June 13, 1944. D. E. ELMENDORF 2,351,254

ELECTRIC DISCHARGE DEVICE

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Fig. 1.

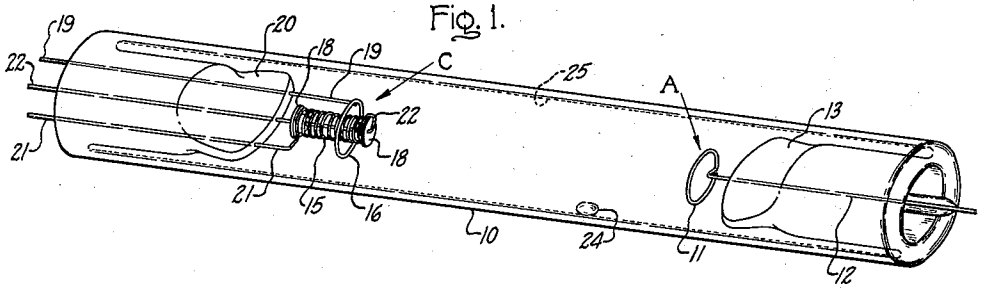


Fig. 2.

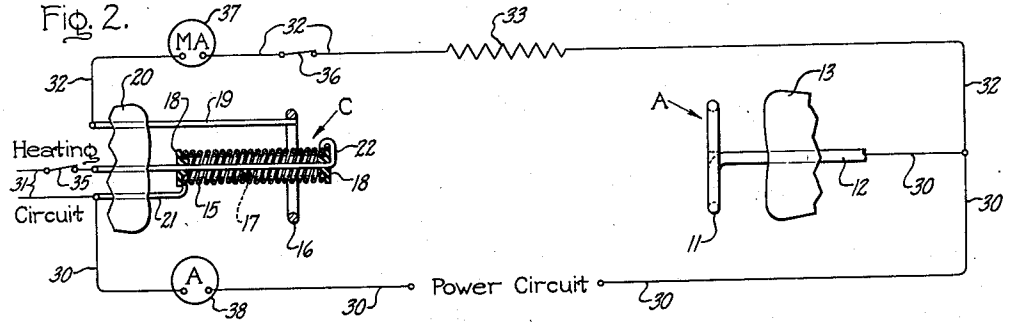


Fig. 3.

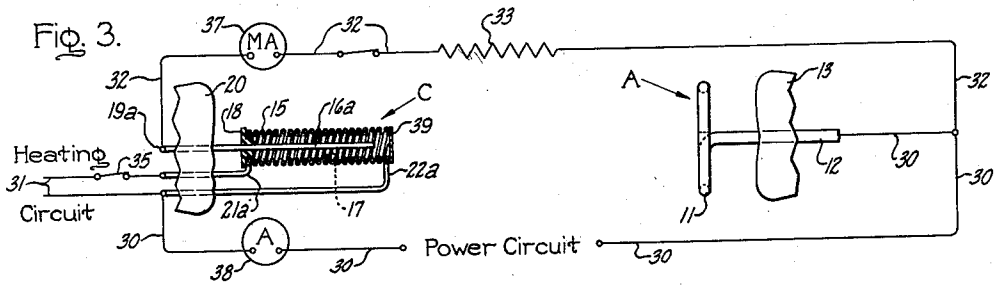
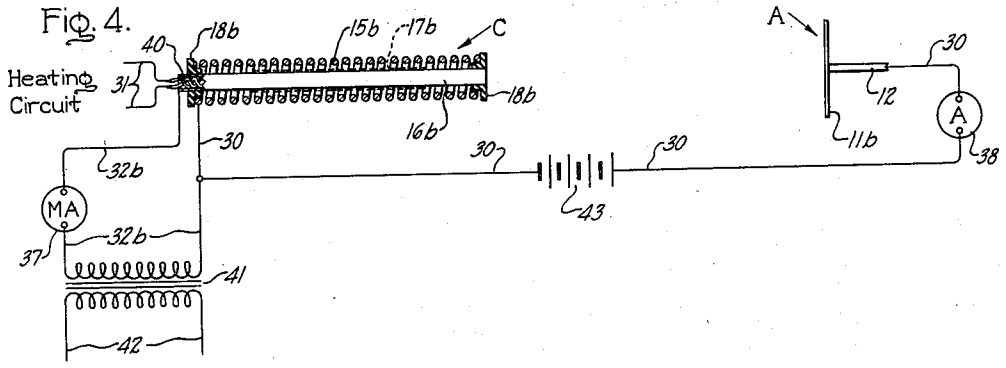


Fig. 4.



