Dec. 8, 1959 T. C. RETZER ET AL 2,916,669

STARTING CIRCUIT FOR GASEOUS DISCHARGE LAMPS

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FIG. 1.

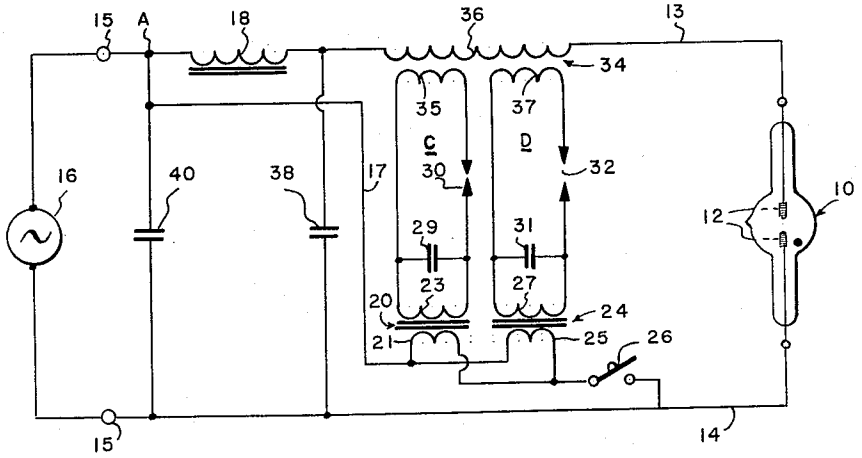


FIG. 2.

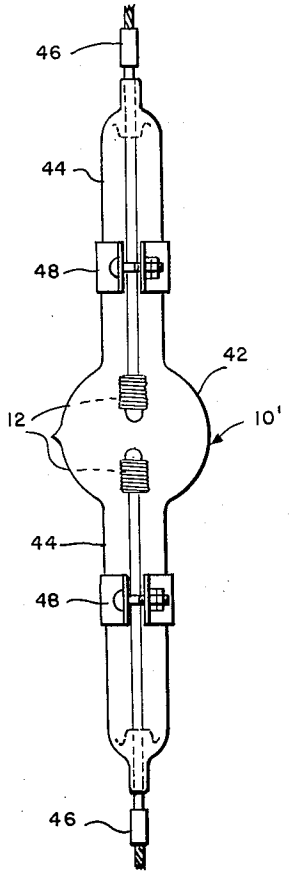
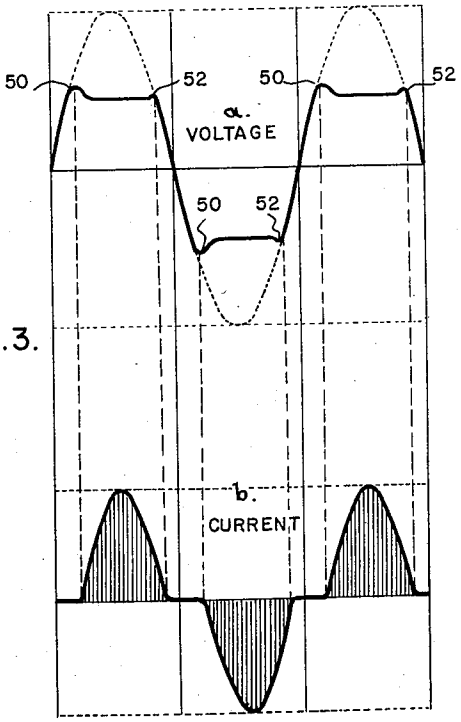


FIG. 3.



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FIG. 4.

