acted upon chemically by the filling material, for example, the refractory boro-silicate known in the market as "Pyrex" glass. The cathode 6 consists of a coiled filament of refractory material, such, for example, as tungsten. It is provided with leading-in conductors 7, 8, sealed into the envelope whereby current may be supplied to the filament to heat the same to incandescence. The anode 9 consists preferably of tungsten although various conductive materials also may be used. A leading-in conductor 10 for the anode is sealed into the envelope in the usual manner.

In preparing the device, the envelope is thoroughly exhausted the glass being heated during exhaust nearly to its softening point to remove water vapor. A quantity of pure sodium is introduced into the bulb, after residual gases and vapors have been removed, as far as possible, and the bulb thereupon is sealed off. Preferably the process of exhaust is carried out by first introducing a small amount of sodium into a dried and exhausted bulb, heating the bulb and expelling the sodium vapor. This process may be repeated. Finally a desired quantity of purified and redistilled sodium is introduced and allowed to remain in the bulb.

The bulb is operated at a temperature high enough to volatilize a portion of the sodium and maintain the pressure of the sodium vapor high enough to be ionized by the electron discharge and within the range throughout which the discharge has stable characteristics. Preferably the bulb should be maintained within a range of about 200 to 300° C. This temperature may be obtained by proportioning the bulb so that the dissipation of heat under ordinary external conditions is adjusted to maintain the temperature within the desired range, or the bulb may be heated or cooled externally to maintain the temperature within the desired range.

With the cathode at a suitably high temperature, the application of current of suitable voltage to the electrodes produces a

brilliant glow in the bulb of the yellowish tint characteristic of the sodium spectrum. A peculiar characteristic of the glow is the uniform distribution of luminescence throughout the bulb which may be due to optical resonance effects in the sodium vapor. The light efficiency of the glow appears to be very high. It is approximately of the order of a tenth of a watt per candle.

The presence of the ionized vapor greatly increases the current-carrying capacity of the device by substantial elimination of the current limiting effect of the negative field of the electrons on each other which is usually known as space charge. For example, a given device carrying in the substantial absence of positive ionization about three milliamperes at 125 volts carries in the presence of sodium vapor at a suitable pressure a current of about 500 milliamperes at the same voltage. Ordinarily the cathode temperature in these devices should correspond to a luminous efficiency of about one watt per candle. At a higher cathode temperature both the total light emitted by the glow discharge and the efficiency of the glow appear to be decreased. At materially higher cathode temperatures the range over which the discharge is stable is decreased.

The relation of the current to the applied voltage is illustrated by a characteristic curve 12, shown in Fig. 4, which is obtained by plotting the applied volts as abscissae and the corresponding currents as ordinates in a device embodying my invention operating at a substantially constant temperature. As illustrated by this curve the current rises rapidly with an increase of voltage from zero, then remains substantially constant with further increase of voltage over a wide range until a second increase of current occurs when the discharge characteristic becomes negative, as indicated by the dotted line. From zero to a limiting value of voltage *oa*, the discharge is stable without a series resistance, as the current cannot increase without a rise of applied voltage. Above the voltage *oa* the discharge becomes unstable. An attempt to increase the voltage further results in an arc-like or "runaway" discharge in which the current increases with a corresponding decrease of voltage across the terminals of the discharge electrodes.

When the temperature of the device is increased, and hence the pressure of sodium vapor is increased, the critical point of instability corresponds to lower voltage values, that is, the operating range of the device is contracted. At a sufficiently high pressure of sodium vapor, corresponding, say, to a temperature above 400° C. the current voltage characteristic of the device is negative at ordinary commercial voltage and is similar to the characteristic of incandescent cathode devices operated in other vapors or gases at relatively considerable pressures.

The device shown in Fig. 2 may be used as a rectifier of alternating currents or as a lamp.

