

March 29, 1960

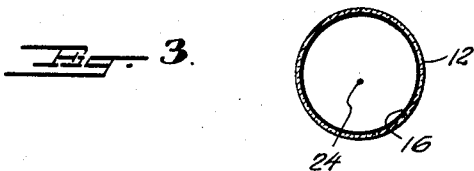
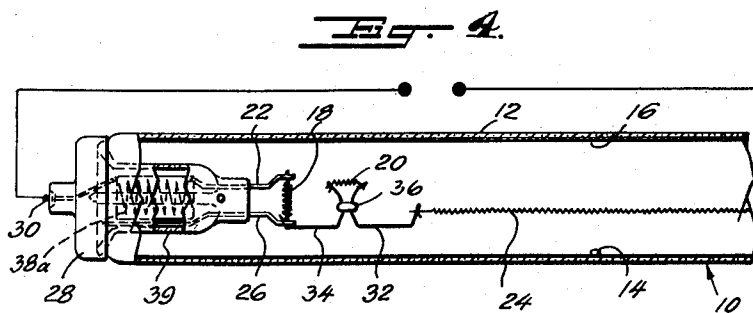
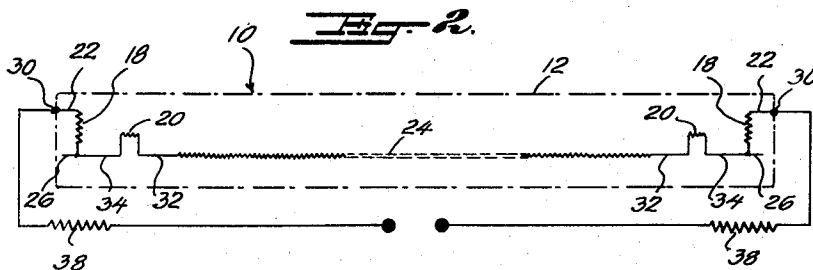
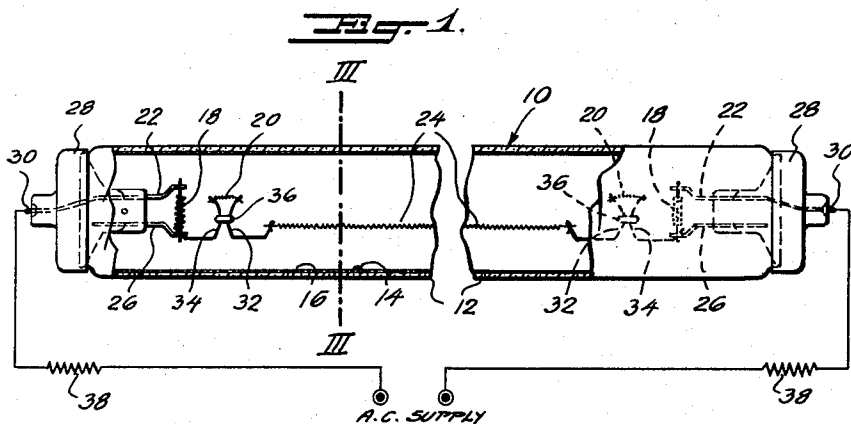
A. W. WAINIO ET AL

2,930,934

DISCHARGE LAMP

Filed Feb. 12, 1958

2 Sheets-Sheet 1



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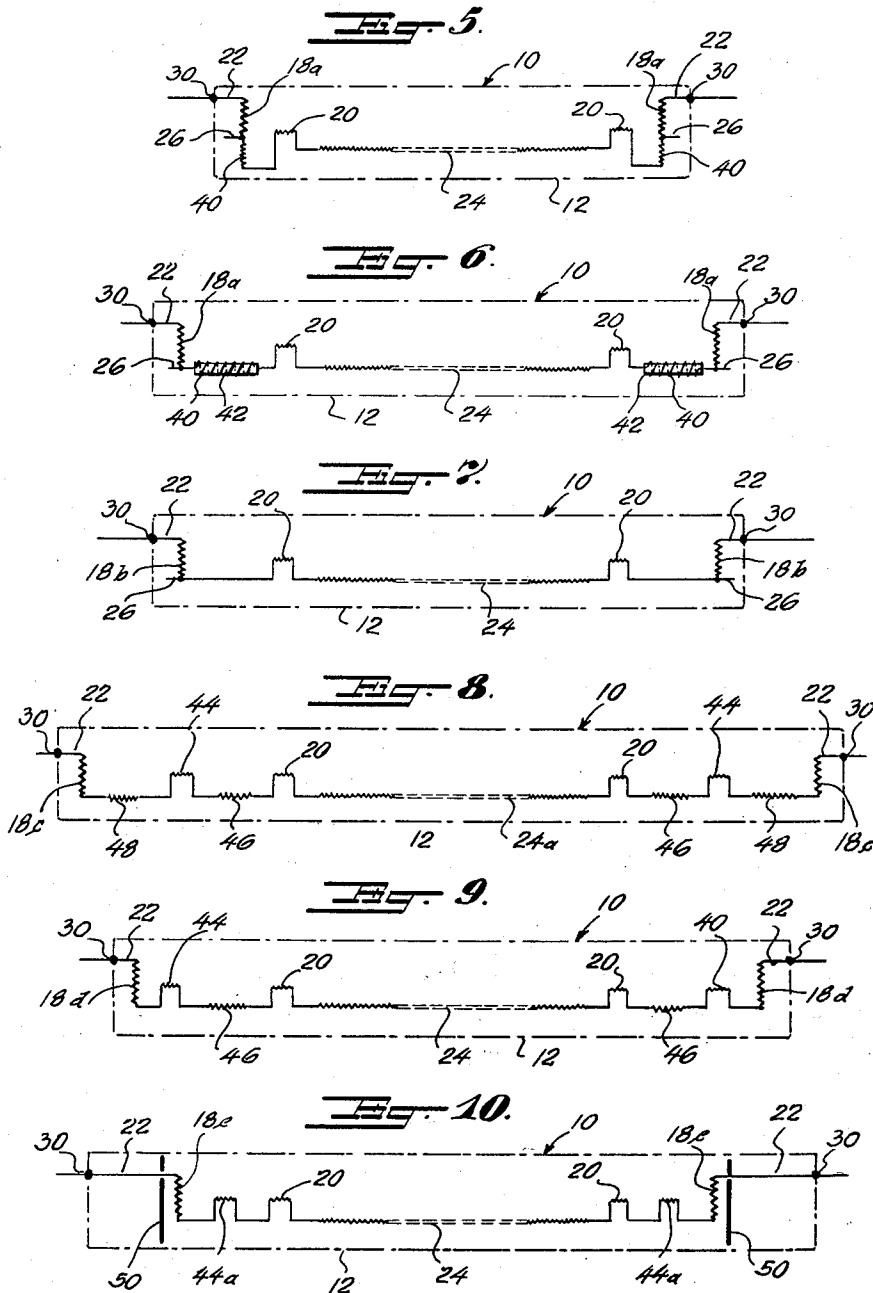
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2,930,934