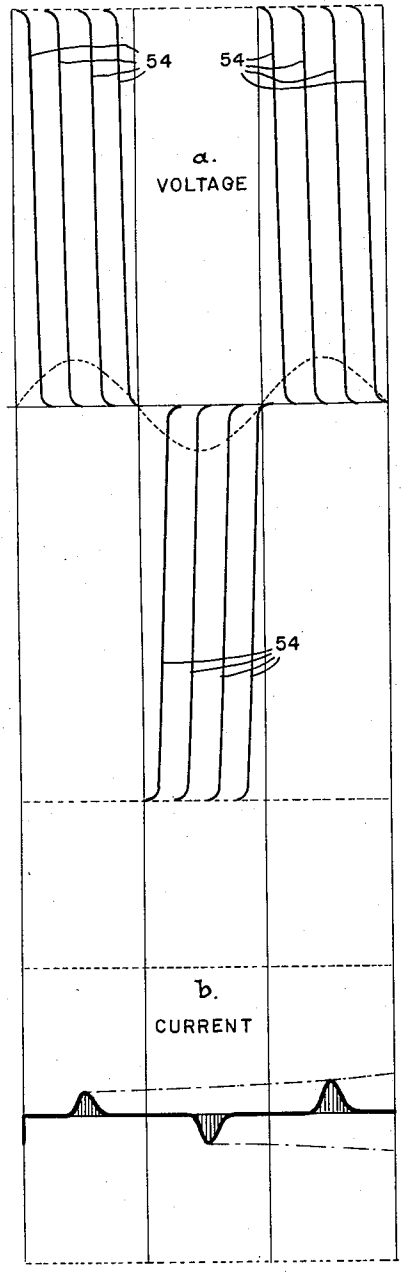
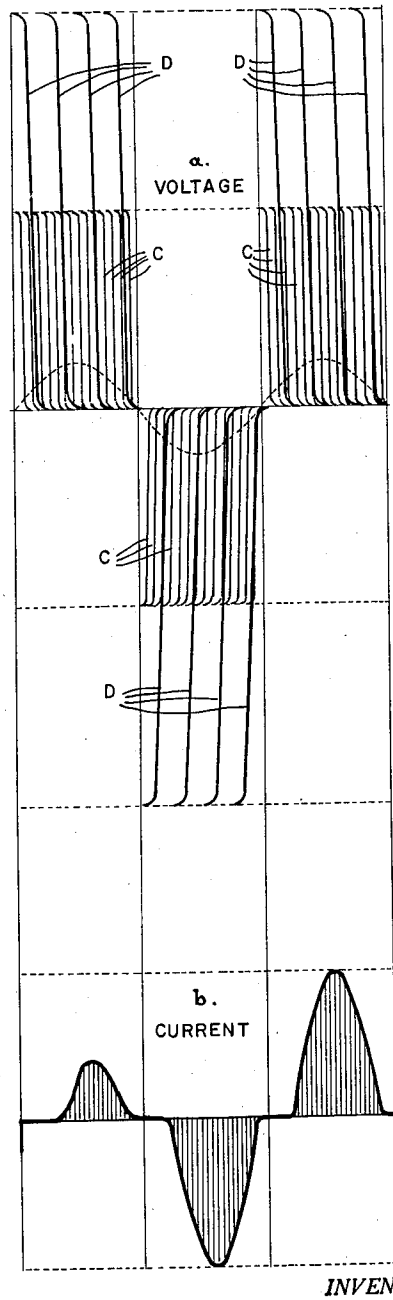


FIG. 5.



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United States Patent Office 2,916,669 Patented Dec. 8, 1959

2,916,669

STARTING CIRCUIT FOR GASEOUS DISCHARGE LAMPS

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Application June 6, 1958, Serial No. 740,274

10 Claims. (Cl. 315—183)

This invention relates to gaseous discharge devices and, more particularly, to a circuit for starting a high intensity gaseous discharge lamp of the so-called "short-arc" type.

As is well known, high intensity short-arc lamps require a higher potential and current during starting than when the lamp has been ignited and the arc discharge stabilized or rendered self-maintaining. This is particularly true if one attempts to restart a lamp while it is still hot or if the fill pressure of the "cold" lamp is around one atmosphere or more as in the case of the mercury-xenon and xenon type short-arc lamps now being marketed. The reason for this requirement is that the voltage applied to the lamp during the starting cycle must be at least equivalent to the sparking potential of the gas at the particular pressure involved before a gaseous discharge can be initiated between the electrodes. After this condition has been reached sufficient starting current must then flow through the lamp to rapidly heat the electrodes, which are relatively massive, to electron-emitting temperature in order that the arc voltage of the discharge may be reduced to a value such that said discharge will be maintained by the voltage applied to the lamp from the supply line on which the lamp is normally operated.

