Feb. 15, 1966 H. L. WATTENBACH 3,235,769

STARTING CIRCUIT FOR DISCHARGE LAMPS

Filed Dec. 27, 1962

Fig. 1.

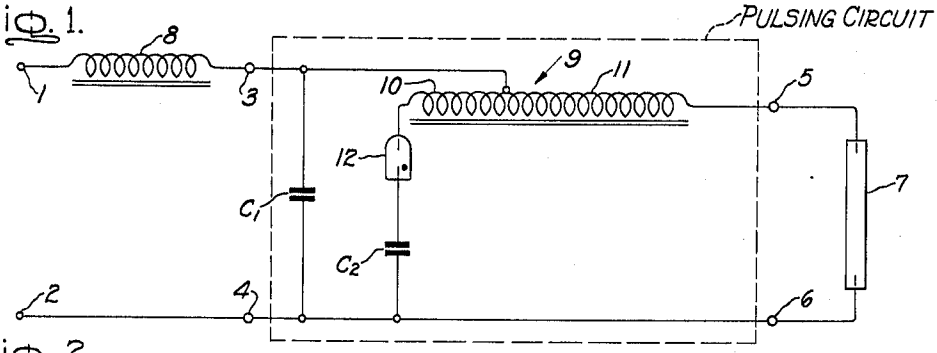


Fig. 2.

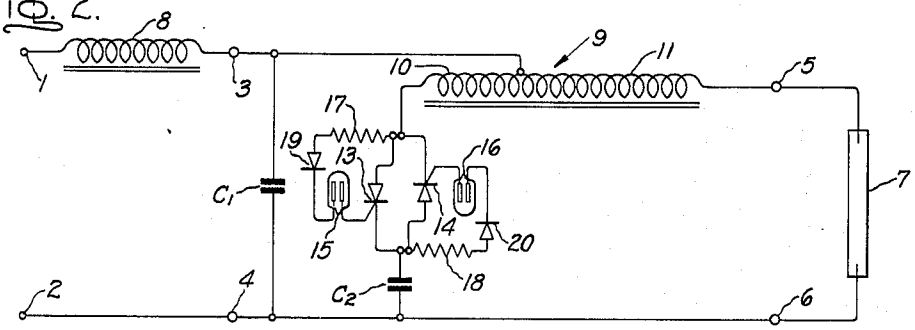


Fig. 3.

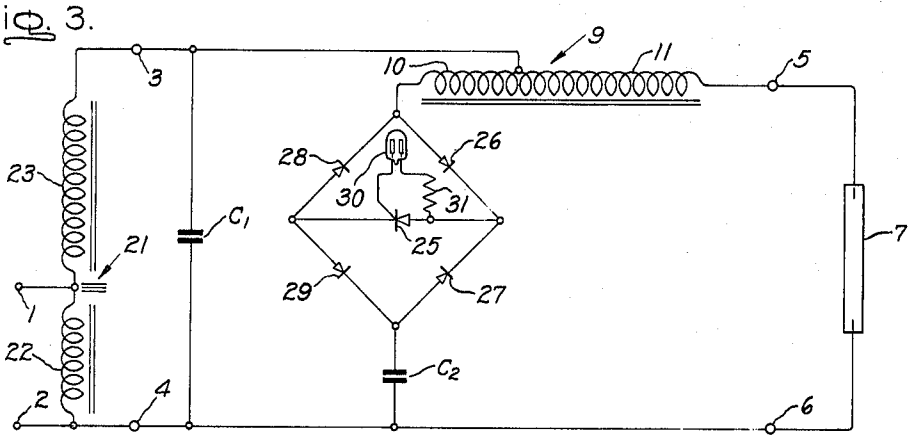
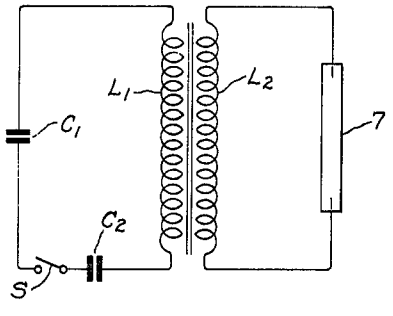


Fig. 4.



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3,235,769

STARTING CIRCUIT FOR DISCHARGE LAMPS

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8 Claims. (Cl. 315—176)

This invention relates to a discharge lamp starting circuit particularly useful for starting lamps such as high pressure arc lamps where a starting voltage much higher than the operating voltage is required.