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Fig. 5.

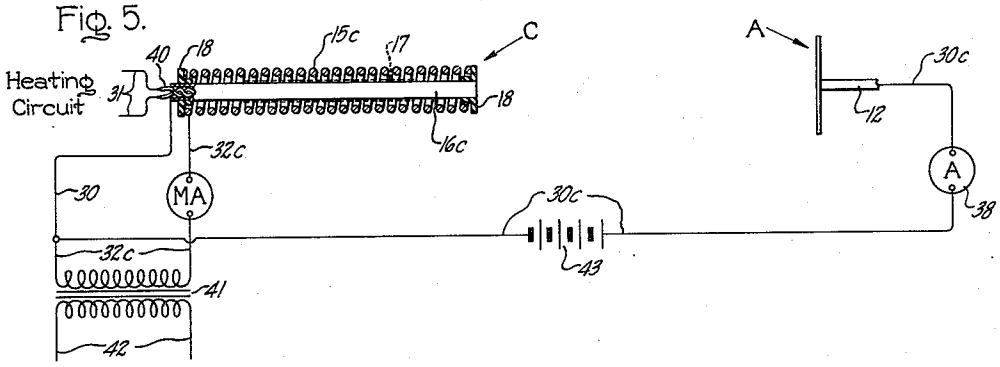


Fig. 6.

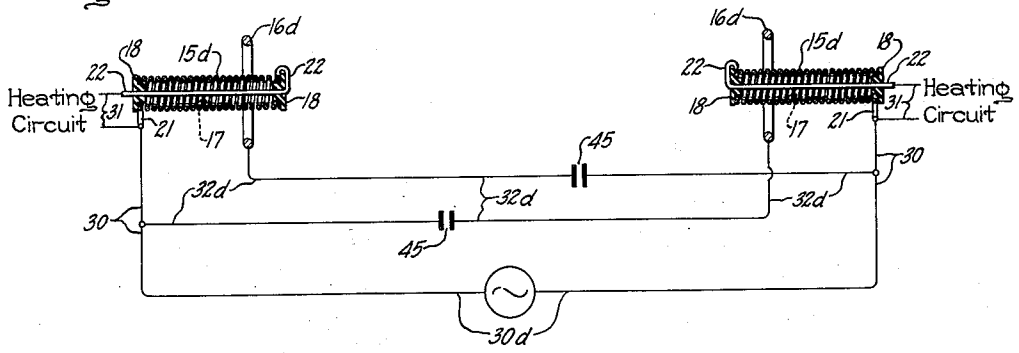
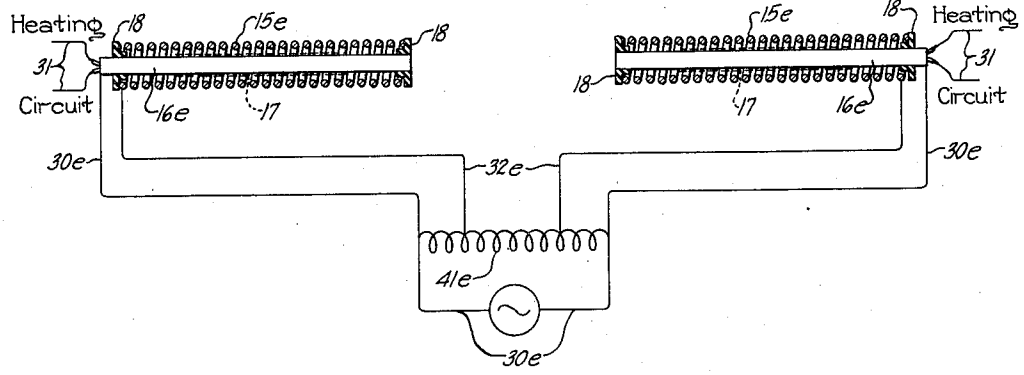


Fig. 7.



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Patented June 13, 1944 2,351,254

UNITED STATES PATENT OFFICE

2,351,254

ELECTRIC DISCHARGE DEVICE

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Application July 25, 1941, Serial No. 404,023

5 Claims. (Cl. 176—126)

This invention relates to electric discharge devices and systems, and aims at improving and simplifying them in various ways. One advantage that can be obtained through the invention is the elimination of troublesome accessories, including starting and current-limiting means like ballasts, thermal cut-out switches, etc. Another advantage is improvement of the voltage-current characteristics of electric discharge devices, especially discharge devices containing gas or vapor—even to the extent of enabling such devices to start and operate with a positive voltage-current characteristic, and without resort to specially high voltage for starting. The invention is applicable to discharge devices producing useful radiations for various purposes, such as germicidal tubes or lamps, and lamps used industrially for irradiating or treating many substances and products, and for fluorescent lighting. I have hereinafter explained the invention with particular reference to a device suitable for use as a fluorescent lamp.