Heretofore, lamps of this character were started by applying a series of extremely high voltage pulses (approximately 30 kv. to 50 kv.) to the lamp during the starting cycle from a suitable oscillatory circuit, as disclosed in U.S. Patent Nos. 2,708,251 and 2,727,188 to C. M. Rively and U.S. Patent No. 2,825,005 to L. F. Bird. While the single oscillatory loop type of high voltage pulse starting system described in the above-mentioned patents have proven quite satisfactory for starting mercury short-arc lamps when they are cold, that is, at room temperature, investigation has shown that in order to reliably "hot start" such lamps, especially those containing xenon, a larger number of high voltage pulses per half cycle of the applied line voltage are required. Since the number of pulses which can be generated by a spark-gap oscillatory circuit decreases as the gap spacing and magnitude of the pulses increase, the adjustment of the spark-gap under "hot starting" conditions becomes very critical and even when properly set may not provide the necessary number of pulses of the desired magnitude if the other components in the starting circuit are not held within close manufacturing tolerances. In addition, it has been found that with repeated use the spark-gap terminals become oxidized thus changing the gap spacing and necessitating frequent cleaning and resetting of the electrodes to assure optimum "hot starting" conditions.

It is accordingly the general object of the present invention to provide an improved starting circuit for gaseous discharge lamps which contain an ionizable medium and require a higher starting voltage than operating voltage.

Another and more specific object of this invention is the provision of a high voltage pulse type circuit for starting a high pressure short-arc lamp which will reliably start

such a lamp under either hot or cold starting conditions and require a minimum of adjustment and maintenance during use.

For a better understanding of the invention and the manner in which the aforesaid objects, and others which will become apparent to those skilled in the art to which the invention pertains as the description proceeds, reference should be had to the accompanying drawings wherein:

Fig. 1 is a schematic illustration of a starting circuit embodying this invention;

Fig. 2 is a side elevational view of a high-wattage short-arc lamp of double-ended construction which characterizes the type of lamp for which the circuit of this invention is especially adapted;

Fig. 3 is a graphic representation of the normal operating voltage and current waveforms for a short-arc lamp of the type shown in Fig. 2; and

Figs. 4 and 5 are graphic representations of typical voltage and line current waveforms illustrating the starting characteristics of a single oscillatory loop type starting circuit used heretofore and the multiple loop type circuit of this invention, respectively, both of which have been tuned to provide the same number of pulses in the extremely high voltage range.

Although the principles of this invention are broadly applicable to various types of gaseous discharge devices which require a higher starting potential and current than are required to normally operate the device once the arc has been initiated and stabilized, especially those devices which can only be ignited by the application of a series of high voltage pulses of predetermined magnitude and frequency during the starting cycle, the invention is particularly adapted for use with high pressure short-arc lamps and hence has been so illustrated and will be so described.

With specific reference to the form of the invention illustrated in Fig. 1 of the drawings, a lamp **10** of the well-known short-arc type containing an ionizable medium, such as argon or xenon and a measured amount of mercury, and having a pair of electrodes **12**, at least one of which is thermionic emitting, is connected to a source of alternating voltage **16** by means of terminals **15**, and conductors **13** and **14**. Connected in series with the lamp **10** is a suitable current limiting device such as an inductive ballast **18**, as here shown, or a resistor adapted to maintain the current passing through said lamp within safe limits during starting and after the lamp has been lighted and is being normally operated directly from the voltage source **16**. The secondary **36** of a pulse transformer **34** is connected in series between the ballast **18** and the lamp **10** thereby providing in conjunction with the voltage source **16** a series circuit for operating said lamp after it has been lighted. The pulse transformer **34** has two primary windings **35** and **37** which are electrically separate from each other and in conjunction with electric discharge devices **30** and **32** (here shown as spark-gaps) and the secondary windings **23** and **27** of two iron-core step-up transformers **20** and **24**, respectively, constitute two separate and independently adjustable oscillatory loop circuits C and D. One end of the step-up transformer primaries **21** and **25** are connected by means of a lead **17** to the conductor **13** on either the line side of the ballast **18** as at point A as shown in Fig. 1, or between said ballast and the secondary **36** of the pulse transformer **34**. Connection to point A is preferred since the step-up transformers **20** and **24** will then be connected directly across the voltage source **16**, as will be hereinafter described, and will accordingly have full line voltage applied thereto at all times even when lamp current begins to flow and there is a voltage drop across the ballast **18**.