The terminal voltage required for starting high pressure arc lamps may be several times the voltage at which the lamp normally operates and depends upon such factors as gas pressure, electrode spacing and envelope geometry. An example of a lamp where such conditions are carried to the extreme is a metal vapor alumina lamp which utilizes an envelope of polycrystalline alumina ceramic. The high melting point of the alumina ceramic (over 1900° C.) allows the construction of a lamp having an extremely small diameter and high current density. However the small diameter increases the breakdown voltage of the lamp and makes starting very difficult. Thus one alumina ceramic lamp wherein the interelectrode distance is 50 to 60 millimeters and the inner diameter of the ceramic tube is 6 millimeters, when filled with argon or xenon to a pressure of about 20 millimeters at room temperature, has a starting voltage of about 1800 volts peak. When a metal vapor such as cesium or sodium is added, the starting voltage decreases to a value of approximately 1100 volts peak. In normal operation, the metal vapor filled lamp may operate at currents from 6 to 12 amperes with a voltage drop from 120 down to 50 volts. The lamp wattage is about 600 watts.

While a high open circuit voltage is required for starting, a high lamp current must be provided during normal operation. This makes the conventional low pressure discharge lamp practice of increasing the open circuit voltage of a high reactance step-up transformer quite unattractive. The use of auxiliary starting electrodes within the lamp to produce auxiliary glow discharges near the electrodes complicates the construction of the lamp and does not reduce sufficiently the required open circuit voltage. For instance, in the metal vapor-alumina lamp example described above, the provision of auxiliary starting electrodes did not reduce the open circuit starting voltage below 570 volts peak. This is still too high to make the high reactance step-up transformer mode of starting economically attractive.

A known method of starting such lamps is to couple high voltage oscillations to the lamp electrodes in order to effect the initial ionization. Such starting circuits as provided in the past have generally been complicated and cumbersome. Where the oscillations are coupled in parallel with the operating voltage source, a high current choke is required to prevent dissipation of the energy in the operating source. On the other hand if the oscillations are coupled in series with the operating voltage source, an air core radio frequency transformer with the secondary in series with the operating supply leads has generally been used but it has the disadvantage of producing radio frequency interference to an objectionable degree.

The object of the invention is to provide a starting circuit for discharge lamps requiring a high starting voltage, which is effective, compact and inexpensive. Other desirable attributes of the circuit are that it be readily adaptable to use with a conventional ballast without requiring a separate power supply; the operation should be automatic, starting as soon as the lamp circuit is switched on and stopping when the lamp has started; the radio frequency interference produced by the device should be kept to a minimum; and the use of moving parts or switching contacts is to be avoided. Finally the energy levels of the high voltage pulses should be low enough to avoid the need for special safety precautions.

In accordance with my invention, the starting circuit includes a pulse transformer having primary and secondary windings, a pair of capacitances, and a pulse switching element. The secondary is connected in series with the lamp, across the output terminals of a conventional ballast which functions to limit the lamp current in operation. One capacitance is connected across the ballast output terminals to form a charging circuit. The other capacitance is connected in series with the primary and the pulse switching element across the ballast output terminals to form a discharging circuit. The pulse switching element, which suitably may be a spark tube, fires and allows one capacitor to discharge into the other through the primary of the pulse transformer at every half cycle of the alternating current supply. A high voltage low energy pulse is thereby generated in the secondary of the pulse transformer which is applied in series with the line voltage across the lamp electrodes. As soon as the lamp has started, the pulse switching element ceases to fire and the circuit becomes quiescent.

For further objects and advantages and for a better understanding of the invention, attention is now directed to the following description of preferred embodiments illustrating the invention. The features believed to be novel will be more particularly pointed out in the appended claims.

In the drawing wherein like symbols denote corresponding elements throughout the several figures:

FIG. 1 is a schematic diagram of a starting circuit embodying the invention and using a spark tube as the pulse switching element.

FIG. 2 is a schematic diagram of a modification using a pair of controlled rectifiers as pulse switching element.

FIG. 3 illustrates another modification utilizing a rectifying bridge plus a controlled rectifier as pulse switching element.

FIG. 4 is a schematic diagram of an equivalent starting circuit.