In a discharge device to operate with a positive voltage-current characteristic in accordance with my invention, a cathode is provided which displays such a characterictic when operating within a proper normal voltage range. In a positive column discharge device embodying such a cathode, its positive voltage-current characteristic predominates over the negative voltage-current characteristic of the positive column portion of the discharge—provided, of course, the voltage on the device is not excessive in relation to its length, and that this length is not inordinately great. Whether of positive column type or not, discharge devices with my cathode of positive voltage-current characteristic can be operated without ballast or other current limiting means, and can be started in any way which does not involve operation, after starting, under excessive voltage. One convenient way of accomplishing this is to provide a thermionic cathode which is heated to render it emissive for starting, also using an auxiliary anode if the distance of the operating anode from the cathode is such that a discharge cannot start between the cathode and said operating anode on a voltage within the proper operating range of the device. Naturally, the device may contain a gaseous or vaporous atmosphere during operation—consisting of any suitable ionizable gas or mixture of such gases, or any suitable vaporizable and ionizable working substance or substances—or a mixed atmosphere comprising both gases and vapors.

As suggested above, my invention includes a novel type of electrode or cathode structure for electric discharges in atmospheres of gas or vapor, which exhibits positive voltage-current characteristics when the voltage of the discharge is not excessive. In forms described hereinafter, my novel electrode involves emissive cathode means surrounded by what is in effect a barrier of negative potential for segregating a region adjacent the emissive cathode means and preventing or limiting entry into this region of positive ions from outside the barrier, while nevertheless permitting free passage of the discharge atmosphere of gas or vapor. In some forms, the more active cathode means consists of the interior surface of the barrier structure itself; in other forms, the barrier structure surrounds a separate activated electrode. In these latter forms, these members of the cathode structure (barrier and cathode proper) may coact with one another as electrodes for one (auxiliary) discharge, while either of them may function as cathode for another (main) discharge. In the forms first mentioned, on the other hand, the barrier may serve as cathode for an auxiliary or starting discharge, as well as for the main discharge.

Other features and advantages of the invention beside those already indicated will appear from the following description of species and forms of embodiment, and from the drawings. Indeed, all the features and combinations shown or described are of my invention, so far as they are novel.

In the drawings,

Fig. 1 is a tilted view of a simple form of electric discharge device conveniently embodying my invention; and Fig. 2 is a general view, largely diagrammatic, showing the current connections and the electrode structures of the device, on a larger scale than Fig. 1, one of said electrode structures being in vertical mid-section.

Fig. 3 is a view similar to Fig. 2 showing a modification of one of the electrode structures.

Fig. 4 is a view similar to Figs. 2 and 3 showing other forms of electrode structure; and Fig. 5 is a similar view showing the same electrode structures as Fig. 4 with different electrical connections.

Fig. 6 is a general view, largely diagrammatic, illustrating a device having at its two ends identical electrode structures like one of those

in Fig. 2, with electrical connections for operation on alternating current; and Fig. 7 is a view similar to Fig. 6 showing a device having at its two ends identical electrode structures like one of those in Fig. 4, with electrical connections (different from those in Fig. 6) for operation on alternating current.