DISCHARGE LAMP

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Application February 12, 1958, Serial No. 714,874

7 Claims. (Cl. 315—46)

This invention relates to discharge devices and, more particularly, to self-starting, low-pressure, positive-column discharge devices.

Fluorescent lamps are very widely used because of their high operating efficiency and long life. The use of such lamps, however, has been somewhat limited because of the relatively expensive ballast and starting equipment which is required to operate these lamps. The starting and ballasting arrangements have taken various forms, but all are similar in that some transformer means is utilized to increase considerably the voltage applied between the lamp electrodes during starting in order to ionize the discharge path which is defined by the lamp electrodes. Various means have been suggested for starting fluorescent lamps, for example such as disclosed in Patent No. 2,097,261 to Spanner. In addition, various electrode arrangements for facilitating starting of such lamps have been disclosed, for example such as described in Patent No. 2,733,371 to Campbell. None of the foregoing or other previously-suggested arrangements for starting fluorescent lamps have ever been practical for starting on a voltage even approaching the lamp operating voltage or the line voltage. Also, where fluorescent lamps are designed to have so-called instant- or rapid-start characteristics, the starting and ballast arrangements become even more expensive. Accordingly, commercially-available fluorescent lamps all require the use of fairly elaborate starting arrangements.

It is the general object of the present invention to avoid and overcome the foregoing and other difficulties of and objections to the prior art by providing a self-starting fluorescent lamp which will immediately start on line voltage without the use of auxiliary voltage-boosting equipment.

It is a further object to provide a self-starting fluorescent lamp which will immediately start with considerably less than the usual starting voltage required;

It is an additional object to provide a self-starting fluorescent lamp which will immediately start with an applied voltage which is only slightly greater than the initial lamp-operating voltage;

It is another object to provide various modifications for such self-starting fluorescent lamps.

The aforesaid objects of the invention, and other objects which will become apparent as the description proceeds, are achieved by providing a self-starting, positive-column, electric-discharge device wherein at least one pair of thermionic auxiliary starting electrode coils are provided at predetermined locations within the lamp envelope and are spaced apart a predetermined distance. These auxiliary starting electrode coils have such configuration and resistance that less current is required to cause them to become thermionically emissive than the thermionic main electrode coils which are provided for the lamp operation. At least one pair of the auxiliary starting electrode coils are connected by a starting resistor whose resistance is preselected according to the re-

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sistances of the electrode coils of the lamp, the spacing between the electrode coils and the potential at which the lamp is desired to start. The lamp main electrode coils, the starting electrode coils and additional starting resistor or resistors are all connected in series to that when a relatively-low potential is applied across this series circuit, an electric discharge will be established between the auxiliary starting electrode coils. Immediately thereafter, an electric discharge will be established between the main or operating electrode coils of the lamp.

For a better understanding of the invention, reference should be had to the accompanying drawings wherein:

Fig. 1 is an elevational view, partly in section, of a fluorescent lamp constructed in accordance with the instant teachings, including current-limiting ballast resistors;

Fig. 2 is a diagrammatic view of the electrode and self-starting circuitry arrangement for the lamp as shown in Fig. 1, including additional lead conductors which may be provided to treat the lamp electrodes;

Fig. 3 is a sectional view taken on the line III—III in Fig. 1;

Fig. 4 is an alternative embodiment of a portion of the lamp as shown in Fig. 1, wherein the ballast resistance is included as an integral part of the lamp;

Fig. 5 is a diagrammatic view of an alternative embodiment for the self-starting lamp as disclosed in Fig. 2, wherein additional resistor elements are provided between the auxiliary starting electrode coils and the main electrode coils;

Fig. 6 is a diagrammatic view of another embodiment corresponding to Fig. 5, but showing the auxiliary starting electrode coils spaced considerably apart from the main electrode coils;

Fig. 7 is a diagrammatic view of still another embodiment showing the auxiliary starting electrode coils spaced considerably apart from the main electrode coils, but wherein only one series-connected starting resistor is utilized;

Fig. 8 is a diagrammatic view of a further alternative embodiment wherein two pairs of starting electrode coils are utilized, with auxiliary starting resistors included between each of the series-connected electrode coils;

Fig. 9 is a diagrammatic view of another embodiment corresponding to Fig. 8, but wherein one pair of auxiliary starting electrode coils are placed proximate the operating electrode coils of the lamp, and the auxiliary starting resistors between the proximate starting electrode coils and operating electrode coils are eliminated;

Fig. 10 is a diagrammatic view of yet another embodiment illustrating a "high-loaded" fluorescent lamp wherein two pairs of auxiliary starting electrode coils are positioned near the operating electrode coils of the lamp, with the innermost pair of auxiliary starting electrode coils connected by a starting resistor.

