July 15, 1958 R. K. BRODERSEN 2,843,805

ELECTRIC DISCHARGE APPARATUS

Filed Aug. 12, 1957

Fig. 1.

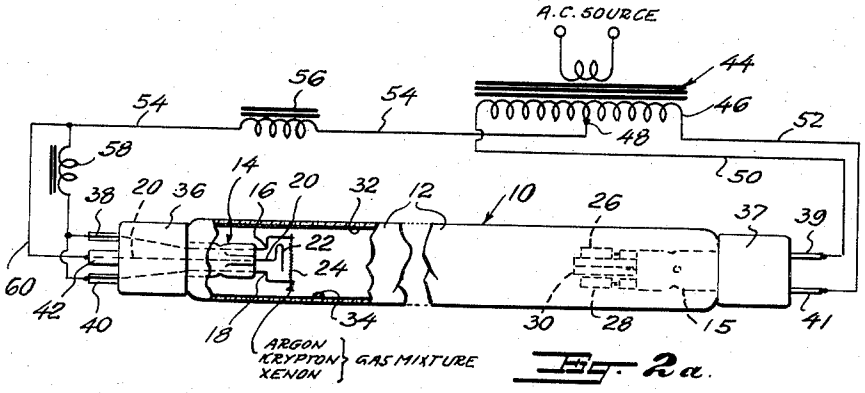


Fig. 2a.

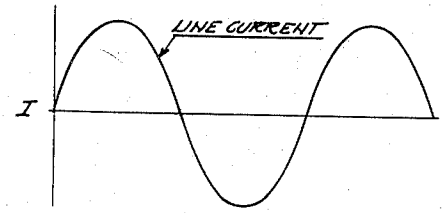


Fig. 4.

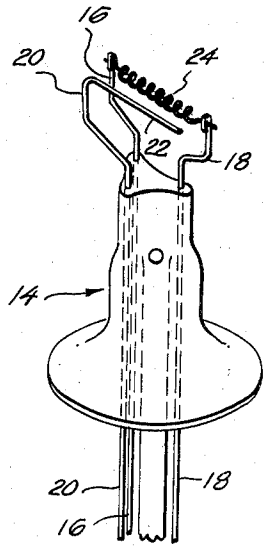


Fig. 2b.

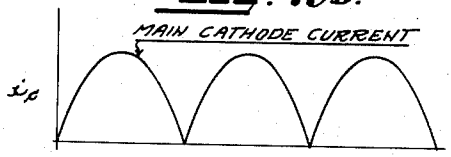


Fig. 2c.

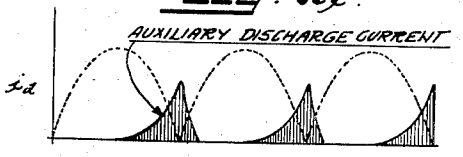


Fig. 2d.

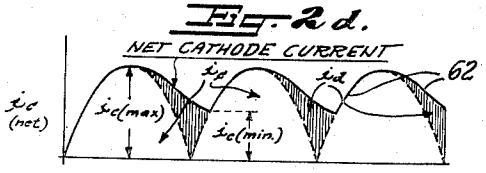
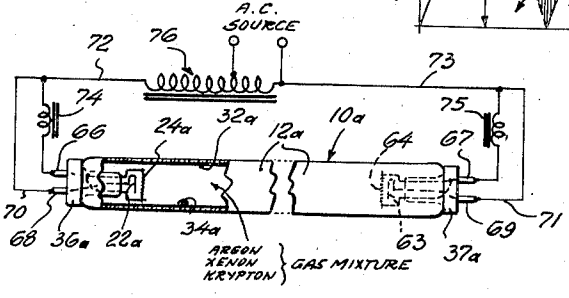


Fig. 3.



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United States Patent Office 2,843,805 Patented July 15, 1958

2,843,805

ELECTRIC DISCHARGE APPARATUS

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Application August 12, 1957, Serial No. 677,624

4 Claims. (Cl. 315—266)

This invention relates generally to an electric discharge apparatus, and more particularly to an A. C.-operable fluorescent lighting system wherein the radio-interference normally generated during operation is suppressed to a minimum and maintained at an unobjectionable level for a substantially greater portion of the lamp life than was heretofore possible.