The device shown in Fig. 1 comprises a tubular vitreous envelope 10 with electrode structures A, C mounted in its opposite ends, and rather widely spaced apart. In the present instance, the electrode structures A, C are dissimilar in function and construction. The right-hand electrode structure A is shown as a simple anode in the form of a circular metal ring 11 attached to the end of a support and current lead 12 sealed through a stem-press 13 forming this end of the envelope 10. The ring 11 may be arranged centrally in the tube 10 and perpendicular to its axis. The left-hand electrode structure C is shown as comprising an electrode 15 of hollow, tubular openwork or grid-like character, consisting in the present instance of a helical wire coil, together with another electrode 16 in relatively close proximity to the electrode 15, so as to assist in starting a discharge between the electrodes 15 and A. As shown in Fig. 2, the wire coil electrode 15 is a thermionic cathode that is rendered interiorly emissive by a coating of activating material 17 on the inner surfaces of its members or convolutions, and can be heated to a sufficient temperature to produce such internal emission of electrons by passage of current through the wire. The members or convolutions of the tubular electrode 15 are rather closely spaced, and refractory flanged insulators 18, 18 are mounted in its ends, as barrier means to prevent electric discharge from passing freely through the ends to the interior of the electrode, or vice-versa. Thus the electrode structure is closed, and closes off the region adjacent the emissive cathode surfaces, against free electric discharge to the interior and the cathode means there. The electrode 16 is here shown as a wire ring or "hoop" coaxially surrounding the electrode coil 15 nearly at mid-length of the coil, and is attached to a supporting current lead 19 that is sealed through a stem-press 20 forming this end of the envelope 10. The ends of the electrode coil 15 are connected to supporting leads 21, 22 that are sealed through the stem-press 20. As here shown, the lead 22 is bent around to extend axially within the coil 15, through axial holes in the insulators 18, 18, thus helping to hold the electrode 15 in shape, so to speak, besides supporting it effectively. The electrode 15 may be arranged lengthwise of the envelope tube 10, coaxial therewith. As here shown, the electrode 16 lies in a transverse plane a little nearer the anode A than mid-length of the electrode 15; however, this electrode 16 may be shifted either way along the tube 10 relative to the electrode 15, and may very well be to the right of the latter.

The envelope 10 should contain a low-pressure atmosphere of suitable starting gas (such for example as argon at an absolute pressure of about ½ to 5 mm. of mercury), and may also contain a charge of vaporizable and ionizable working substance (indicated by a mercury globule 24) sufficient in amount to assure an excess in the device, so that the pressure of vapor during operation will depend on the temperature of the envelope walls. While neither the vapor pressure nor that of the starting gas is critical, yet at present I prefer a gas pressure near the lower figure of ½ mm. above mentioned. In Fig. 1, an internal coating of fluorescent material or phosphor 25 is indicated on the envelope 10.

Fig. 2 shows one suitable system of current supply connections for the device. As here shown, the main power circuit 30 (which may be either D. C. or A. C.) is connected between the leads 12, 21 across the electrodes A and 15. A heating power-circuit 31 (D. C. or A. C.) is connected between the leads 21, 22 to heat the electrode coil 15. The voltage in this circuit 31 should, of course, be lower than the ionizing potential(s) of the atmosphere in the envelope 10 to prevent arcing along the electrode coil. An auxiliary power circuit (D. C. or A. C.) is connected across the electrodes 15 and 16—being here shown as provided by one side of the circuit 30 and by a circuit lead 32 connected from the other side of the circuit 30 to the lead 19, and including a resistor 33. The voltage applied by this auxiliary power circuit across the electrodes 15, 16 should be relatively low as compared to that applied across the electrodes A and 15 from the main power circuit 30, though sufficient (initially, at least) to ionize the starting gas, as well as the vaporizable working substance. The polarization of the connections is made such that the electrode 15 is negative to the electrode 16 when the anode A is positive in relation to both of said electrodes. Control switches 35, 36 are shown interposed in the circuits 31, 32. A milliammeter 37 and an ammeter 38 are shown at suitable points in the auxiliary and main circuits 32 and 30 for measuring the current values of the auxiliary and main discharges. These, however, are of course unessential, and have no connection with my present invention.

The device being connected and the circuits energized as above described, the cathode 15 is heated and rendered emissive from its inner surface 17, and a discharge is thus started between the electrodes 15, 16, ionizing the starting gas and, ultimately, the mercury or other vapor that evolves as the envelope 10 heats up. If the electrode 16 is close enough to the cathode 15, and the voltage between them is sufficiently low, this discharge may have the character of a negative cathodic glow; otherwise, it may partake of the character of a positive column discharge. The electrode 16 acts as a starter anode in relation to the cathode 15, providing excitation of the starting gas under which the device breaks down to the anode A, so that a positive column arc discharge is established between the electrodes 15 and A. The heating of the cathode 15 by this main discharge soon renders heating thereof from the circuit 31 unnecessary, so that the switch 35 in this circuit may be opened. If the power line 30 is D. C., the starting of the discharge between the electrodes 15 and A also renders unnecessary the continued energization of the auxiliary power circuit between electrodes 15 and 16 that includes the line 32, and its switch 36 may also be opened; but if the power line 30 is A. C., energization of this auxiliary circuit must be continued, to restart the arc after its extinction at each reversal of voltage in the main power circuit 30.