With specific reference to the form of the invention illustrated in the drawings, in Figs. 1, 2 and 3 are shown a self-starting, positive-column, electric-discharge lamp 10 which generally comprises a vitreous, light-transmitting, elongated envelope 12, containing a low pressure of inert, ionizable gas and a small charge of mercury 14, as is usual. The inert ionizable gas may comprise argon at a pressure of four millimeters, for example, and in the case of a twenty-watt lamp having an envelope diameter of one and one-half inches, the mercury charge may be in the order of forty milligrams. Starting gases other than argon may be utilized, as is well known. Also, the starting gas pressure may be varied over wide limits and is not critical. Likewise, the charge of mercury 14 may be varied considerably, as is well known.

A coating of phosphor material 16 is normally coated on the interior surface of the lamp envelope 12, which phosphor material is excitable by the 2537 A.U. radi-

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ations which are generated by the mercury discharge in order to convert these ultraviolet radiations into visible light. Such phosphor materials are well known and as an example, a zinc silicate phosphor may be utilized. If desired, the lamp envelope need not include the phosphor coating and such a construction may be utilized with bactericidal types of lamps which may be provided with an envelope which is transmissive to the 2537 A.U. radiations.

Operatively disposed proximate either end of the envelope 12 are a pair of main electrode coils 18, each of which may be formed a refractory metal such as 1.4 mil tungsten wire, for example, and which coils desirably have the configuration of a coiled-coil, with the turns of each inner coil filled with electron-emissive material such as barium oxide or a mixture of alkaline-earth oxides. Other additive materials may be included with the alkaline-earth oxides, such as a small amount of zirconia, for example. Electron-emissive materials other than the alkaline-earth oxides may be used to activate the electrode coils in order to render them thermionically emissive and such other electron-emissive materials are well known.

As disclosed in Figs. 1 and 2, a pair of thermionic starting electrode coils 20 are connected in series with the main operating electrode coils 18 and are positioned proximate thereto with a spacing therebetween of one inch, for example. This spacing may be increased or decreased, if desired. The starting electrode coils 20 may also be fabricated of a refractory material such as 1.0 mil tungsten wire and desirably are provided with a coiled-coil configuration and, as in the case of the main electrode coils, are activated with electron-emissive material.

Lead-in conductors 22 are sealed through the lamp envelope 12 and are electrically connected to one side of each of the main electrode coils 18 in order to supply electrical power thereto and the starting electrode coils 20 are electrically connected to the other coil sides of the main electrode coils. Connected between the other coil sides of the starting electrode coils 20 is an elongated resistor element 24 which is preferably coiled and under tension in order to facilitate lamp fabrication and in order that the resistor element 24 is always maintained apart from the phosphor coating 16, as shown in Fig. 3. The resistor element 24 may be fabricated of "Nichrome" alloy, such as 15% chromium, 61% nickel and 24% iron, for example. "Nichrome" is a trademark of Driver-Harris Co., Harrison, N.J.

If the lamp main and starting electrode coils 18 and 20 are activated with alkaline-earth-oxide materials, such materials are normally applied to the refractory electrode coils as alkaline-earth carbonates and it is necessary to treat these carbonates with heat in order to break them down to the thermionic oxides. Such electrode-treatment is facilitated by two additional conductors 26 which also serve to support the electrode coils and one each of which additional conductors are connected intermediate each of the starting and main electrode coils. In such electrode treating, a potential may be applied across each of the lead-in conductors 22 and additional conductors 26 in order to treat the main electrode coils 18, and an additional potential may be applied across the additional conductors 26 in order to treat the starting electrode coils 20. Such electrode treating procedures may proceed simultaneously in order to facilitate speed of lamp manufacturing. Alternatively, electrode treating could be accomplished by induction heating.

After electrode treating the envelope is provided with the proper gas fill and mercury charge, the outwardly-extending ends of the additional lead conductors 26 are cut off and base caps 28 are secured to the ends of the lamp envelope 12. In the instant lamps, only one electrical connection is required at each end of the envelope 12 and this is provided by base contacts 30 which are electrically connected to the lead conductors 22. The finished lamps incorporating the alternative embodiments

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shown in diagrammatic form in Figs. 5 through 10 may correspond to the lamp as shown in Fig. 1, with respect to the base connections.

The starting electrode coils 20 are each supported by a lead conductor and insulating bead support, wherein two lead conductors 32 and 34, which support a starting electrode coil 20 between their ends, are retained in spaced relationship by an insulating glass bead 36. One of the lead conductors 34 is supported by one of the additional treating and support conductors 26 and the other lead conductor 32 connects to the starting resistor 24. Other modifications for supporting the starting electrode coils 20 are also possible, but the foregoing support arrangement is quite simple and easily fabricated.