Referring to FIG. 1, the illustrated starting and operating circuit for a metal vapor lamp has ballast input terminals **1**, **2** for energization from the usual 115–120 volt, 60 cycle alternating current supply. In a conventional circuit, the lamp would be connected across ballast output terminals **3**, **4**. However, in accordance with the invention, a pulsing circuit is connected to terminals **3**, **4** and it in turn has output or lamp terminals **5**, **6** across which metal vapor lamp **7** is connected. The ballast may or may not include transforming means to step up the line voltage, but does include an impedance for regulating the discharge current. In this embodiment, the ballast consists merely of an iron core reactor **8** which is serially inserted between terminals **1** and **3**; by way of example, it may be proportioned to limit the lamp current to 12 amperes when the voltage drop across the lamp is 50 volts. Terminals **2**, **4** and **6** are all conductively joined and need not be physically distinct.

The pulsing circuit or pulse starter proper is enclosed within the dotted rectangle between terminals **3**, **4** and **5**, **6**. It comprises pulse transformer **9** having primary winding **10** and secondary winding **11**, a pair of capacitors C_1, C_2 desirably of equal value, and a pulse switching element indicated as a spark tube **12**. Secondary winding **11** is connected between terminals **3** and **5** so that it and the lamp **7** are connected in series across the ballast output terminals **3**, **4**. Capacitor C_1 is connected across ballast output terminals **3**, **4** to form a charging circuit

whereas capacitor C_2 is connected in series with the pulse switching element and primary winding **10** of the pulse transformer across the ballast output terminals to form a discharging circuit.

In the operation of the circuit, when an A.-C. voltage is applied to terminals **1**, **2**, capacitor C_1 charges or discharges as it follows the open circuit voltage of ballast **8**. The capacitance of capacitor C_1 is small enough that there is substantially no resonant effect with the inductance of ballast **8**; in other words, the capacitive reactance of capacitor C_1 is much higher than the inductive reactance of reactor **8**. Thus the voltage across capacitor C_1 follows substantially the line voltage. However the voltage across capacitor C_2 cannot change so long as spark tube **12** is not conducting. Thus across the electrodes of the spark tube there exists the difference in the instantaneous values of voltage across capacitors C_1 and C_2 The breakdown voltage of the spark tube is selected to be within the peak value of the line voltage provided at terminals **1**, **2**. Therefore the breakdown voltage of the spark tube is exceeded at every half cycle; upon breakdown, it conducts current with a maintaining voltage of 10 to 15 volts. At this low voltage, the spark tube is able to transfer high current pulses and only a small part of the pulse energy is dissipated internally. The spark tube may be compared to a very fast switch wherein the time required for turn-on is about 10^{-7} second. After each oscillatory discharge of the condensers, the spark tube extinguishes, it fires again at the next half cycle.

Upon breakdown of the spark tube, a current pulse passes through primary winding **10** of the pulse transformer, discharging capacitor C_1 and charging capacitor C_2. During the next half cycle, the current flow is in the opposite direction and the charges on the capacitors are likewise reversed. The current pulses produce voltage pulses of a duration between 1 and 10 microseconds and of a peak voltage of about 2000 volts in the secondary **11** of the pulse transformer. These pulses are delivered to the lamp in series with the line voltage applied through ballast **8** and cause the initial ionization and eventually the starting of the lamp. After the lamp has started, the open circuit voltage of the ballast decreases to the operating voltage of the lamp which is lower than the breakdown voltage of the spark tube, so that the generation of pulses ceases.

An important feature of the circuit resides in the provision of the two capacitors C_1, C_2 in the pulse circuit. Capacitor C_1 is charged from the line and supplies energy rapidly to the pulse circuit consisting of capacitors C_1 and C_2, spark tube **12** and primary **10** of the pulse transformer. Capacitor C_2 charges when the spark tube breaks down. Capacitor C_1 also acts as a low impedance path for the high frequency pulse through the lamp. The presence of capacitor C_2 presents the output of ballast **8** from being permanently short circuited by spark tube **12**.