It will readily be apparent to those skilled in the art that the use of electrode 16 for starting, as above described, may be dispensed with when the electrodes 15 and A are arranged close enough to one another to allow of starting the discharge directly between them, on the normal

operating voltage. Or, to state the matter differently, use of the electrode A for normal operation may be done away with when the location of the electrode **16** relative to the electrode **15** is such as to give an adequate volume of discharge in the device for the purpose in view; and the electrode **16** may be positioned as far from the electrode **15** as will allow of starting the discharge between them on the normal operating voltage of the device.

Under a relatively low voltage sufficient to ionize the initial atmosphere in the envelope **10**, and with the auxiliary electrode **16** sufficiently close to the cathode **15**—e. g., at a distance of the order of the mean free path of the positive ions, more or less—the discharge between the electrodes **15** and **16** takes place under relatively low pressure between relatively large available electrode areas and at relatively low current density, and is largely in the nature of a negative cathodic glow discharge. As the activating material **17** is on the interior of the cathode electrode **15**, a high negative space charge of electrons accumulates inside this cathode, which limits the further emission of electrons and the ionization of gas outside the cathode by electrons coming out of the cathode. Furthermore, the close spacing of the members or convolutions of the electrode **15** and the restriction of the activating material **17** to the interior of this electrode results in the "capture" of a high proportion of the positive ions outside the cathode by its negative external surface—which with connections and polarization such as described is naturally negative to the surrounding discharge—diminishing the number that reach its interior to neutralize the negative space charge there. In this connection, it must be appreciated that the highly negative openwork members or convolutions exercise a strong attraction for the positive ions, so that any whose course takes them close to the members are drawn to the latter and captured, as well as those that spontaneously drive against the members. Hence an opening between the members that is sufficiently narrow is almost or virtually equivalent to no opening at all, so far as entrance of positive ions therethrough is concerned; while at the same time it permits comparatively free egress of electrons, which are repelled by the negative openwork members. Thus the closely spaced barrier members or convolutions **15** limit the positive ions entering the segregated region within, during discharge, and the current drawn from said region by the anode **16** or A; though for starting, the anode **16** is rendered sufficiently positive to draw discharge-initiating current despite the barrier, thus bringing about discharge to anode A, as already mentioned. In sum, the usual effect of positive ions in augmenting cathode emission and total discharge in a cumulative manner is not produced; or, in other words, the auxiliary discharge does not show the usual negative voltage-current characteristic of a gaseous discharge: on the contrary, an increase in the voltage across the electrodes **15**, **16** is required to increase the discharge. This remains true, however, only so long as the voltage across the electrodes **15**, **16** is kept reasonably low, and the other conditions indicated are fulfilled.

The restrictive influences pointed out in the preceding paragraph are also effective as regards the discharge between the electrodes **15** and A; so that as long as the voltage across these electrodes is not too high in relation to the distance between the electrodes, this over-all discharge also exhibits a positive voltage-current characteristic.

With an atmosphere in the envelope **10** comprising both starting gas and vaporizable working substance, such as argon and mercury, the discharge between the electrodes **15** and **16** tends to exhibit a double character, depending on the argon pressure and the cathode temperature, as well as on the voltage across the electrodes **15**, **16**. For example, with an argon pressure of ½ mm., and a relatively low but emissive cathode temperature, the device for which illustrative dimensions are given below operates with a mercury discharge and glow at the electrodes **15**, **16** when the voltage across them is about 11 volts; while with the same argon pressure and a higher cathode temperature, this device operates with an argon discharge and glow at the electrodes **15**, **16** when the voltage across them is about 18–25 volts. Under both conditions of the discharge across the electrodes **15**, **16** (argon glow and mercury glow), the device operates with a mercury glow for the positive column between the more widely spaced electrodes **15** and A, and shows a positive voltage-current characteristic under a voltage of 25 to 50 volts across these electrodes. In general, the voltage for this main discharge between the more widely spaced electrodes **15** and A must be higher when the auxiliary discharge between the electrodes **15**, **16** exhibits the argon glow than when it exhibits the mercury glow.

For the device to operate with positive voltage-current characteristics as above described, the electrode structure C—or, more especially, the electrode **15**—must be suitably proportioned, as already suggested. Here an important consideration is that the intervals between the members or wire turns of the electrode **15** should be so small that the members constitute an effective barrier against entrance of sufficient positive ions into its interior to largely neutralize the negative space charge there, so that electrons could be emitted more freely to ionize the atmosphere outside the electrode coil **15**, to augment the discharge cumulatively and produce a negative voltage-current characteristic. For the assistance of those desiring to use my invention, I will now give illustrative dimensions and other particulars of an actual device.