Fig. 1 illustrates a lamp embodying my invention containing a looped filament 14 consisting of tungsten, or other suitable refractory material, and supported upon a framework comprising a stem 15 upon which are mounted two buttons 16, 17, in which are embedded hooks 18 upon which the filament is supported. The stem 15 and the hooks 18 consist preferably of a material more refractory than glass, for example, such as tungsten, "Nichrome" or the like. The buttons 16, 17, in which the hooks 18 are embedded consist either of suitable heat-resisting glass or of porcelain. Current connection is made by conductors 19, 20, consisting of relatively heavy wires composed of tungsten, molybdenum or the like. These wires preferably extend from the seal 21 to the opposite end of the framework where attachment is made to the ends of the filament in the usual manner. The lamp is exhausted and provided with a quantity of metallic sodium, as already described in connection with the device shown in Fig. 2.

When a lamp embodying my invention constructed and prepared as above described is operated in the usual way on either direct or alternating current, a discharge will pass through the sodium vapor across the space between the loops of the filaments by reason of the difference of voltage between these filament sections and cause the entire bulb to be pervaded with a brilliant yellow glow. The amount of light obtained from a glow produced under these conditions is remarkably great and depending upon the size of the bulb may emit several times the candle power of the filament. These effects, which are of such a different order from those hitherto observed with gases at such low pressures, may be partly due to the purity of the sodium vapor. The sodium vapor itself seems to bring this about by "cleaning up" any traces of foreign gases which may be present.

In an alternating current device the conductors immediately adjacent the leading-in wires have alternately the highest positive potential and act as anode for the discharge from other more negative filament sections. These sections therefore tend to overheat as they are heated both as resistance conductors and as anodes to a glow discharge. In a direct current device the above would apply only to the conductor adjacent the positive lead.

In the devices shown in Figs. 1 and 3, the conductors adjacent the leading-in conductors consist of stout wire thereby preventing

ing overheating of the same. The lamp shown in Fig. 3 has a double-walled envelope, the space between the two walls preferably being evacuated. This construction reduces the heat losses from the device. When a lamp such as shown in Fig. 3 is provided with a base, a suitable heat insulator should be placed so as to prevent cooling that portion of the inner bulb which is not insulated by the outer bulb and the evacuated space.

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

1. An electrical discharge device comprising a cathode adapted to be heated to incandescence, heating means therefor, an anode, and means for furnishing, subject to the ionizing influence of an electron discharge between said electrodes, a gas which when ionized will leave said electrodes intact from electrical disintegration, said gas having a pressure at which a discharge of stable characteristics may be produced with currents of the order of magnitude of 100 milliamperes at voltages materially above the ionization voltage of said gas.

2. An electric discharge device comprising a sealed envelope, means for producing therein an electron discharge and a substance within said envelope having a pressure less than about fifty microns of mercury at the operating temperature of said device and capable of becoming ionized in the space between said electrodes to increase materially the current carrying capacity of the space between said electrodes, said discharge having a stable electrical characteristic and leaving intact from electrical disintegration the source of said electron discharge.

3. The method of converting electrical energy into light which consists in passing an electrical discharge between an incandescent cathode and an anode through sodium vapor and maintaining the pressure of said vapor at a value at which a luminous discharge is produced having a stable electrical characteristic.

4. The method of converting electrical energy into light which consists in passing an electrical discharge through sodium vapor and maintaining the pressure of said vapor within the range of vapor pressure of metallic sodium corresponding to temperatures between about 200 to 300° C.

5. An electrical device comprising the combination of a sealed envelope, a refractory cathode adapted to operate at incandescence, an anode and a quantity of alkali metal within said envelope, said device having a heat dissipating capacity adapted to maintain the vapor pressure of said alkali metal at a value at which an electrical discharge therethrough has stable electrical characteristics.

6. An electrical discharge device comprising the combination of a tungsten cathode, an anode, means for heating said cathode, an enclosing bulb and a quantity of sodium in said bulb, said lamp being proportioned to maintain the vapor pressure of said sodium below the value at which the volt-ampere characteristic of a discharge therethrough becomes negative.