As is well known, when a gaseous discharge device such as a fluorescent lamp is operated from an A. C. power supply high-frequency electromagnetic radiations are generated which, unless proper preventive measures are taken, emanate from the lamp or its supply line or are fed back into the latter creating a disturbance which interferes with radio reception or the reliable operation of other apparatus, such as radiation-sensitive instruments or the like. The phenomenon of radio-interference generation is not as yet perfectly understood but is a fault common to "hot cathode" gaseous discharge devices of all types and manufactures and, because of the inconvenience and expense involved in minimizing the deleterious effects of the radiations by indirect methods after the device has been installed, constitutes a major problem in the fluorescent lamp industry. While the noise-generative process is a very complex one it has been determined that the cathode is the primary source of these undesirable radiations which apparently evolve when the ionization efficiency abruptly changes during the transition of the cathode fall voltage within the A. C. half cycle. In the copending U. S. application Serial No. 677,623 of J. J. Mason entitled "Electric Discharge Apparatus and Method," filed concurrently herewith and which is assigned to the instant assignee, there is disclosed a means for substantially eliminating the most pronounced components of radio interference noise, i. e. the so-called "ignition" and "extinction" components, by sequentially effecting an auxiliary discharge from the cathode to an auxiliary electrode which, in conjunction with the main discharge, keeps the net cathode current unidirectional and above a predetermined value thereby maintaining at all times a normal cathode fall and producing the desired stabilizing effect on the cathode. In U. S. Patent No. 2,714,681 to R. L. Keiffer et al. a different approach to the problem is disclosed wherein it is proposed to minimize the generation of these undesirable electromagnetic radiations by utilizing, in addition to the mercury vapor and argon normally employed in fluorescent lamps, a gas mixture of xenon and krypton to provide a gradation of ionizing potentials such that sudden changes in the ionization process during the transition from low to high current conditions are avoided.

Neither of the foregoing arrangements have proven entirely satisfactory insofar as the radio-interference is frequently only temporarily suppressed, in many cases lasting only during the first 100 to 300 hours of lamp life. It has been theorized that perhaps the reason for this reoccurrence of R. F. noise is that while the most prevalent of the transitional noise components are suppressed a "D. C." type noise subsequently appears or becomes more pronounced as the operating conditions of the cathode change with lamp life until the intensity of the radio-interference again reaches an objectionable level.

It is accordingly the general object of the present invention to provide an electric discharge apparatus which may be operated from an alternating voltage source without generating objectionable amounts of radio-interference even after prolonged periods of operation.

A more specific object of the invention is the provision of a fluorescent lighting system adapted for A. C. operation wherein the suppression of radio-frequency noise is sustained over a greater portion of the lamp life than heretofore.

Another object of the invention is the provision of a fluorescent lamp and circuit wherein the generation of radio-interference is not only effectively suppressed but accomplished with a minimum dissipation of electrical energy.

The foregoing objects and others which will become obvious to those skilled in the art as the description proceeds are achieved by utilizing as a fill gas a mixture of gases of such character that a suitable gradation of ionization potentials is obtained, as disclosed in U. S. Patent No. 2,714,681, and providing an auxiliary electrode and circuit adapted to maintain a normal cathode fall at all times in the manner disclosed in the aforementioned copending U. S. application of J. J. Mason. According to the preferred form of the invention these features are incorporated in a rectifying type fluorescent lamp system thus not only increasing the longevity of the noise-suppression but materially reducing the amount of auxiliary discharge current required to maintain the net cathode current above the preselected minimum value and effecting a proportionate increase in lamp efficiency. It has been found that the synthesis of these two modes of radio-interference suppression maintains the noise intensity below an objectionable level for a greater length of time than that heretofore obtained from either of the modes alone or expected on the basis of their mere additive effect. In addition, by incorporating these modes into a device which is operated in accordance with the principles of full-wave rectification the power consumption necessitated by the "D. C. operated" type cathode arrangement is reduced to a minimum.