FIG. 4 is the equivalent circuit diagram of the pulse starting circuit wherein the spark tube **12** is replaced by the switch S and is valid for the moment when the voltage across the spark tube attains the breakdown value, switch S being considered to close at such moment. Thereupon, capacitor C_1 discharges through inductance L_1 corresponding to the primary of the pulse transformer, and transfers its charge to capacitor C_2 and vice versa, cycling as a damped oscillation. The two condensers C_1 and C_2 are in series and can be replaced by a single equivalent capacity C determined as follows:

$$C=\frac{C_1C_2}{C_1+C_2} \qquad \text{I}$$

For the preferred case where $C_1=C_2$, then $C=\frac{1}{2}C_1$ or $\frac{1}{2}C_2$.

In order to generate the pulses necessary for the lamp and obtain good switching characteristics for the spark tube, the breakdown voltage V_{br} of the spark tube should be no higher than the peak value of the open circuit voltage

of the ballast under minimum line voltage conditions. I prefer to use a spark tube having a breakdown voltage which is 1.0 to 1.2 times the R.M.S. value of the average open circuit voltage of the ballast. As an example, in a starting circuit for use on a 118 volt supply using merely a series reactor ballast as in FIG. 1, I use a spark tube having a breakdown voltage V_{br} of approximately 140 volts.

The energy E_c stored in the equivalent capacity C at the instant of breakdown is given by:

$$E_c=\tfrac{1}{2}V_{br}^2C \qquad \text{II}$$

and the resonance frequency f_r is determined by:

$$f_r=\frac{1}{2\pi\sqrt{LC}} \qquad \text{III}$$

wherein E_c is measured in watt-seconds, and f_r in cycles per second when V_{br} is measured in volts, C in farads and L in henries. For the metal-vapor alumina lamp described earlier, I have found it suitable to use a value for E_c of 2.5 milliwatt-seconds. Good switching characteristics are obtained using a spark tube when the resonance frequency f_r is in the range of 50 to 120 kilocycles per second.

The inductance of a coil with n turns on a magnetic core is given by

$$L=\frac{n^2u'a_c}{l_m} \qquad \text{IV}$$

wherein

L=inductance of the coil measured in henries or volt-seconds per ampere,

n=number of turns,

u'=effective permeability $\dfrac{\text{(volt-second)}}{\text{ampere-cm.}}$

a_c=cross-sectional area of the core (cm.^{2}), and

l_m=average length of the magnetic lines in the core (cm.).

The pulse transformer must provide a peak pulse voltage V_p higher than the maximum breakdown voltage of the lamp (2000 volts peak) at room temperature. The ratio of secondary to primary turns in the pulse transformer will therefore be determined by the ratio of such peak voltage V_p to the breakdown voltage V_{br} of the spark tube.

Using an iron or ferrite core for the pulse transformer, the maximum allowable flux density must not be exceeded when the current pulse from the condenser discharges through the primary turns. The flux density B_1 measured in volt-second per cm.^{2} caused by the condenser discharge is given by the following relationship:

$$B_1=V_{br}\frac{Cu'}{a_cl_m} \qquad V$$

wherein C is the substituted capacity for C_1 and C_2, and the other symbols have the significance stated earlier.

The lamp current which flows through the secondary turns of the pulse transformer after the lamp has started is an alternating current. Therefore, the magnetic field in the core of the pulse transformer is continuously changing in value. Depending upon the design, the core will usually saturate when the instantaneous lamp current exceeds a certain level and thereupon the inductance of the secondary turns becomes small. However at every half cycle the current passes through zero and at this time the secondary turns have their full inductance because the permeability of the core is then at its maximum initial value. In order to minimize the influence of this inductance on the value and waveform of the lamp current, either the inductance of the secondary turns of the pulse transformer must be much smaller than the inductance of the ballast, or the core of the pulse transformer must saturate early in the cycle. In the latter alternative

wherein saturation is reached at a small instantaneous value of lamp current, the inductance of the secondary turns drops to a much lower value on larger instantaneous values of lamp current. Thus only in a small range around current zero is the value and wave form of the lamp current influenced.