A device operating satisfactorily as above described and exhibiting positive voltage-current characteristics for both auxiliary and main discharges may be built with an envelope **10** of hard glass (such as the nonex grade of Pyrex glass) of nominal 1 inch internal diameter; with an anode A formed by bending the end of a lead **12** of 0.04 inch nickel wire into a ring of about $\frac{7}{16}$ inch diameter; with a gap of about 7¾ inches between this anode A and the adjacent end of the cathode coil **15**; with a coil **15** of molybdenum wire of 0.02 inch diameter coiled 40 turns per inch to an internal diameter of 0.10 inch, and $\frac{9}{16}$ inch long; and with an electrode ring **16** having a diameter of about $\frac{7}{16}$ inch, formed of molybdenum wire of 0.04 inch diameter. Operating with an auxiliary voltage of 11 volts across the electrodes **15**, **16**, this device shows a current of about 10 milliamperes for the auxiliary discharge as measured at **37**, and a current of about 0.10 ampere for the main discharge, as measured at **38**, under a voltage of 50 volts across the main electrodes **15**, A. However, it will be understood that by suitably proportioning and arranging the electrodes **15**, **16** and suitably spacing the electrode

A from them, the voltages and currents for both discharges can be varied rather widely without sacrificing the positive current-voltage or resistance characteristics of these discharges.

The electrode structure C shown in Fig. 3 differs from that in Figs. 1 and 2 in having for its auxiliary electrode an axially arranged wire or rod *16a* inside the cathode coil *15*, which is in effect an extension of the current lead *19a*; also, the current lead *22a* from the inner end of the coil *15* extends outside this coil to the stem press *20* through which it is sealed; and this inner end of the coil *15* is closed by a disc *39* of sheet metal (e. g., molybdenum) welded thereto, instead of by an insulator *18*. Moreover, the circuit connections of the leads *21a* and *22a* are interchanged as compared with the leads *21* and *22* in Figs. 1 and 2. In other respects, this device and its construction, circuit connections, and operation may be essentially like those of the device shown in Figs. 1 and 2. Accordingly, various parts and features in Fig. 3 are marked with the same reference numerals as the corresponding parts and features in Figs. 1 and 2, as a means of dispensing with repetitive description—a distinctive letter being added where such distinction appears necessary.

Fig. 4 illustrates a device with electrode A consisting of a sheet metal anode disc *11b* attached to the end of the support and current lead *12*. Its electrode structure C comprises an openwork or grid-like electrode *15b*, shown as a helical coil, without any special activation or provision for heating it, and an associated specially heated thermionic cathode *16b* arranged inside the screen-like electrode *15b* and externally coated with activating material *17b* over a major portion of its surface. While the electrode *15b* serves as anode for auxiliary discharge between it and the cathode *16b*, it may also function as cathode for the main discharge to the anode A, as explained hereinafter. The cathode *16b* may consist of a hollow metal cylinder with a heating coil unit *40* inside it. Flanged refractory insulators *18b*, *18b* are fitted around the ends of the inner electrode *16b* inside and overlapping the end convolutions of the coil *15b*, to prevent electric discharge from passing freely through the ends of the coil. The current supply connections shown in Fig. 4 resemble those of Figs. 2 and 3 in that the electrodes A and *15b* are connected across the main power circuit *30* and the electrodes *15b*, *16b* across the auxiliary power circuit *32b*; but instead of being derived from the main power circuit *30* as in Figs. 2 and 3, the auxiliary circuit is separately energized with A. C. by being connected across the secondary of a transformer *41* whose primary is connected across an A. C. power circuit *42*, while the main circuit *30* is energized from any suitable D. C. source *43*. The D. C. resistance of the secondary of the transformer *41* will naturally be so low as to have no appreciable ballasting effect. The proper polarization for this system of connections is such as to make the cathode *16b* negative to the electrode *15b* when the anode A is positive relative to said electrode *15b*. Various parts and features in Fig. 4 are marked with the same reference numerals as the corresponding parts and features in Figs. 1 and 2, in order to dispense with repetitive description—a distinctive letter being added where such distinction appears necessary.