A better understanding of the invention may be obtained by referring to the accompanying drawing wherein:

Fig. 1 is an elevational view of a rectifying type fluorescent lamp and schematic diagram of an A. C. energizing circuit therefor according to the present invention;

Figs. 2*a*, *b*, *c* and *d* are graphical representations of the line current, the main and auxiliary discharge currents and the net cathode current, respectively, of the lamp shown in Fig. 1 during the A. C. operation thereof according to the invention;

Fig. 3 is an elevational view of a conventional dual-cathode fluorescent lamp and schematic diagram of an "instant start" A. C.-energizing circuit therefor according to an alternative embodiment of the present invention;

Fig. 4 is an enlarged view of an electrode mount employed in the lamp shown in Figs. 1 and 3.

While the invention may be utilized in conjunction with any A. C.-operated electric discharge device which produces R. F. noise, it is especially adapted for use with a fluorescent lighting system and hence has been so illustrated and will be so described.

Turning now to the drawing, particularly Fig. 1, the invention may be incorporated into a rectifying type fluorescent lamp **10** which, briefly stated, comprises a tubular light-transmissive envelope **12** sealed at both

ends by mounts **14** and **15** and containing an ionizable medium such as a droplet of mercury **34** and an inert gas mixture of argon, krypton and xenon at substantially equal partial pressures, as for example, 1.17 mm. of mercury to provide a total pressure of about 3.5 mm. of mercury. The total gas pressure within the lamp may vary over a rather wide range depending upon the starting voltage and efficiency desired, as pointed out in the previously-mentioned U. S. Patent No. 2,714,681, thereby providing an ionizable medium having graded ionization potentials of such character that the rate of change of the cathode current is controlled and the amount of R. F. noise generated by fluctuations in the cathode fall and current is minimized in accordance with the principles disclosed in the patent. A quantity of phosphor material is distributed over the inner surface of the envelope **12** to form a coating **32** as is well known in the art. The mount **14**, as shown more particularly in Fig. 4, may be of conventional glass stem construction wherein three lead wires **16**, **18** and **20** are hermetically sealed through a press formed at the end of a flared section of glass tubing. A thermionic electrode, as for example a coil of tungsten wire which has been impregnated with suitable electron-emissive material such as the conventional alkaline earth compounds, is transversely connected to the ends of the lead wires **16** and **18** and serves as a cathode **24** which axially protrudes into the envelope **12** when the mount **14** is sealed therein. The end section of the remaining lead wire **20** is bent in the shape of a hook having a straight end which is disposed in adjacent and generally parallel relation with the cathode **24** to thus form an auxiliary electrode **22**. Inasmuch as the auxiliary electrode **22** is formed from the lead wire or other non-activated material it is less electron-emissive than the cathode **24** and hence always functions as an anode with respect thereto.

At the opposite end of the lamp **10** a pair of axially-extending tubular electrodes depend from the mount **15** into the lamp envelope **12** to serve as a pair of anodes **26** and **28**. In order to minimize sputtering the anodes **26** and **28** are preferably fabricated from carbon or other suitable material. An insulated shield **30** separates the anodes **26** and **28** from each other thereby preventing arcs therebetween during the operation of the lamp. Base members **36** and **37** attached to opposite ends of the lamp envelope **12** enclose the sealed-in portions of the envelope **12** and carry contacts **38**, **40**, **42** and **39** and **41**, respectively, which serve to facilitate the connection of the lamp to a source of electrical energy. The lead wires **16** and **18** connect with the contacts **38** and **40**, respectively, whereas the lead wire **20** is connected to the remaining contact **42** that protrudes from the base member **36**. In a similar fashion the anodes **26** and **28** at the opposite end of the lamp **10** exteriorily connect with the contacts **39** and **41**, respectively, carried by the base member **37**.

Operation of the lamp **10** is effected by connecting the contacts **39** and **41** to opposite ends of a center-tapped secondary winding **46** of a transformer **44** through suitable conductors **50** and **52**, respectively, and by connecting the contacts **38** and **40** to each other and by means of a suitable conductor **54** to the center-tap **48** of the secondary winding **46** through a suitable ballast **56** and electrical-energy storage element **58** arranged in series. Thus, the anode **26** is connected to one end of the secondary winding **46** and the other anode **28** to the opposite end of said winding whereas the cathode **24** is connected to the center-tap **48** thereby constituting a main energizing circuit and permitting the lamp **10** when operated from single-phase A. C. power source to function as a full-wave rectifier. Upon the energization of the transformer **44** the anodes **26** and **28** alternately become positive with respect to the cathode **24** causing a predetermined voltage to be impressed across the lamp **10** such that a gaseous discharge occurs between the cathode **24** and the anodes **26** and **28**, the discharge alternating between the latter on each half cycle of applied voltage and terminating at whichever one is positive.