While the step-up voltage converting means has been here illustrated as comprising two separate transformers **20** and **24**, it will be obvious that a single transformer having two electrically isolated secondaries and a common primary and core may also be utilized but since this would require a specially designed transformer to insure proper balancing of the voltage on the primary and would accordingly increase the cost of the starting circuit, it is not preferred.

The other ends of the step-up transformer primaries **21** and **25** are connected to one side of a switch **26**, preferably a push-button switch, which is normally open and is in turn connected to the conductor **14** thereby providing means for connecting said primaries across the voltage source **16**. The conversion or turns ratio of the step-up transformers **20** and **24** are selected to transform the line voltage to a predetermined value, such as 7500 volts for example, so that a sufficiently high voltage is applied to the electric discharge devices **30** and **32** and to the capacitors **29** and **31** connected across the step-up transformer secondaries **23** and **27**, respectively, to enable the aforesaid oscillating circuits C and D to generate a series of voltage pulses when the switch **26** is closed and said step-up transformers are energized. Thus, means are provided for separately generating two series of voltage pulses of predetermined magnitude and frequency and then applying such pulses by means of the pulse transformer **34** to the lamp **10** along with the potential developed across said lamp by the voltage source **16**. In order to prevent the high voltage pulses from feeding back into the supply line by-pass capacitors **38** and **40** are connected to the conductors **13** and **14** on the lamp side of the ballast **18** between said ballast and the secondary **36**, and on the line side of said ballast (as for example at point A as shown in Fig. 1) respectively, so as to shunt the voltage source **16**. If the step-up transformer primaries **21** and **25** are connected to the lamp energizing circuit at a point between the ballast **18** and secondary **36** then the second by-pass capacitor **40** can, of course, be eliminated.

While only two oscillatory loop circuits C and D have been shown it will be obvious that any desired number can be employed by merely increasing the number of step-up transformer secondaries and, in like manner, the number of primaries on the pulse transformer. Similarly, while the capacitors **29** and **31** as here shown are connected in parallel with the step-up transformer secondaries **23** and **27**, and the spark-gaps **30** and **32** in series with said secondaries and the pulse transformer primaries **35** and **37**, the electrical disposition of said capacitors and spark-gaps may be interchanged without materially changing the mode of operation of the oscillatory loop circuits as is well known in the art. Moreover, since the starting circuit in order to function merely requires a source of alternating current to energize the step-up transformers **20** and **24** it is in this sense independent from the series operating circuit which energizes the lamp after the latter has been ignited and is operating normally. Thus, the starting circuit of this invention may also be employed to start lamps which are normally operated from a D.C. power source by either incorporating in the starting circuit means to temporarily convert the D.C. voltage to an A.C. voltage, such as a vibrator for example, or by providing a separate A.C. voltage source for energizing the step-up transformers **20** and **24** during the starting cycle.

The starting circuit of this invention is particularly adapted for use in conjunction with a high pressure short-arc lamp of the double-ended construction type such as the lamp **10'** illustrated in Fig. 2. As is well known, lamps of this character comprise briefly an envelope **42** of quartz or the like having two oppositely-disposed stems or arms **44** through which are sealed suitable lead-in assemblies each having an electrode **12** and an outer terminal **46** attached to their inner and outer ends respectively. Affixed to the arms **44** are mounting collars **48** for securely and accurately orienting the lamp **10'** in its position of use.

As shown by the typical voltage and current waveforms illustrated in Figs. 3*a* and 3*b*, respectively, of a normally operating short-arc lamp such as that shown in Fig. 2, lamp current can only flow during each half cycle of the applied line voltage when the latter reaches and exceeds a value equal to the re-ignition voltage **50** of the discharge. When this point on the leading portion of the half cycle is reached current starts to flow through the lamp and continues to flow until the line voltage reaches the extinguishing point **52** during the latter part of the half cycle at which time the line voltage falls below the arc voltage and the current through the lamp stops. As shown, this is repeated every half cycle of the applied line voltage during normal operation so that the lamp current is somewhat pulsating in character, as illustrated in Fig. 3*b*, rather than perfectly sinusoidal as is the applied voltage, which voltage is indicated by the dotted line in Fig. 3*a*. Thus, line current can only flow through the lamp **10** or **10'** during that portion of each half cycle when the applied line voltage is equal to or greater than the re-ignition and extinction voltages for the particular lamp and fill pressures involved.

