United States Patent

Kaneda et al.

[15] **3,665,243**

[45] **May 23, 1972**

[54] DISCHARGE-LAMP OPERATING DEVICE USING THYRISTOR OSCILLATING CIRCUIT

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[73] Assignee: **New Nippon Electric Company Ltd.,** Osaka, Japan

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[21] Appl. No.: **14,325**

[30] **Foreign Application Priority Data**

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Apr. 30, 1969	Japan	44/34011
Apr. 26, 1969	Japan	44/38565
June 10, 1969	Japan	44/54290
June 16, 1969	Japan	44/47720

[52] **U.S. Cl.** ..... **315/101,** 315/105, 315/241 R, 315/242, 315/244

[51] **Int. Cl.** **H05b 41/16,** H05b 41/20, H05b 41/23

[58] **Field of Search** ..... 315/99, 101, 105, 241 R, 242, 315/244, DIG. 2, DIG. 7, 202, 207

[56] **References Cited**

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Primary Examiner—Herman Karl Saalbach
Assistant Examiner—Marvin Nussbaum
Attorney—Roberts & Cohen

[57] **ABSTRACT**

A circuit including a starting device and in which a discharge lamp is connected to the output terminal of a nonlinear thyristor oscillator. The thyristor oscillator includes a first closed circuit comprising a power source, a choke coil and a capacitor. This first closed circuit is set for a first oscillating condition. A second closed circuit is also employed. It comprises an inductance element and a voltage responsive switch such as a thyristor which elements are connected to said capacitor. This second closed circuit is set for a second oscillating condition, preferably near resonance state. A high frequency transformer can be combined with the second closed circuit in order to realize a faster turning on or initiation of the discharge lamp. In a hot-cathode type discharge lamp, a third circuit for increasing preheating current is included in said oscillator circuit.

5 Claims, 31 Drawing Figures

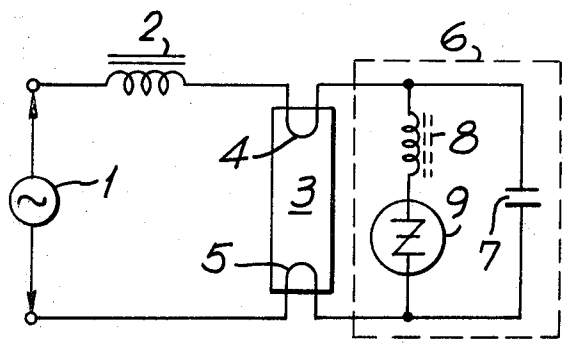


FIG. 1(A)

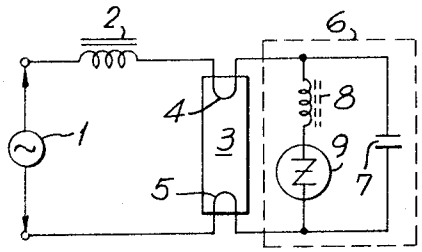


FIG. 1(B)

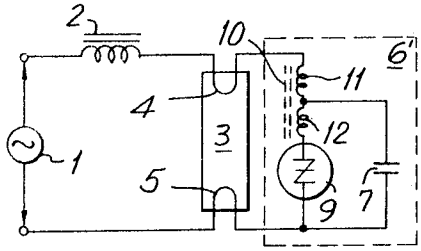


FIG. 1(C)

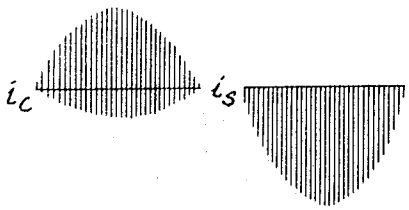


FIG. 2(A)