The lead wire **20** connects the auxiliary electrode **22** with the line side of the electrical-energy storage element **58** by means of the base contact **42** and a suitable conductor **60**. This provides a branch circuit at the cathode end of the lamp **10** which circuit comprises the auxiliary electrode **22**, lead wire **20**, base contact **42**, conductor **60** and (in common with the main energizing circuit) the electrical-energy storage element **58**, contacts **38** and **40**, lead wires **16** and **18** and the cathode **24**. The electrical-energy storage element **58** is preferably a choke of such inductance that it stores sufficient energy during the rising-current portion of each half cycle that an auxiliary discharge of the desired intensity and duration will occur between the cathode **24** and auxiliary electrode **22** during the falling-current portion of the same half cycle and leading part of the succeeding half cycle. In this manner the branch circuit serves as an auxiliary D. C. circuit which, while including a part of the main energizing or lamp operating circuit, does not form a part thereof nor interfere with the normal A. C. operation of the lamp **10** in accordance with the principles disclosed in the aforementioned copending application of J. J. Mason.

Hence, although the wave-form of the alternating line current I applied to the lamp **10** through the transformer **44** is generally sinusoidal as shown in Fig. 2*a*, the main cathode current i_c is unidirectional and pulsating in nature as illustrated in Fig. 2*b*. The cathode **24** during the operation of the lamp **10** accordingly supplies a D. C. current which reaches a peak and falls to zero twice during each cycle of the applied A. C. voltage. When the main cathode current i_c reaches a peak and begins to fall off, the electrical energy stored in the choke **58** during the rising-current portion of the half-cycle is progressively released and causes an auxiliary discharge to occur between the cathode **24** and the adjacent auxiliary electrode **22**, which discharge continues during the falling-current portion of the half cycle and the beginning of the rising-current portion of the succeeding half-cycle. This cyclic storing and release of electrical energy produces an intermittent auxiliary discharge current i_d of sharply-peaked character which flows in the previously-described auxiliary circuit at the cathode end of the lamp **10** bridging the gaps between successive pulses of the main discharge current i_c as illustrated in Fig. 2*c*.

Insofar as both the main cathode current i_c and the auxiliary discharge current i_d are supplied by the cathode **24**, the net cathode current $i_{c(net)}$ which flows is equal to the sum of the aforesaid currents and will undulate above a predetermined minimum value $i_{c(min.)}$ in the manner indicated by the solid-line portion **62** of the composite wave-form diagram of the currents shown in Fig. 2*d*. The unshaded area under the solid-line portion **62** of the diagram represents the main discharge current i_c and the shaded area the auxiliary discharge current i_d, as is indicated in the drawing. It will be evident, therefore, that the net cathode current $i_{c(net)}$ reaches a maximum $i_{c(max.)}$ during each half cycle and thereafter expotentially decays to a minimum value $i_{c(min.)}$ during the time interval when it would normally fall to zero and subsequently rise to the latter value. Thus, the current drawn from the cathode **24** is at all times maintained above a predetermined critical value $i_{c(min.)}$ assuring a normal cathode fall voltage and substantially eliminating the most pronounced components of radio-interference noise incident with subcritical current values in the manner disclosed in the aforementioned copending application of Mason. It should be particularly noted that in this embodiment of the invention the amount of power dissipated in the auxiliary discharge and the size of the electrical-energy storage component **58** are reduced to a

minimum since only sufficient auxiliary discharge current i_d must be supplied to fill in the relatively small gaps between adjacent pulses of the main discharge current i_c as compared to the comparatively large blocks of current required to fill in the voids between the intermittent main current pulses when a non-rectifying type energizing system such as that disclosed in the above-noted copending application of J. J. Mason is employed.