It has been found that high-pressure mercury-xenon or xenon short-arc lamps of double-ended construction can be "cold started" within 3 seconds with from 5 to 10 pulses of approximately 12,000 volts per half cycle of applied line voltage, while lamps of the same construction but employing mercury alone as the ionizable medium can be started with from 5 to 10 pulses of approximately 1,000 volts per half cycle. However, under the most adverse or "hot" starting condition, that is, when the lamp stops operating due to a power interruption and the lamp electrodes have cooled to a temperature well below their electron-emitting temperature whereas the lamp proper is still hot and near operating temperature and pressure, reliable starting can best be achieved with from 10 to 20 pulses of 50,000 volts (50 kv.) per half cycle.

With the single loop type high-voltage pulse starting system generally used heretofore only one series of pulses of a particular magnitude and frequency of occurrence can be obtained. While a sufficient number of pulses may readily be obtained with this type of circuit to "cold start" any of the aforementioned type lamps, it has proven very difficult and frequently impossible due to the criticality of the spark-gap spacing and mismatching of the circuit components to obtain the aforesaid 10 to 20 pulses of 50 kv. magnitude required to reliably "hot start" xenon or xenon-mercury type short-arc lamps. In most instances, the gap-spacing required to produce a voltage pulse of this magnitude with standard type pulse starters now in use is so great that only about 3 or 4 such pulses **54** per half cycle of the applied line voltage can be obtained under practical operating conidtions (see Fig. 4*a*). Thus, with this number of pulses only two or possibly three would occur during that portion (see Fig. 3) of each half cycle of applied line voltage when line current could flow, as will be observed in Fig. 4*a*. The applied line voltage is indicated by the dotted line in the drawing and, as will be obvious, has been greatly exaggerated for the purpose of illustration. In reality, the high voltage pulses **54** are many times greater in magnitude than the applied line voltage and are superimposed thereon rather than blended therewith as here shown. However, since only a very small number of such pulses occur at the right time of each half cycle, only a very small amount of line current will flow through the lamp during the first half cycle of applied voltage, the amount of current gradually increasing with succeeding half cycles as shown in Fig. 4*b*. The build up of the line

current during the starting cycle with this number of high voltage pulses is accordingly very slow, as indicated by the slope of the broken line in Fig. 4*b*. While the lamp would probably eventually start under these conditions, it is well known that if the high starting voltage is applied to the lamp for too long a period excessive electrode material will be sputtered off and deposited on the bulb walls resulting in early blackening and prematurely shortening the useful life of the lamp. It is, accordingly, necessary that the lamp start within a predetermined period of time after the starting circuit has been energized, three seconds being the generally accepted figure to insure optimum lamp life.

In contrast, it will be observed in Fig. 5*a* that by properly selecting the various components and adjusting the spark gaps of the oscillatory loop circuits C and D a corresponding number (four as in the case above-described) of 50 kv. pulses (pulses D in Fig. 5*a*) as was practically attainable heretofore may be provided and combined with a much greater number of pulses of small magnitude (pulses C in Fig. 5*a*), as for example fourteen pulses of approximately 20 kv. Thus, the gas between the electrodes **12** is periodically broken down by the relatively small number of high voltage pulses D as before but in this instance is maintained in an ionized state by the large number of relatively low-voltage pulses C thus permitting line current to flow for a much greater portion of each half cycle of the applied line voltage than heretofore. The line current, accordingly, builds up to its full value within the first two or three half cycles of applied line voltage after the switch **26** is closed, which in time is represented by the left-hand edges of the graphs shown in Figs. 4 and 5, thereby rapidly heating the electrodes to electron-emitting temperature and providing almost instantaneous starting.