7. An electrical device comprising the combination of an enclosed envelope, a cathode adapted to operate at incandescence, an anode, and a quantity of sodium in said envelope, said envelope being proportioned to operate at a temperature at which the vapor pressure of said sodium is sufficiently high to enable an electric discharge therethrough to ionize said vapor but below the value at which a discharge through said device has a negative volt-ampere characteristic.

8. An electrical device comprising the combination of a sealed envelope, a cathode of refractory material adapted to operate at incandescence, an anode and a quantity of sodium within said envelope, said device having a heat dissipating capacity adapted to maintain said device at a temperature corresponding to a pressure of sodium vapor less than about fifty microns of mercury.

9. An electric lamp comprising a bulb, a filament of refractory material capable of operating at incandescence and a substance in said bulb which is gaseous at the operating temperature of the lamp and is capable of conducting a luminous discharge from an end of said filament when at incandescence to the opposite end, and in parallel with the connecting part without disintegrating said filament, said discharge having a constant current value over a range of voltages.

10. An electric lamp comprising a bulb, a conductor therein capable of conducting current with a voltage drop between terminals of the order of magnitude of about one hundred volts and a quantity of material therein having at the operating temperature of the bulb a vapor pressure sufficiently high to conduct current by a stable electrical discharge across the space in said bulb between a section of said conductor when at incandescence, and another section having a positive potential with respect to said incandescent section.

11. An electric lamp comprising a sealed exhausted container, a quantity of metallic sodium in said container, and a filament of refractory material adapted to be heated to incandescence mounted within said container, said lamp being adapted to dissipate heat generated therein at a rate which will maintain the operating temperature of said lamp at a value at which the pressure of said sodium is high enough to produce a glow discharge, but below about 300° C. to

avoid the formation of an arc-like discharge having an unstable electrical characteristic.

12. An electric lamp comprising the combination of a sealed evacuated container, a tungsten filament, a quantity of metallic sodium in said bulb, said lamp being constructed to operate at ordinary external temperatures with said sodium in a vapor state at a pressure high enough to be ionized by a discharge therethrough but below about fifty microns of mercury.

13. An electric device comprising a bulb, a filament of refractory material therein, and a quantity of metallic sodium in said bulb, said device being operable with a discharge having a stable electrical characteristic conducted through said sodium in a vaporized state, in parallel with a portion of said filament.

14. The method of increasing the current-carrying capacity of an electron discharge which consists in maintaining in the path of said discharge the vapor of an alkali metal within pressure limits sufficiently high to cause substantial positive ionization by collision but insufficient to permit of an arc-like discharge having a negative volt-ampere characteristic.

15. An electrical discharge device comprising an evacuated envelope, electrodes therein, means for heating one of said electrodes to incandescence independently of a discharge therebetween, an alkali metal contained therein, said device being constructed to maintain the vapor pressure of alkali

metal during operation high enough to increase the current carrying capacity of said device, but below the value at which an arc-like discharge of negative volt-ampere characteristic may occur.

16. An electrical discharge device comprising a container, cooperating electrodes therein, means for producing an electron discharge between said electrodes, a quantity of an alkali metal in said container, and means surrounding said container for maintaining the temperature of said device at a value at which the metal vapor has a sufficiently high pressure to permit substantial positive ionization during operation but will not be so high as to permit an arc-like discharge.

17. An electrical discharge device comprising a sealed evacuated envelope, a filamentary cathode consisting of refractory material, terminal conductors therefor whereby a heating current may be conveyed to said cathode, an anode, and a quantity of alkali metal in said envelope, said device being proportioned, when dissipating heat under ordinary external conditions, to operate at a temperature at which the vapor pressure of said alkali metal is sufficiently high to enable an electric discharge therethrough to ionize said vapor but below the value at which a discharge through said device has a negative volt-ampere characteristic.

In witness whereof, I have hereunto set my hand this 22nd day of January, 1920.

GEORGE M. J. MACKAY.