An example of a starting device suitable for use with the metal vapor alumina lamp described earlier is a unit comprising a pulse transformer constructed on a toroidal ferrite core, a dual condenser built into a single metal can, and a spark tube having a breakdown voltage of 140 volts peak. By utilizing Equation II upon the assumption of 2.5 milliwatt-seconds of stored energy E_c, the equivalent capacity C is determined to be .25 microfarad. Assuming equal capacities for C_1 and C_2, each becomes .5 microfarad. Assuming a resonance frequency of 70 kilocycles per second, application of Equation III determines a coil inductance L of 20 microhenries. For the core of the pulse transformer, a ferrite toroid was used having an inside diameter of 3.2 centimeters, outside diameter of 5.1 centimeters and height or thickness of 1.9 centimeters. The effective permeability u' was $300\times4\pi10^{-9}$ volt-second per ampere-centimeter, the initial permeability u_{in}' was $1100\times4\pi10^{-9}$ volt-second per ampere-centimeter, and the maximum allowable flux density B max. was 5000 gauss or 5000×10^{-8} volt-second per cm.^{2}. By application of Equation IV, the number of primary turns n_1 is determined as 6 turns. In order to obtain a peak secondary voltage of 2000 volts, a turns ratio of 15 is chosen and the number of secondary turns is thereby determined to be 90. The flux density when the current pulse of the condenser discharge passes through the primary turns is calculated by Equation V to be 2800 gauss so that the maximum allowable flux density of 5000 gauss is not exceeded. The inductance of the secondary turns at current zero is 15.5 millihenries; this compares with an inductance of about 20 millihenries for the choke or ballast reactor on a 118 volt, 60 cycle line for a metal vapor alumina lamp of 50 volt, 10 ampere rating. The saturation of the ferrite material begins at a magnetic field strength H of approximately 10 oersteds and this corresponds to an instantaneous value of lamp current of approximately 1.15 amperes. Thus the alternative or second condition for minimum influence of the pulse coil inductance on the value and wave form of lamp current is complied with. I have also determined experimentally that the influence of the secondary of the pulse transformer upon the lamp current is negligible. Using No. 14 magnet wire for the pulse transformer windings, the losses in the secondary during normal running of the lamp are about 7 watts.

Because of the relatively low resonance frequency of the pulse circuit and due also to the absence of any air gap in the toroidal ferrite core, the coupling factor of the pulse transformer is close to unity and almost all the energy of the condensers except for the losses in the spark tube is transferred to the lamp. The internal capacity of the secondary turns in the pulse transformer is negligibly small. Experiments have shown that the capacity of the leads to the lamp must not exceed 150 micromicrofarads in order to avoid capacitive leakage of the high voltage, high frequency pulse energy. The above-described example of a starting device provides a peak pulse voltage of 2800 volts with a peak pulse current of 3 amperes and a pulse duration of 1.0 microsecond. The pulses are oscillatory but rapidly damped and the significant portion is the first half cycle which is in additive polarity in the line voltage. The pulse repetition per half cycle is 1 pulse, that is, 120 pulses are produced per second on a 60 cycle supply. The pulse energy is so low that there is no shock hazard despite the high voltage, the pulses merely causing a slight tickling to the hand.

The function of the pulse switching element is to discharge condenser C_1 into condenser C_2 at the proper time.

It must have certain features: high resistance before switching on, and low resistance or voltage drop when switched on; it must also permit a very fast switching on and off. The use of a spark tube for this purpose has definite advantages inasmuch as it is inexpensive and easily built, conducts electricity in both directions, and switches on and off in a very short time. The operating voltage drop across the spark tube entails losses and should be as low as possible.

For the present purpose, a spark tube is desired having a breakdown voltage in the range of 90 to 100 volts. One form of spark tube which I have found particularly suited by reason of very low operating voltage at low electrode temperatures utilizes electrodes activated with alkaline earth oxides and defining an arc gap of 0.4 millimeter in an argon gas atmosphere at a pressure of 60 millimeters of mercury. This spark tube has a breakdown voltage of 130 to 140 (peak) volts and an operating voltage of 10 volts, with the result that the percentage of energy lost in the spark tube is very small, being in the range of 10 to 12 percent of that stored in the pulsing condensers. For further details of a spark tube construction which is preferred for the present application, attention is directed to my copending application Serial No. 247,633, filed of even date herewith, entitled "Spark Tube" and assigned to the same assignee as the present invention.

Although a mechanical switch or vibrator may be used as the pulse switching element, it has the disadvantage of the need for periodic maintenance resulting from the use of mechanical moving parts. Therefore, I do not favor it for the present application but it may be used particularly where low cost is a prime consideration and a long trouble-free life is of less import.