As shown in Fig. 3, the invention may also be applied to the more commonly used dual-cathode lamp **10***a* wherein a pair of electrodes **24***a* and **64** are disposed at opposite ends of a light-transmissive envelope **12***a* which includes a quantity of mercury **34***a*, the usual phosphor coating **32***a* and an inert gas composition consisting of argon, krypton and xenon at predetermined partial pressures and a total pressure selected as discussed in connection with the preferred embodiment. The cathodes **24***a* and **64**, at least one of which is thermionic, are connected by means of suitable lead wires to the contacts **66** and **67**, respectively, which depend from the bases **36***a* and **37***a* attached to the ends of the lamp envelope **12***a* and by means of suitable electrical-energy storage components **74** and **75** and conductors **72** and **73** to an energizing source such as an auto-transformer **76** for example. Auxiliary electrodes **22***a* and **63** of less electron-emissivity than the adjacent cathodes **24***a* and **64** are connected to the remaining base pins **68** and **69**, respectively, and by means of suitable conductors **70** and **71** to the line side of the aforementioned electrical-energy storage components **74** and **75**, respectively, thus providing a D. C. cathode lamp, an auxiliary circuit, and an instant-start energizing circuit of the type described in detail in the aforesaid copending application of J. J. Mason. While the foregoing circuit components and arrangement are identical to those disclosed by Mason, the inclusion of krypton and xenon within the lamp in accordance with the present invention renders the lamp operation different in kind as regards R. F. noise generation from that achieved in accordance with the teachings of Mason or Keiffer et al. resulting in the unexpected advantageous effect hereinafter disclosed.

Actual test data have indicated that the magnitude of radio-interference produced by lamps incorporating both the "D. C. cathode" and multiple gas composition having graded ionization potentials is not only reduced to a negligible level but effectively suppressed for a longer period of time than that heretofore possible with lamps separately incorporating the foregoing elements or contemplated on the basis of their additive effect alone. Experience has shown that lamps constructed and operated in accordance with the principles disclosed in the aforementioned application to Mason and patent to Keiffer et al. were not entirely satisfactory in that the expected degree of noise suppression would not always be achieved and when it was effected would only last for about the first 100 to 300 hours of lamp life at which time a D. C. or other type of noise component would become sufficiently pronounced to cause the overall noise intensity to reach an objectionable level. Thus, on the basis of the mere additive effect of these two modes of noise-suppression one would expect that at best a lamp incorporating both modes would, under ideal conditions, operate twice as long or for about 200 to 600 hours before generating an objectionable amount of noise. It was discovered, however, that when the two modes of noise-suppression were combined in the same lamp in accordance with the present invention the R. F. noise would be maintained at a level comparable to that described by Mason and Keiffer et al. for approximately the first 900 hours of lamp life thereby effecting at least a 300% increase in the longevity of the noise-suppressive effect. Moreover, this disideratum is advantageously accomplished according to the preferred embodiment of the invention with a minimum amount of electrical power through the utilization of a rectifying type energizing circuit.

It will be obvious that the objects of the invention have been achieved by providing a gaseous discharge apparatus of such character that through the synthesis of two basically different cathode-stabilizing means conveniently and economically fabricated not only are the most pronounced components of radio-interference incident with the A. C. operation of such devices substantially eliminated but the suppression of these and other components of R. F. noise is sustained below an objectionable level for a greater portion of the lamp life than was heretofore possible.

While in accordance with the patent statutes one best known and one alternative embodiment of the invention has been illustrated and described in detail, it is to be particularly understood that various modifications may be made without departing from the spirit and scope of the invention.

I claim:

1. Electric discharge apparatus comprising a gaseous discharge device, an energizing circuit, and an auxiliary discharge circuit; said device comprising an envelope containing a plurality of main electrodes, one of which is thermionic and serves as a cathode during the operation of said device, an auxiliary electrode adjacent to and having less electron-emissivity than said cathode, and an ionizable medium including a gaseous atmosphere consisting of argon, krypton and xenon; said energizing circuit comprising a transformer connected to said cathode and the other of said main electrodes and operable when energized to initiate and sustain a controlled gaseous discharge therebetween, and an electrical-energy storage means connected in series with and between said cathode and transformer; and said auxiliary discharge circuit comprising conductor means connecting said auxiliary electrode to said energizing circuit and said cathode through the electrical-energy storage means; said electrical-energy storage means being operable to sustain during the operation of said device an intermittent D. C. auxiliary discharge between said cathode and auxiliary electrode of such magnitude and duration that the current from said cathode is maintained above a predetermined value, which condition in conjunction with the additional stabilizing effect produced by the said ionizable medium reduces to a minimum the radio-frequency noise generated by said device over a substantial portion of its life.