The resistance and the configuration of the starting electrode coils 20 and the main electrode coils 18 are so selected that less current is required to cause the starting coils 20 to become thermionically emissive than the main electrode coils 18. Also, the preselected resistances and configurations of the electrode coils are also dependent upon the voltage which will be utilized to start and operate the lamp and the spacing between the starting electrode coils, as well as the resistance of the starting resistor 24. As a specific example, with a spacing between the starting electrode coils of twenty-four inches, each starting electrode coil 20 may have a hot resistance of 285 ohms (cold resistance 57 ohms), each main electrode coil may have a hot resistance of 50 ohms (cold resistance 10 ohms) and the "Nichrome" alloy starting resistor may have a hot or cold resistance of 900 ohms. Each starting coil may carry 1.2 milligrams of electron-emissive material comprising 56% by weight barium oxide, 13% calcium oxide and 31% strontium oxide and each main coil may carry 5 milligrams of similar electron-emissive material.

The usual fluorescent lamp operates with what is known as a negative-volt-ampere characteristic. That is, the greater the current through the lamp, the lower the resistance of the electric discharge. Without some additional ballasting resistor or reactance, this would result in a runaway discharge which would destroy the lamp. The instant self-starting lamps are no different from the usual fluorescent lamp in this respect, and additional ballasting impedances 38 may be provided in series with one or with both of the lead conductors 22, as shown in Fig. 1. Such ballasting impedances may be provided external to the lamp or they may be built within the lamp base or envelope as shown in Fig. 4 wherein the ballast resistance 38a is contained within an elongated flare tube 39. While in the embodiments as disclosed, the ballasting impedances have taken the form of resistors, suitable reactances could be utilized, as is well known.

In the operation of the lamp as disclosed in Figs. 1 and 2, if 110 volts is applied across the ballast resistors and lamp, a current will flow through the series circuit which is formed by the main electrode coils 18, the starting electrode coils 20 and the starting resistor 24. For the specified embodiment, the ballast resistors 38 may be so selected that the voltage which is applied between the main electrode coils 18 will be approximately 102 volts. This will cause a current of 0.065 ampere to be drawn by the series circuit, with 95.5 volts potential drop occurring across the starting coils and the starting resistor 24. This indicated series current will cause the starting electrode coils 20 to become thermionically emissive and the total potential drop between the starting electrode coils will cause an electric discharge to be established between these starting electrode coils 20. Since the electric discharge which occurs from starting coil to starting coil has a much lower resistance than the resistor element 24 and those portions of the starting coils 20 which are shorted out by the discharge, a heavier current such as 0.25 ampere, for example, will be drawn by the lamp. This increased current will cause the main electrode

coils 18 to become thermionically emissive. In addition, the increased current will cause an increased potential drop across the main electrode coils so that the maximum potential drop between these coils, after the initial discharge between the starting coils 20 has been established, will be about 95 volts, for example. The increased electron emissivity of the main electrode coils 18 and the increased potential drop therebetween will cause an electric discharge to be established between these main electrode coils. The series circuit which was utilized to start the lamp will continue to draw some current, but since the discharge which occurs between the main electrode coils 18 has a much lower resistance than the series circuit included between the hot spot or operating portion of the main electrode coils, the power loss will be relatively small. As an example, for the embodiment as described 91 percent of the total current drawn by the lamp will traverse the discharge path between the main electrode coils 18.

If the path between the auxiliary starting electrode coils 20 is shortened to 16 inches, for example, the components comprising the series circuit utilized to start the lamp are desirably varied somewhat. As an example, for 110 volt operation, the resistance of the starting coils may be such that when a current of 0.065 ampere is drawn by the series circuit during starting, a potential drop of 18.5 volts will occur across these starting coils and a potential drop of 33.6 volts across the shorter starting resistor will be satisfactory to start the lamp. Thus the resistance and configuration of the starting coils and the main electrode coils as well as the resistance and length of the primary resistor element are preselected in accordance with the lamp design and the voltage under which the lamp is designed to start and operate. All of the foregoing are readily determinable for each specific lamp design.

In Fig. 5 is shown an alternative embodiment of the lamp as illustrated in Fig. 2, wherein additional resistor elements 40 are included between each of the auxiliary starting coils 20 and the main coils 18a. In such an embodiment, the starting coils 20 may be proximate the main coils, the spacing between the starting coils may be 24 inches, for example, and the resistors 40, which may be "Nichrome" alloy, may each have a hot or cold resistance of 150 ohms. This enables the main coils 18a to be fabricated from 2.3 mil tungsten wire, for example, with slightly-lower, hot electrical resistance, such as 11.75 ohms. The other components comprising the series circuit may be the same as in the embodiment shown in Fig. 2. Such a construction assists in assuring positive starting throughout the life of the lamp.

In Fig. 6 is illustrated a further embodiment of the lamp as shown in Fig. 2, wherein the starting coils 20 are spaced in predetermined locations within the envelope and are spaced apart from the main coils 18a. Also, the additional resistor elements 40 are included in the series circuit between each of the starting coils 20 and the main coils 18a. The components which comprise the series circuit may be as described for the embodiment as shown in Fig. 5 except that the spacing between each of the starting coils 20 and the nearest operating coil 18a may be eight inches, for example. The starting electrode coils 20 may be supported with a lead conductor and insulating head support, as described previously for the embodiment shown in Fig. 1, and additional insulating members 42, such as glass members, may be used to provide support between the supporting conductors 26 and the supports for the starting electrode coils 20. If desired, the additional starting resistors 40 may be wrapped around the insulating support members 42 in order to facilitate fabrication. While other supporting arrangements for the starting electrode coils 20 and starting resistor 24 may be utilized, the foregoing arrangement has been found to be very satisfactory.