In the operation of the device as shown in Fig. 4, electrons emitted from the cathode *16b* issue between the members or convolutions of the outer electrode *15b* into the atmosphere around it. The outer electrode *15b* acts as a starter anode in conjunction with the cathode *16b*—very much as described above with reference to Figs. 1 and 2—providing excitation of the starting gas immediately adjacent the electrode *15b*. Under this excitation, the device breaks down to the anode A, and a positive column arc discharge results between the electrodes *15b* and A. As in the case of the devices shown in Figs. 1–3, the negative members or convolutions of the outer electrode *15b* constitute an effective barrier against entrance of sufficient positive ions formed in the gas around the electrode *15b* to neutralize the space charge around the cathode *16b* and being about freer emission of electrons, thus ultimately augmenting the discharge cumulatively. Accordingly, this Fig. 4 device exhibits positive voltage-current characteristics as regards both the auxiliary discharge between the electrodes *15b*, *16b* and the main discharge between the electrodes *15b* and A. Both discharges start readily on normal operating voltages. However, the main discharge does not maintain itself without the auxiliary discharge; for, as the electrode *15b* is but a rather poor emitter of electrons at the temperatures which it attains in operation, electron emission from the electrode *16b* is needed to produce the supply of ions on which the main discharge depends. The spacing of the members or convolutions of the outer electrode *15b* is determined by the same considerations as in the case of the electrode *15* in Figs. 1 and 2; but for the benefit of those who may wish to use this form of device, I give illustrative dimensions and other particulars of an actual device.

A device operating satisfactorily on voltages of 20 to 50 volts across the main gap between electrodes A and *16b* and 10–11 volts across the auxiliary gap between electrodes *15b* and *16b* may be built with an anode disc *11b* of sheet nickel about ⅜ inch in diameter; with a 7 inch gap between this anode and the adjacent ends of the electrodes *15b*, *16b*; with an electrode shell *15b* of nickel about $\frac{1}{16}$ inch in diameter and 1 inch long activated by a coating of the usual mixture of barium and strontium oxides; and with an electrode coil *16b* of molybdenum wire of 0.02 inch diameter coiled about 30 turns per inch and 1⅛ inch long, of about 0.100 inch internal diameter, spaced about 0.025 inch around the cathode *15* and having an interval of about 0.013 inch between its adjacent convolutions. Operating with an auxiliary voltage of 11 volts across the electrodes *15*, *16*, this device shows a current of about 10 milliamperes for the auxiliary discharge, as measured at *37*; and with a voltage of 50 volts across its electrodes A and *16*, it shows a current of about 0.10 ampere for the main discharge as measured at *38*. Speaking more generally, it may be said that if the auxiliary current is less than 40 milliamperes and the interval or clearance within the coil *16b* around the electrode *15b* is not over about 0.5 inch, these electrodes *15b*, *16b* show positive resistance characteristics and the device may be operated at proper auxiliary voltage without any ballast of any kind in either of its discharge circuits.

Fig. 5 illustrates a device such as shown in Fig. 4 with different electrical connections: i. e., the main power circuit *30c* is connected across the electrodes *16c* and A, while the auxiliary power circuit *32c* is connected across the electrodes *15c* and *16c*. Thus connected, the device shows a voltage-current characteristic that is positive, but

is much steeper than with the Fig. 4 connections. While the electrode 16c serves as cathode for the main discharge, instead of the electrode 15c as in Fig. 1, the electrode 15c serves as a barrier against entry of positive ions into its interior, very much as in Fig. 4; for the connections are made such that both of the electrodes 15c and 16c are negative when the anode A is positive, though the barrier electrode 16c is less negative than the cathode 15c. In Fig. 5, various parts and features are marked with the same reference numerals as the corresponding parts and features in Figs. 1–4 in order to dispense with repetitive description—a distinctive letter being added where such distinction seems necessary.

The device shown in Fig. 6 differs from those in Figs. 1–4 in having electrode structures C such as shown in Figs. 1 and 2 at both ends, instead of only at one end. This device is intended for A. C. operation, with each electrode structure C functioning alternately as cathode and anode on the alternate current cycles. As shown in Fig. 6, the main A. C. power circuit 30d is connected across the two electrodes 15d, 15d. and the auxiliary or starting electrodes 16d, 16d are cross-connected to opposite sides of this circuit 30d by leads 32d, 32d, each of which has a condenser 45 interposed therein, instead of a resistor as in Figs. 2 and 3. In Fig. 6, various parts and features are marked with the same reference numerals as are used for corresponding parts and features in Figs. 1–5 in order to dispense with repetitive description—a distinctive letter being added where such distinction appears necessary.