It has been found that at least two voltage pulses per half cycle of applied line voltage of approximately 50 kv. magnitude will reliably start the various types and sizes of short-arc lamps now being marketed under either "hot" or "cold" starting conditions, with the optimum being from about three to eight pulses within a range of approximately 30 to 50 kv., when such pulses are simultaneously applied to the lamp in accordance with the invention along with at least ten pulses of at least 10 kv. magnitude, with the optimum number of such lower voltage pulses being from about twelve to twenty pulses within a range of approximately 10 to 30 kv. In contrast, experience has shown that in order to achieve the same degree of reliability during starting with the single loop type circuits generally used heretofore at least 10 to 20 pulses of approximately 50 kv. would be required. It will, of course, be obvious that various combinations as regards the number and magnitude of high and lower voltage pulses can be used depending on the particular lamp type involved and the starting conditions most likely to be encountered.

As will be apparent from the foregoing, the objects of the invention have been achieved by providing a starting circuit which is adapted to ignite lamps containing an ionizable medium reliably and within a predetermined time limit, even under the most adverse starting conditions. In addition, by utilizing a plurality of oscillatory loop circuits an exceptionally versatile starting system is provided which not only obviates the criticality of adjustment and maintenance heretofore encountered with circuits having only one loop but which can supply a wide range of voltage pulses both as regards their magnitude and frequency thereby permitting the same basic circuit to be used with the various types and sizes of high-wattage double-ended lamps now being marketed.

While one specific embodiment of the invention has been described in detail by way of illustration and example for the purposes of clarity and understanding in accordance with the patent statutes, it is understood that various changes and modifications may be made without departing from the spirit and scope of the invention.

We claim:

1. A starting circuit for a lamp containing an ionizable medium comprising, a first oscillating circuit comprising a transformer secondary and an electrc discharge device operable to generate a series of voltage pulses of predetermined frequency and magnitude, a second oscillating circuit comprising another transformer secondary and another electric discharge device operable to generate a second series of voltage pulses of predetermined frequency and magnitude, means for energizing said transformer secondaries, and means for simultaneously applying the outputs of said first and second oscillating circuits to said lamp.

2. A starting circuit for a lamp containing an ionizable medium comprising, a transformer having a primary and two secondaries, a first and second oscillating circuit each comprising one of said secondaries and an electric discharge device electrically disposed to generate a series of voltage pulses of predetermined frequency and magnitude when said transformer is energized, means for connecting said primary to an alternating current power source, and means for simultaneously applying the outputs of said first and second oscillating circuits to said lamp.

3. A starting circuit for a lamp containing an ionizable medium comprising, first and second transformers each having a primary and secondary, each said secondary having a capacitor and an electric discharge device connected thereto electrically disposed to provide in conjunction with said secondary a first and second oscillating circuit which are independently adjustable and operable, means for connecting each said primary to an alternating current power source, and means for simultaneously applying the outputs of said first and second oscillating circuits to said lamp.

4. A starting circuit for a lamp containing an ionizable medium comprising, first and second step-up transformers each having a primary and secondary, a pulse transformer having two primaries and a secondary, each of the secondaries of said first and second step-up transformers having a capacitor in parallel and a spark-gap and one of the primaries of said pulse transformer in series therewith thereby to provide two oscillatory loop circuits which are independently adjustable and operable, and means including a switch for connecting the primaries of said first and second step-up transformers to an alternating current power source, the secondary of said pulse transformer being connected in series with said lamp and constituting a part of the circuit for normally operating said lamp after it has been lighted thereby providing means for simultaneously applying the outputs of said oscillatory loop circuits to said lamp when said switch has been actuated and said first and second step-up transformers energized.

5. A starting and operating circuit for a lamp containing an ionizable medium comprising, conductor means for connecting said lamp to an alternating current power source, current limiting means connected in series with said lamp through said conductor means, first and second step-up transformers each having a primary and secondary, a pulse transformer having two primaries and a secondary, the secondary of said pulse transformer being connected in series with said lamp and said current limiting means through said conductor means and in conjunction therewith constituting a series circuit adapted to operate said lamp after it has been lighted, each of the secondaries of said first and second step-up transformers having a capacitor in parallel and a spark-gap and one of the primaries of said pulse transformer in series therewith thereby to provide two oscillatory loop circuits which are independently adjustable and operable, and switch means in series with the primaries of said

first and second step-up transformers for connecting said primaries across the line side of said conductor means.