In the embodiment as shown in Fig. 7, the additional

starting resistors 40 have been eliminated and the voltage drop which occurs across the main electrode coils 18b, after the electric discharge has been established between the starting electrode coils 20, is sufficient to cause the discharge to be established between the main electrode coils 18b. In such an embodiment, the main electrode coils 18b may be fabricated of 1.4 mil tungsten wire, for example, with a hot electrical resistance of 70 ohms and the starting electrode coils 20 as well as the starting resistor 24 may be as described in the embodiment shown in Fig. 2. The spacing between the starting electrode coils 20 may be twenty-four inches and the spacing between each of the starting electrode coils 20 and the nearest main electrode coil 18b may be eight inches, for example.

In Fig. 8 is shown another embodiment which enables a still-longer lamp to be started with a much-lower voltage than is normally required to start a lamp of such length dimensions. In this embodiment, the two centrally-disposed primary starting electrode coils 20 may have a spacing therebetween of twenty-seven inches and these primary starting electrode coils may be as described in the embodiment shown in Fig. 2. The first starting resistor 24a may be fabricated of "Nichrome" alloy with a resistance of 1864 ohms. The series circuit, which includes the starting electrode coils 20 and first starting resistor 24a, also includes two secondary starting electrode coils 44. These are positioned within the envelope in predetermined locations intermediate the main operating coils 18c and the primary pair of starting electrode coils 20 and each may be fabricated of 2.3 mil tungsten wire with a hot resistance of 11 ohms and a cold resistance of 2.2 ohms. The main operating coils 18c may be fabricated of 5.0 mil tungsten wire with a hot resistance of three ohms, for example, and are desirably positioned proximate either end of the envelope. Connecting the primary starting coils 20 and the secondary starting coils 44 are second resistor elements 46, each of which may be fabricated of "Nichrome" alloy, for example, and may have a hot or cold resistance of 67 ohms. Connecting the secondary starting coils 44 and the operating coils 18c are third resistor elements 48, each of which may be fabricated of "Nichrome" alloy, for example, with a hot or cold resistance of 27 ohms. Such a lamp also includes a ballasting resistor arrangement (not shown), as in the embodiment illustrated in Figs. 2 or 4, although because of the increased current such a lamp will draw, the total ballasting resistance need only be 60 ohms, for example. As noted, the primary starting coils may be spaced twenty-seven inches apart and each of the secondary and operating coils may be positioned ten and twenty inches, respectively, from the nearest primary starting coil 20 to form a 72T12-type lamp.

The resistance and configuration of the primary and secondary starting coils 20 and 44 and the operating coils 18c is so selected that less current is required to cause the secondary starting coils 44 to become thermionically emissive than the operating coils 18c and more current is required to cause the secondary starting coils 44 to become thermionically emissive than the primary starting coils 20. The resistance of the primary or first resistor element 24a and that of the second and third resistor elements 46 and 48 is preselected according to the resistance of the electrode coils within the lamp and the spacing between these electrode coils, with the resistance of each of the second resistor elements 46 being less than the resistance of the first resistor element 24a and greater than the resistance of each of the third resistor elements 48. Of course the various configurations and resistances of each of the elements comprising the series circuit formed by the current lead-ins, resistance elements and electrode coils may be varied considerably depending upon the lamp design.

In the operation of the lamp embodiment as shown in Fig. 8, when a potential such as 176 volts, for example,

is applied across the ballast and series-starting circuit, the series circuit draws a current of .065 ampere, for example, which causes the primary starting coils 20 to become thermionically emissive. This, when coupled with the potential drop between the primary starting coils 20, causes an electric discharge to be established therebetween. Since the resistance of the electric discharge formed between these primary starting coils 20 is considerably less than the resistance of the paralleling starting resistor 24a and the portions of the primary starting coils which are shorted out by the discharge, an increased current will be drawn by the lamp and this will increase the potential drop across the second starting resistors 46 and will also increase the potential drop between the secondary starting coils 44. This in turn will cause an electric discharge to be established between the secondary starting coils 44 which will in turn increase the current through the main operating electrode coils 18c and third resistor elements 48. This increased current will cause the main operating electrodes 18c to become thermionically emissive and the increased potential drop between the operating electrode coils 18c will cause an electric discharge to be established therebetween. With such an arrangement, a lamp having a length of 72 inches, for example, may readily be started and operated with 176 volts. This is to be contrasted with the 525 volts usually required to start such a lamp or with the 250 volts required if external preheat is provided.

If desired, the third resistor elements 48 may be eliminated from the circuit and the secondary starting coils 44 may be placed proximate the operating coils 18d as shown in Fig. 9. In such an embodiment, all of the corresponding components may be the same as for the embodiment shown in Fig. 8, except that the first starting resistor 24 may be as described for the embodiment as shown in Fig. 2 and the main operating coils 18d may each be fabricated from 5.0 mil tungsten wire with a hot electrical resistance of 12 ohms, for example, and a total distance therebetween of 47 inches.

In the usual fluorescent lamp, the current drawn by the lamp, which represents the lamp loading, is relatively small so that the mercury discharge will operate with a maximum of efficiency in generating 2537 A.U. radiations. As an example, the usual 40 watt T12-type of lamp draws a current of about 0.430 ampere. In some types of fluorescent lamps, the ballast impedance is decreased so that the lamp will draw a much-heavier current in order that the power consumption of the lamp is increased to increase the light output. Such lamps may be termed "high-loaded" fluorescent lamps. With such high-loaded fluorescent lamps, the mercury-vapor pressure may be controlled by special envelope configurations or by the provision of cool ends within the envelope so that the efficiency of the discharge is not decreased appreciably by the increased loading. The operating electrode coils for such highloaded fluorescent lamps necessarily have a relatively small resistance. Thus where the instant self-starting designs are utilized with high-loaded fluorescent lamps, the current drawn by the series starting circuit and the current drawn by the lamp after the initial discharge between the primary starting electrode coils has been established may not be sufficient to cause the operating electrode coils of the lamp to become sufficiently thermionically emissive to establish the operating discharge therebetween.