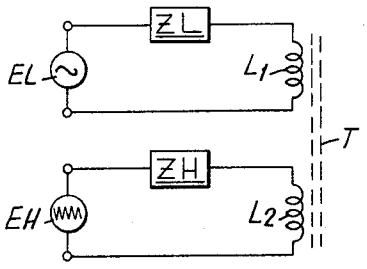
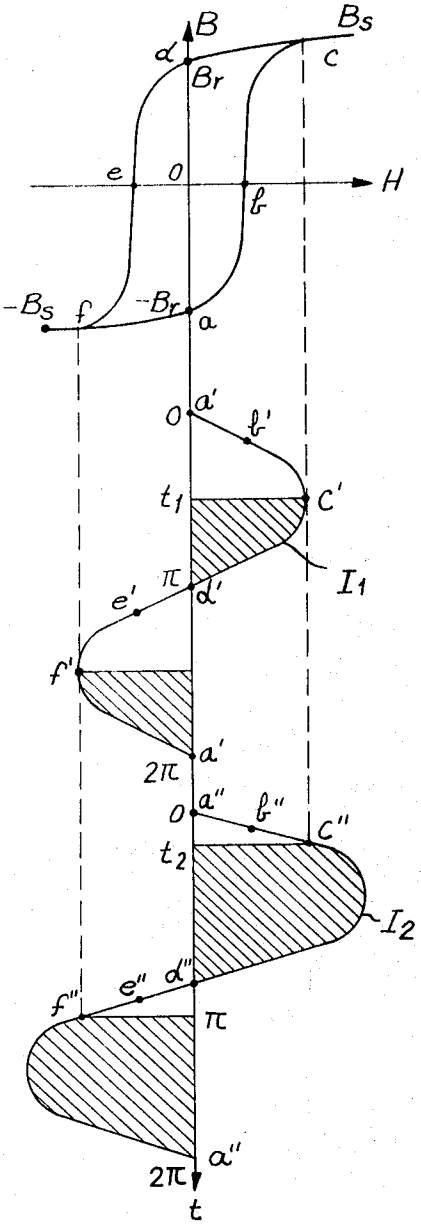


FIG. 2(B)



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FIG. 2(C)

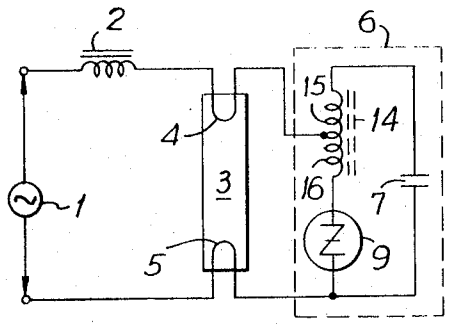


FIG. 2(D)

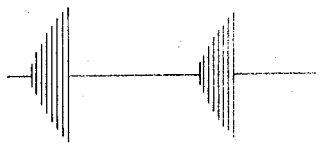


FIG. 3

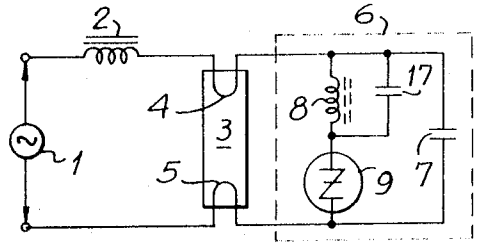


FIG. 4

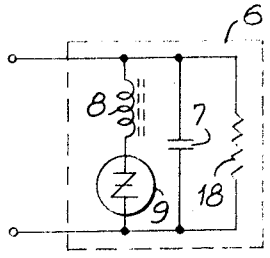


FIG. 5(A)

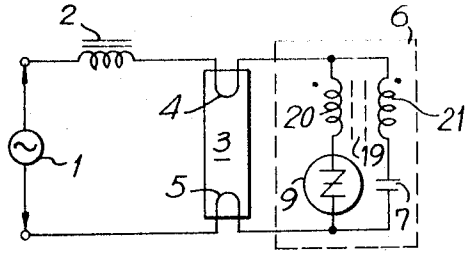
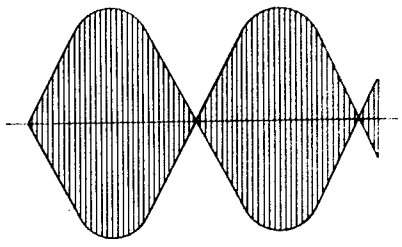