6. A starting and operating circuit for a high intensity lamp containing an ionizable medium comprising, conductor means for connecting said lamp to an alternating current power source, an inductive ballast connected in series with said lamp through said conductor means, first and second iron-core step-up transformers each having a primary and secondary, a pulse transformer having two primaries and a secondary, the secondary of said pulse transformer being connected in series between said lamp and said inductive ballast and in conjunction with said conductor means constituting a series circuit for operating said lamp after it has been lighted, each of the secondaries of said first and second step-up transformers having a capacitor in parallel and a spark-gap and one of the primaries of said pulse transformer in series therewith thereby to provide two oscillatory loop circuits which are independently adjustable and operable, and means including a switch for connecting the primaries of said first and second step-up transformers across said conductor means at a point on the series operating circuit closer to the input terminals thereof than the inductive ballast.

7. In an energizing circuit for a lamp which contains an ionizable medium, a starting circuit comprising a transformer having at least two secondaries which are electrically separate from each other, a plurality of oscillating circuits equal in number to the number of secondaries and each comprising one of said secondaries and an electric discharge device operable to generate a series of high voltage pulses, and means for energizing said transformer and simultaneously applying the outputs of said oscillating circuits to said lamp.

8. In an energizing circuit for a lamp which contains an ionizable medium, a starting circuit comprising a step-up transformer having two secondaries which are electrically separate from each other, means including a switch for connecting said step-up transformer to an alternating current power source, a pulse transformer having two primaries and a secondary which are electrically separate from each other, the secondary of said pulse transformer being connected in series with said lamp and constituting a part of the energizing circuit for operating said lamp after it has been lighted, two oscillatory loop circuits each comprising one of the secondaries of said step-up transformer and one of the primaries of said pulse transformer and an electric discharge device connected in series, each of the secondaries of said step-up transformer having a capacitor connected in parallel therewith, and means for simultaneously applying the outputs of said oscillatory loop circuits to said lamp, said electric discharge devices having breakdown characteristics such that the number and magnitude of the voltage pulses generated by one of said oscillatory loop circuits differ by a substantial and predetermined amount from those generated by the other loop circuit.

9. In an A.C. energizing circuit for a lamp which contains an ionizable medium, a starting circuit comprising a step-up transformer having two secondaries, means for energizing said step-up transformer, a pulse transformer having two primaries and a secondary, two oscillating circuits each comprising one of the step-up transformer secondaries and one of said pulse transformer primaries and a spark-gap operable to generate a series of voltage pulses when said step-up transformer is energized, and means including the secondary of said pulse transformer for simultaneously applying the outputs of said oscillating circuits to said lamp, the adjustment of said spark-gaps being such that one of said oscillating circuits generates at least two voltage pulses of approximately 50 kv. and the other of said oscillating circuits generates at least ten voltage pulses of at least 10 kv. during each half cycle of the voltage applied to said lamp from the energizing circuit during the starting cycle.

10. In an A.C. energizing circuit for a lamp which contains an ionizable medium, a starting circuit comprising a step-up transformer having two secondaries which are electrically separate from each other, means for temporarily connecting said step-up transformer to said energizing circuit, a pulse transformer having two primaries and a secondary which are electrically separate from each other, two oscillatory loop circuits each comprising one of the secondaries of said step-up transformer and one of the primaries of said pulse transformer connected in series and a spark-gap and capacitor electrically disposed to generate in conjunction with said pulse transformer primary and step-up transformer secondary a series of voltage pulses of predetermined frequency and magnitude, and means including the secondary of said pulse transformer for simultaneously applying the outputs of said oscillatory loop circuits to said lamp, the adjustment of said spark-gaps being such that one of said oscillatory loop circuits generates from about three to eight voltage pulses within a range of approximately 30 to 50 kv. and the other of said oscillatory loop circuits generates from about twelve to twenty voltage pulses within a range of approximately 10 to 30 kv. during each half cycle of the voltage applied to the lamp by said energizing circuit during the starting cycle.

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