In Fig. 10 is shown an embodiment wherein a high-loaded fluorescent lamp has been adapted for self-starting in accordance with the instant teachings, which lamp is designed to operate with a low-impedance choke ballast. In the embodiment as illustrated, heat-reflector shields 50 are provided at either end of the lamp envelope 12 in order to make the lamp-envelope ends operate relatively cool to limit the mercury-vapor pressure in order to maintain an efficient discharge. Such designs are well known. The operating electrode coils 18e are spaced

interiorly of and proximate the heat-reflector shields 50 and each may comprise a 5.0 mil wire tungsten coiled-coil or triple-wound coil, for example, coated with 20 milligrams of alkaline-earth, electron-emissive material as specified hereinbefore. Positioned interiorly of the operating electrode coils 18e are a pair of primary starting electrode coils 20 connected by a starting resistor 24. The construction and spacing for these primary starting electrode coils 20 and starting resistor 24 may be as described for the embodiment shown in Fig. 2. As noted, the operating electrode coils 18e for this high-loaded fluorescent lamp are designed to carry heavy currents and each may have a hot resistance of 18 ohms and a cold resistance of 3.6 ohms. In such an embodiment, the current drawn by the lamp after the discharge has been initiated between the primary starting electrode coils 20 will be relatively small, such as 0.360 ampere, and this may be insufficient to cause the operating electrode coils 18e to become sufficiently thermionically emissive to enable the main discharge to be established. In order to enable such a high-loaded fluorescent lamp to be started with the instant design, it is desirable to include a secondary pair of starting electrode coils 44a between the operating electrode coils 18e and primary starting electrode coils 20. Such secondary pair of starting electrode coils may each be formed of 2.3 mil tungsten wire with a coiled-coil configuration and be coated with alkaline-earth oxides as specified hereinbefore. The hot resistance of each of these electrode coils 44a may be 50 ohms and the cold resistance may be 10 ohms. The current lead-ins 22, the operating electrode coils 18e, starting electrode coils 20 and 44a and starting resistor 24 are all connected to form a series circuit as in the previous embodiments. As a specific example, the spacing between the primary starting electrode coils 20 may be twenty-four inches, the spacing between each of the operating electrode coils 18e and the nearest primary starting electrode coil 20 may be eight inches and each of the secondary starting electrode coils 44a may be positioned intermediate therebetween. In the operation of this embodiment, when the starting potential such as 105 volts is applied across the lamp, a discharge will be initiated between the primary starting electrode coils 20 which will cause the lamp to draw a current of 0.360 ampere. Immediately thereafter, the discharge will be initiated between the secondary starting electrode coils 44a which will cause the lamp to draw a current of 1.0 ampere. Immediately thereafter, the discharge will be established between the operating electrode coils 18e which will cause the lamp to draw a current of 1.3 amperes, for example. The instant starting design operates very efficiently with such a lamp design as shown in Fig. 10, since the series circuit which is formed by electrode coils and starting-resistor arrangement has a much higher resistance than the main discharge. As an example, for the embodiment described in Fig. 10, 96 percent of the total current drawn by the lamp will traverse the discharge path between the operating electrode coils and will be effective in generating ultraviolet radiations. The so-called "high-loaded" fluorescent lamps operate on a relatively low voltage because of the comparatively heavy current which such lamps draw. However, the initial operating voltage, before the lamp has fully warmed up, is relatively high and for the specific example described may be 95 volts. In the instant design, the lamp starting voltage will be only slightly greater than the initial lamp-operating voltage. It should be noted that electrode treating for the embodiments as shown in Figs. 8 through 10 may be accomplished by induction heating, for example.

In the operation of the embodiments shown in Figs. 8 through 10, the initial discharge is established between the primary starting electrode coils and thereafter progresses to the operating electrode coils via the secondary starting electrode coils. These progressive discharges

which occur during lamp starting progress very rapidly and the main discharge is established almost immediately upon application of the potential across the lamp.

Still-further embodiments are possible. For example, the third resistor elements 48 as shown in Fig. 8 could be included between the secondary starting electrode coils 44 when such coils are positioned proximate the operating electrode coils, as shown in Fig. 9. Also, it may be desirable to provide additional support members for the components comprising the series starting circuit for the embodiments as shown in Figs. 8 through 10, although an insulating-bead-support arrangement as shown in Fig. 1 may be used.

It will be recognized that the objects of the invention have been achieved by providing a self-starting fluorescent lamp which will immediately start on line voltage without the use of auxiliary voltage-boosting equipment. In addition there have been provided self-starting fluorescent lamps which will immediately start with considerably less than the usual starting voltage required and which will immediately start with an applied voltage only slightly greater than the initial lamp-operating voltage. Also, there have been provided various alternative embodiments for such self-starting fluorescent lamps.

While best-known embodiments have been illustrated and described in detail, it is to be particularly understood that the invention is not limited thereto or thereby.