2. Electric discharge apparatus comprising a gaseous discharge device having an envelope, arc-supporting means within said envelope between which a gaseous discharge occurs during the operation of said device, said arc-supporting means comprising three main electrodes one of which is thermionic and serves as a cathode in conjunction with the other two which function as anodes, an auxiliary electrode disposed adjacent said cathode, said auxiliary electrode being less electron-emissive than said cathode, means for operating said device from an alternating voltage source including a ballast and a transformer having a center-tapped secondary winding, conductor means connecting said anodes to opposite ends of said secondary winding and said cathode and auxiliary electrode to each other and to the center-tap of said secondary winding to thus provide a full-wave rectifying circuit, electrical-energy storage means in said circuit between said alternating voltage source and said cathode operable to sustain during the operation of said device a D. C. auxiliary discharge between said cathode and said auxiliary electrode such that the net current from said cathode is maintained above a predetermined value, and an ionizable medium within said envelope including a gaseous atmosphere consisting of argon, krypton and xenon which in conjunction with the said electrical-energy storage means produces an enhanced stabilizing effect on the cathode such that the radio-frequency noise generated by said

device is reduced to a minimum, even after prolonged periods of operation thereof.

3. A light-generating system comprising a low-pressure type fluorescent lamp and an energizing circuit for operating said lamp from an A. C. power source; said lamp comprising a light-transmissive envelope containing three main electrodes one of which is thermionic and disposed at one end of said envelope to constitute a cathode and the other of said main electrodes being disposed at the opposite end of the envelope and serving as anodes, an auxiliary electrode adjacent said cathode, a coating of phosphor on the inner surface of said envelope, and an ionizable medium including mercury vapor and a gaseous atmosphere consisting of argon, krypton and xenon at substantially equal partial pressures and at a total pressure of approximately 3.5 mm. of mercury; said energizing circuit including a ballast and a transformer having a center-tapped secondary winding, the ends of said secondary winding being connected to said anodes and the center-tap thereof to said cathode to thus constitute a full-wave rectifying circuit; conductor means connecting said auxiliary electrode with said cathode and said energizing circuit and in conjunction with a portion of said energizing circuit constituting an auxiliary circuit; and a choke in the said portion of the energizing circuit common to said auxiliary circuit; said choke being connected in a series with said cathode and the secondary winding of said transformer and operable in response to the decrease in the cathode current during the operation of said lamp to initiate and sustain an intermittent D. C. auxiliary discharge between said cathode and auxiliary electrode of such magnitude and duration that the current from said cathode is maintained above a predetermined value during that portion of each half cycle when said cathode

current would normally drop below said value, which condition in conjunction with the additional stabilizing effect produced by said argon, krypton and xenon reduces to a minimum the radio-frequency noise generated by said lamp over a substantial portion of its life.

4. A fluorescent lighting system comprising a fluorescent lamp; an energizing circuit; and an auxiliary discharge circuit; said lamp comprising a phosphor-coated light-transmissive envelope containing an ionizable medium, three main electrodes, one of which is thermionic and serves as a cathode in conjunction with the other of said main electrodes which function as anodes, and an auxiliary electrode adjacent to and less electron-emissive than said cathode; said energizing circuit comprising a transformer having a center-tapped secondary winding, conductor means connecting said anodes to opposite ends of said secondary winding and said cathode and auxiliary electrode to each other and to the center-tap of said secondary winding to thus provide a full-wave rectifying circuit, and an electrical-energy storage component connected in series with and between said cathode and transformer; and said auxiliary discharge circuit comprising conductor means connecting said auxiliary electrode to said energizing circuit and said cathode through the electrical-energy storage component; said electrical-energy storage component being operable to sustain during the operation of said lamp an intermittent D. C. auxiliary discharge between said cathode and auxiliary electrode such that the current from said cathode is maintained above a predetermined value with a minimum of auxiliary discharge current.

No references cited.