The pulse switching element may take the form of a controlled rectifier, that is a three-junction semi-conductor device having characteristics similar to a thyratron tube. Since a controlled rectifier can conduct current in one direction only, two controlled rectifiers are used in a reverse parallel arrangement. This is illustrated in FIG. 2 wherein the spark gap tube of FIG. 2 has been replaced by silicon controlled rectifiers **13**, **14** connected in reverse parallel. Controlled rectifier **13** is connected to pass current into capacitor C_2, that is it conducts on the positive half cycle. Controlled rectifier **14** is connected to discharge capacitor C_2 or in other words, it will conduct on the negative half cycle. However, the controlled rectifiers will only conduct when glow tubes **15**, **16** which are connected in series with resistors **17**, **18** in their respective firing circuits, break down and pass current. Since the glow tubes need only provide the small control current to the ignition circuit, the duty imposed upon them is much less severe than that imposed on the spark tube in FIG. 1. Also, since the controlled rectifiers **13**, **14** have a very low impedance when turned on, the result is an efficient transfer of energy from capacitors C_1, C_2 into the pulse transformer. The glow tubes **15**, **16** are of course selected to break down at the appropriate voltage during the half cycle. Diodes **19** and **20** in the firing circuits assure that each controlled rectifier firing circuit conducts in the appropriate polarity and is protected in the reverse polarity.

FIG. 3 illustrates another variant of the invention suitable for lamps of higher operating voltage such that an open circuit voltage higher than the line voltage is needed for effective regulation of the lamp current. The simple series reactor which constitutes the ballast in the circuits of FIGS. 1 and 2 is replaced by a high reactance transformer **21** having a primary winding **22** connected to line terminals **1**, **2**, and a loosely coupled secondary winding **23** connected in series with the primary across ballast output terminals **3**, **4**. The leakage reactance of the secondary winding regulates the lamp discharge current during normal operation.

In the circuit of FIG. 3 a pulsing circuit is still needed on account of the high starting voltage of the lamp. A controlled rectifier **25** is used as the pulse switching element and is connected in a bridge rectifier circuit on account of its unilateral conductivity. Diodes **26**, **27**, **28** and **29** are so poled that bilateral conduction can take place from pulse transformer **9** to capacitor C_2 while conduction through controlled rectifier **25** connected across the diagonal points of the bridge always takes place in the same direction. A glow tube **30** in series with a resistance **31** forms the firing circuit to the control electrode of the controlled rectifier. The illustrated arrangement causes the discharge pulses of capacitor C_1 into capacitor C_2 always to flow through the controlled rectifier in the same direction, and no peak inverse voltage reaches the controlled rectifier. However the rectifiers **26** to **29** of the bridge must withstand at least the breakdown voltage applied to the circuit. The duty imposed upon the glow tube **30** is of course very light and a small tube of one-quarter watt or one-half watt rating is insufficient. The glow tube delivers the trigger pulses to the gate or control electrode of the controlled rectifier while resistor **31** limits the peak current of the trigger pulses to a safe value as determined by the characteristics of the semiconductor. Although the peak pulse current through the controlled rectifier is about 30 amperes, the average current rating of the controlled rectifier and of the diodes may be quite small because the pulse duration is very short (1 to 10 microseconds) and there is only one pulse per half cycle of line voltage.

As an alternative to a silicon-controlled rectifier, one may use a four layer diode (Shockley diode) which breaks down under the applied voltage at the proper value without the use of an auxiliary firing circuit.

While certain specific embodiments of the invention have been illustrated and described in detail, they are intended as illustrative and not in order to limit the invention thereto. The scope of the invention is to be determined by the appended claims which are intended to cover any modifications falling within its spirit.

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

1. An operating and starting circuit for an electric discharge lamp comprising ballasting means having input terminals for connection to an alternating voltage source and output terminals at which a regulated current is supplied, lamp terminals for connection to said electric discharge lamp, a pulse transformer having primary and secondary windings, pulse switching means, and a pair of capacitors, one of said capacitors being connected across said output terminals to form a charging circuit, the primary of said transformer, said pulse switching means, and the other of said capacitors being connected in series across said output terminals to form a discharging circuit, and the secondary of said transformer and said lamp terminals being connected in series across said output terminals to form an operating circuit, said pulse switching means being switched on cyclically by the alternating voltage applied thereto and operating thereupon to discharge said one capacitor into the other through the primary of said pulse transformer in order to induce a high voltage pulse in the secondary of said pulse transformer.