We claim:

1. A self-starting, positive-column, electric-discharge device comprising: a light-transmitting, elongated envelope containing a low pressure of inert, ionizable gas and a small charge of mercury; a pair of thermionic main electrode coils, activated with electron-emissive material, operatively disposed proximate either end of said envelope; lead-in conductors sealed through said envelope and connecting to said main electrode coils; a pair of thermionic starting electrode coils, activated with electron-emissive material, spaced apart a predetermined distance and positioned in predetermined locations within said envelope; the resistance and configuration of said starting coils and said main electrode coils being so selected that less current is required to cause said starting coils to become thermionically emissive than said main electrode coils; a primary nonthermionic resistor element within said envelope and connecting said starting coils; additional nonthermionic resistor elements within said envelope and connecting said starting coils and said main electrode coils; the resistance of said primary resistor element and said additional resistor elements being preselected according to the resistance of said electrode coils and the spacing between said starting electrode coils, with said primary resistor element having a substantially higher resistance than either of said additional resistor elements; a series circuit formed by said lead-in conductors, said starting coils, said main coils and said connecting resistor elements; upon application of a predetermined potential across said lead conductors, said starting coils becoming thermionically emissive with the potential drop across said starting coils and said primary resistor element causing an electric discharge to be established between said starting coils resulting in an increased current through said main electrode coils and said additional resistor elements, the resulting increased current through said main electrode coils causing same to become thermionically emissive with the increased potential drop across said main electrode coils and said additional resistor elements causing an electric discharge to be established between said main electrode coils.

2. A self-starting, positive-column, electric discharge device comprising: a light-transmitting, elongated envelope containing a low pressure of inert, ionizable gas and a small charge of mercury; a pair of thermionic main electrode coils, activated with electron-emissive material, operatively disposed proximate either end of said envelope; lead-in conductors sealed through said envelope

and connecting to said main electrode coils; a pair of thermionic starting electrode coils, activated with electron-emissive material, spaced apart a predetermined distance intermediate said main electrode coils and positioned in predetermined locations within said envelope; the resistance and configuration of said starting coils and said main electrode coils being so selected that less current is required to cause said starting coils to become thermionically emissive than said main electrode coils; a primary nonthermionic resistor element within said envelope and connecting said starting coils; additional nonthermionic resistor elements within said envelope and connecting said starting coils and said main electrode coils; the resistance of said primary resistor element and said additional resistor elements being preselected according to the resistance of said electrode coils and the spacing between said starting electrode coils, with said primary resistor element having a substantially higher resistance than either of said additional resistor elements; a series circuit formed by said lead-in conductors, said starting coils, said main coils and said connecting resistor elements; upon application of a predetermined potential across said lead conductors, said starting coils becoming thermionically emissive with the potential drop across said starting coils and said primary resistor element causing an electric discharge to be established between said starting coils resulting in an increased current through said main electrode coils and said additional resistor elements, the resulting increased current through said main electrode coils causing same to become thermionically emissive with the increased potential drop across said main electrode coils and said additional resistor elements causing an electric discharge to be established between said main electrode coils.

3. A self-starting, positive-column, electric-discharge device comprising: a light-transmitting, elongated envelope containing a low pressure of inert, ionizable gas and a small charge of mercury; a pair of thermionic main electrode coils, activated with electron-emissive material, operatively disposed proximate either end of said envelope; lead-in conductors sealed through said envelope and connecting to said main electrode coils; a pair of thermionic starting electrode coils, activated with electron-emissive material, spaced apart a predetermined distance within said envelope and positioned proximate said main electrode coils; the resistance and configuration of said starting coils and said main electrode coils being so selected that less current is required to cause said starting coils to become thermionically emissive than said main electrode coils; a primary nonthermionic resistor element within said envelope and connecting said starting coils; the resistance of said primary resistor element being preselected according to the resistance of said electrode coils and the spacing between said starting electrode coils; a series circuit formed by said lead-in conductors, said starting coils, said main coils and said connecting resistor element; upon application of a predetermined potential across said lead conductors, said starting coils becoming thermionically emissive with the potential drop across said starting coils and said primary resistor element causing an electric discharge to be established between said starting coils resulting in an increased current through said main electrode coils, the resulting increased current through said main electrode coils causing same to become thermionically emissive with the increased potential drop therebetween causing an electric discharge to be established between said main electrode coils.

4. A self-starting, positive-column, electric-discharge device comprising: a light-transmitting, elongated envelope containing a low pressure of inert, ionizable gas and a small charge of mercury; a pair of thermionic main electrode coils, activated with electron-emissive material, operatively disposed proximate either end of said envelope; lead-in conductors sealed through said envelope

and connecting to said main electrode coils; a pair of thermionic starting electrode coils, activated with electron-emissive material, spaced apart a predetermined distance and positioned in predetermined locations within said envelope; the resistance and configuration of said starting coils and said main electrode coils being so selected that less current is required to cause said starting coils to become thermionically emissive than said main electrode coils; a primary nonthermionic resistor element within said envelope and connecting said starting coils; the resistance of said primary resistor element being preselected according to the resistance of said electrode coils and the spacing between said starting electrode coils; a series circuit formed by said lead-in conductors, said starting coils, said main coils and said connecting resistor element; additional electrode treating lead-in conductors sealed through said envelope and respectively electrically connected between said main electrode coils and said starting coils; upon application of a predetermined potential across said lead conductors, said starting coils becoming thermionically emissive with the potential drop across said starting coils and said primary resistor element causing an electric discharge to be established between said starting coils resulting in an increased current through said main electrode coils, the resulting increased current through said main electrode coils causing same to become thermionically emissive with the increased potential drop therebetween causing an electric discharge to be established between said main electrode coils.