Fig. 7 shows a device with electrodes C like that in Fig. 4 at both ends, for A. C. operation as in Fig. 6, and with electrical connections similar to those shown in Fig. 5. As shown in Fig. 7, an autotransformer 41e is connected across the main A. C. power circuit 30e, as well as the electrodes 16e, 16e; and the electrodes 15e, 15e are connected by the leads 32e, 32e to taps on opposite sides of the mid-point of the transformer winding. Here the thermionic electrodes 16e. 16e serve as cathodes for the auxiliary discharge and as both cathodes and anodes, alternately, for the main discharge; while the barrier electrodes 15e, 15e also serve as auxiliary anodes. To dispense with repetitive description, the reference numerals used in Figs. 1–5 are applied to corresponding parts and features in Fig. 7, a distinctive letter being added where distinction appears necessary.

While I have described particular forms of construction and particular circuit connections, and even mentioned particular materials and dimensions, it is to be understood that these are given merely by way of concrete illustration, and not as limiting or defining the invention. On the contrary, the device and its circuit connections can be varied in many ways that will readily suggest themselves to those skilled in the art: the design, construction, materials, and arrangement of the electrode structures in the envelope or tube may be varied, as, for instance, the anode A and the coil electrode 15 may be of tantalum or various other metals; likewise, the gaseous and vaporizable substances for starting or for operation, and the pressures thereof, may be different; likewise, the system of connections may be altered. Moreover, the currents in the main, auxiliary, and heating circuits need not be of the same kinds—as is, indeed, exemplified in Fig. 4 above, where the main power circuit 30 is D. C., as well as the heating circuit, while the auxiliary circuit 32 is A. C. The cathodes 15 and 15d and 16b, 16c, 16e may be activated with the usual mixture of barium and strontium oxides, or with any other suitable activating material, or may even be without activating coatings, if they are heated to temperatures that render them sufficiently emissive. In this latter case, the outer surfaces of the coil 15 or 15d would of course be rendered more or less unemissive by any suitable means.

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

1. An electrode structure for electric discharge in a low pressure atmosphere, said electrode structure comprising an internally activated but externally unactivated openwork hollow cathode structure closed against free electric discharge to its interior, with means for passing current through said cathode to heat it to a temperature of internal emission, the openwork members being so closely spaced together that when maintained at negative potential relative to the surrounding discharge, while said cathode is functioning as such, they limit the positive ions entering the interior of the open work and the discharge current to be drawn from said interior by coacting anode means.

2. An electrode structure for electric discharge in a low pressure atmosphere, said electrode structure comprising an internally activated but externally unactivated cathode coil, with means for passing current through said coil to heat it to a temperature of internal emission, and means for closing the ends of said coil against free electric discharge to its interior, the coil convolutions being so closely spaced together that when maintained at negative potential relative to the surrounding discharge, while said cathode is functioning as such, they limit the positive ions entering the interior of the coil and the discharge current to be drawn from said interior by coacting anode means.

3. An electrode structure for electric discharge in a low pressure atmosphere, said electrode structure comprising electron-emissive cathode means and barrier means enclosing the emissive cathode means and segregating and closing off a region adjacent the latter against free electric discharge to said cathode means, while permitting free passage of the atmosphere of the device, said barrier means comprising screen members so closely spaced together that when maintained at negative potential relative to the surrounding discharge, while said cathode means is functioning as such, they limit the positive ions entering said region and the discharge current to be drawn from said region by coacting anode means, and screen members aforesaid having activated internal surfaces which serve as emissive cathode means.

4. An electrode structure for electric discharge in a low pressure atmosphere, said electrode structure comprising an externally unactivated openwork electrode structure with emissive cathode means in its interior closed off by said structure against free electric discharge to said cathode means, the openwork electrode members being so closely spaced together that when maintained at negative potential relative to the surrounding discharge, while said cathode means is functioning as such, they limit the positive ions entering the interior of the openwork and the discharge current to be drawn from said interior by coacting anode means, and openwork electrode members aforesaid being activated at their inner

sides, and thus serving as emissive cathode means.

5. A low pressure atmosphere electric discharge device comprising a sealed envelope containing anode means and an opposed electrode structure, said electrode structure comprising electron-emissive cathode means for coacting with said anode means in an electric discharge and barrier means enclosing the emissive cathode means and segregating and closing off a region adjacent the latter against free electric discharge to said cathode means, while permitting free passage of the atmosphere of the device, said barrier means comprising screen members having activated internal surfaces which serve as emissive cathode means and are so closely spaced together that when maintained at negative potential relative to the surrounding discharge, while said cathode means is functioning as such, they limit the positive ions entering said region and the discharge current to be drawn from said region by said anode means, whereby the voltage-current characteristic of the discharge between said anode means and cathode means is positive.

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