2. A pulse starting circuit for an electric discharge lamp operating circuit of the kind including ballasting means having input terminals for connection to an alternating current source and output terminals at which a regulated current is supplied, and an electric discharge lamp requiring a starting voltage higher than the open-circuit voltage of said ballasting means, comprising a pulse transformer having primary and secondary windings, pulse switching means, and a pair of capacitors, one of said capacitors being connected across said output terminals to form a charging circuit, the primary of said transformer, said pulse switching means, and the other of said capacitors being connected in series across said output terminals to form a discharging circuit, and the secondary of said transformer and terminals for said lamp being connected in series across said output terminals to form an operating circuit, said pulse switching means being switched on cyclically by the alternating voltage applied thereto and operating thereupon to discharge said one capacitor into the other through the primary of said pulse transformer in order to induce high voltage pulses in the secondary.

3. In combination an alternating voltage source, ballasting means having an input circuit connected across said source and an output circuit supplying a regulated current, an electric discharge lamp requiring an ignition voltage much higher than its operating voltage, a pulse transformer having primary and secondary windings, a load circuit comprising said secondary winding and said lamp connected in series across said output circuit, a first capacitor connected across said output circuit to form a charging circuit, a second capacitor, pulse switching means and said primary winding connected in series across said output circuit to form a discharging circuit, said pulse switching means being switched on cyclically by the alternating voltage applied thereto and operating thereupon to discharge said first capacitor into said second capacitor at a predetermined voltage not less than the minimum voltage of said output circuit prior to starting of said lamp but greater than the voltage across said lamp in normal operation thereof.

4. The combination defined in claim **3** wherein said pulse switching means is a spark tube having a breakdown voltage corresponding to said predetermined voltage.

5. The combination defined in claim **3** wherein said pulse switching means comprises a pair of controlled rectifiers connected in reverse parallel, each controlled rectifier having a firing circuit including in series a glow tube, a resistance and a diode for turning on the controlled rectifier at said predetermined voltage.

6. The combination defined in claim **3** wherein said pulse switching means comprises a rectifying bridge, a controlled rectifier connected across a diagonal thereof for unidirectional current flow therethrough, and a firing circuit including a glow tube and a series resistance for turning on the controlled rectifier at said predetermined voltage.

7. In combination an alternating voltage source, ballasting means having an input circuit connected across said source and an output circuit supplying a regulated current, an electric discharge lamp requiring an ignition voltage much higher than its operating voltage, a pulse transformer having primary and secondary windings, a load circuit comprising said secondary winding and said lamp connected in series across said output circuit, a first capacitor connected across said output circuit to form a charging circuit, a second capacitor, pulse switching means and said primary winding connected in series across said output circuit to form a discharging circuit, said pulse switching means being switched on cyclically by the alternating voltage applied thereto and operating thereupon to discharge said first capacitor into said second capacitor at a predetermined voltage not less than the minimum voltage of said output circuit prior to starting of said lamp but greater than the voltage across said lamp in normal operation thereof, the ratio of the capacitive reactance of said capacitors to the inductive reactance of said primary winding providing a resonance frequency in the range of 50 to 120 kilocycles, said pulse transformer having a secondary to primary turns ratio resulting in a voltage pulse of sufficient amplitude to start said lamp upon breakdown of said pulse switching element, and said pulse transformer having a magnetic core which saturates early in the cycle of the normal operating current to said lamp.

8. A pulse starter for insertion in an electric discharge lamp operating circuit of the kind including ballasting

means energized by alternating current which supplies a regulated current to a load circuit including an electric discharge lamp which requires a starting voltage higher than the open-circuit voltage of said ballasting means, comprising a pulse transformer having primary and secondary windings, pulse switching means, a pair of capacitors, load circuit terminals and lamp terminals, one of said capacitors being connected across the load circuit terminals to form a charging circuit, the primary of said transformer, said pulse switching means, and the other of said capacitors being connected in series across the load circuit terminals to form a discharging circuit, and the secondary of said transformer being connected in series with the lamp terminals across said load circuit terminals, said pulse switching means being switched on cyclically by the alternating voltage applied across said load circuit

terminals and operating thereupon to discharge said one capacitor into the other through the primary of said pulse transformer in order to induce high voltage pulses in the secondary.

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GEORGE N. WESTBY, *Primary Examiner.*