5. A self-starting, positive column, electric-discharge device comprising: a light-transmitting, elongated envelope containing a low pressure of inert, ionizable gas and a small charge of mercury; a pair of thermionic operating electrode coils, activated with electron-emissive material, operatively disposed proximate either end of said envelope; lead-in conductors sealed through said envelope and electrically connecting to said operating coils; a primary pair of starting electrode coils, activated with electron-emissive material, positioned within said envelope in predetermined locations intermediate said operating coils and spaced apart from one another a predetermined distance; a secondary pair of starting electrode coils, activated with electron-emission material, respectively spaced in predetermined locations on either side of and further apart than said primary starting coils; the resistance and configuration of said primary and said secondary starting coils and said operating coils being so selected that less current is required to cause said secondary starting coils to become thermionically emissive than said operating coils and more current is required to cause said secondary starting coils to become thermionically emissive than said primary starting coils; a first nonthermionic resistor element within said envelope and connecting said primary starting coils; second nonthermionic resistor elements within said envelope and connecting said primary starting coils and said secondary starting coils; third nonthermionic resistor elements within said envelope and connecting said secondary starting coils and said operating coils; the resistance of said first resistor element and said second and third resistor elements being preselected according to the resistance of said electrode coils and the spacing between said electrode coils, with the resistance of each of said second resistor elements being less than the resistance of said first resistor element and greater than the resistance of each of said third resistor elements; a series circuit formed by said current lead-ins and said electrode coils and the resistor elements connecting therebetween; upon application of a preselected potential across said current lead-ins, said primary starting coils becoming thermionically emissive with the potential drop across said primary starting coils and said first resistor element causing an electric discharge to be established between said primary starting coils resulting in an increased current through said secondary starting coils and said second resistor elements, the resulting in-

creased current through said secondary starting coils causing same to become thermionically emissive with the increased potential drop across said secondary starting coils and said second resistor elements causing an electric discharge to be established between said secondary starting coils to increase the current through said operating coils and said third resistor elements, the increased current through said operating coils causing same to become thermionically emissive with the increased potential drop across said operating coils and said third resistor elements causing an electric discharge to be established between said operating coils.

6. A self-starting, positive column, electric-discharge device comprising: a light-transmitting, elongated envelope containing a low pressure of inert, ionizable gas and a small charge of mercury; a pair of thermionic operating electrode coils, activated with electron-emissive material, operatively disposed proximate either end of said envelope; lead-in conductors sealed through said envelope and electrically connecting to said operating coils; a primary pair of starting electrode coils, activated with electron-emissive material, positioned within said envelope in predetermined locations intermediate said operating coils and spaced apart from one another a predetermined distance; a secondary pair of starting electrode coils, activated with electron-emissive material, respectively spaced in predetermined locations on either side of and further apart than said primary starting coils; the resistance and configuration of said primary and said secondary starting coils and said operating coils being so selected that less current is required to cause said secondary starting coils to become thermionically emissive than said operating coils and more current is required to cause said secondary starting coils to become thermionically emissive than said primary starting coils; a first nonthermionic resistor element within said envelope and connecting said primary starting coils; second nonthermionic resistor elements within said envelope and connecting said primary starting coils and said secondary starting coils; the resistance of said first resistor element and said second resistor elements being preselected according to the resistance of said electrode coils and the spacing between said starting electrode coils, with the resistance of each of said second resistor elements being less than the resistance of said first resistor element; a series circuit formed by said current lead-ins and said electrode coils and the resistor elements connecting therebetween; upon application of a preselected potential across said current lead-ins, said primary starting coils becoming thermionically emissive with the potential drop across said primary starting coils and said first resistor element causing an electric discharge to be established between said primary starting coils resulting in an increased current through said secondary starting coils and said second resistor elements, the resulting increased current through said secondary starting coils causing same to become thermionically emissive with the increased potential drop across said secondary starting coils and said second resistor elements causing an electric discharge to be established between said secondary starting coils to increase the current through said operating coils, the increased current through said operating coils causing same to become thermionically emissive with the increased potential drop therebetween causing an electric discharge to be established between said operating coils.

7. A self-starting, positive column, electric-discharge device comprising: a light-transmitting, elongated envelope containing a low pressure of inert, ionizable gas and a small charge of mercury; a pair of thermionic operating electrode coils, activated with electron-emissive material, operatively disposed proximate either end of said envelope; lead-in conductors sealed through said envelope and electrically connecting to said operating coils; a primary pair of starting electrode coils, activated with electron-emissive material, positioned within said en-

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velope in predetermined locations intermediate said operating coils and spaced apart from one another a predetermined distance; a secondary pair of starting electrode coils, activated with electron-emission material, respectively spaced in predetermined locations on either side of and further apart than said primary starting coils; the resistance and configuration of said primary and said secondary starting coils and said operating coils being so selected that less current is required to cause said secondary starting coils to become thermionically emissive than said operating coils and more current is required to cause said secondary starting coils to become thermionically emissive than said primary starting coils; a first nonthermionic resistor element connecting said primary starting coils; the resistance of said first resistor element being preselected according to the resistance of said electrode coils and the spacing between said primary starting electrode coils; a series circuit formed by said current lead-ins and said electrode coils and the resistor element connecting between said primary starting coils; upon application of a preselected potential across said current lead-ins, said primary starting coils becoming thermionically emissive with the potential drop across said primary starting coils and said first resistor element causing an electric discharge to be established between

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said primary starting coils resulting in an increased current through said secondary starting coils, the resulting increased current through said secondary starting coils causing same to become thermionically emissive with the increased potential drop therebetween causing an electric discharge to be established between said secondary starting coils to increase the current through said operating coils, the increased current through said operating coils causing same to become thermionically emissive with the increased potential drop therebetween causing an electric discharge to be established between said operating coils.

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