FIG. 5(B)



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FIG. 5 (C)

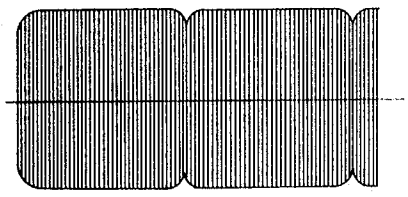


FIG. 5 (D)

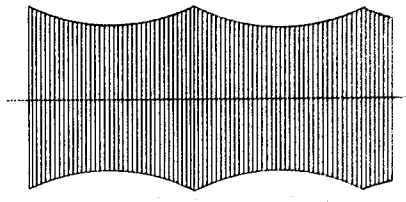


FIG. 6

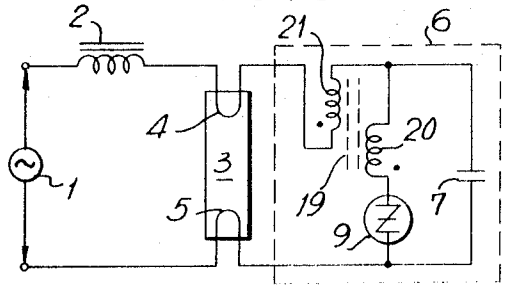


FIG. 7

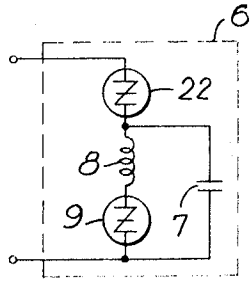


FIG. 8 (A)

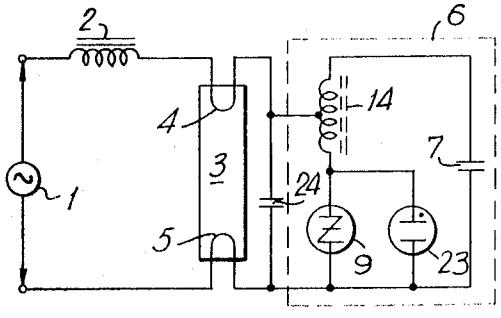
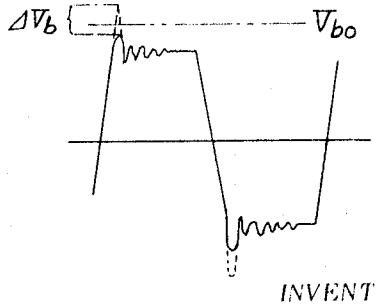


FIG. 8 (B)



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FIG. 9

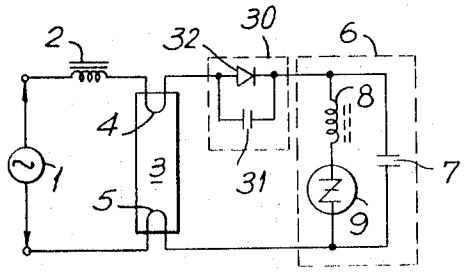


FIG. 11

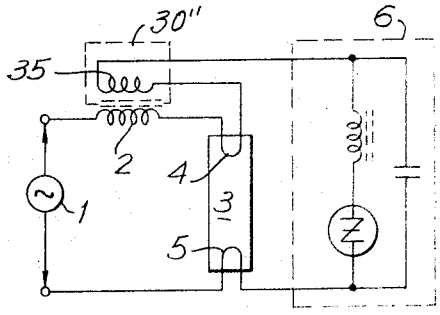


FIG. 10

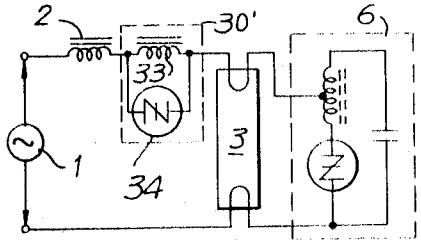


FIG. 12

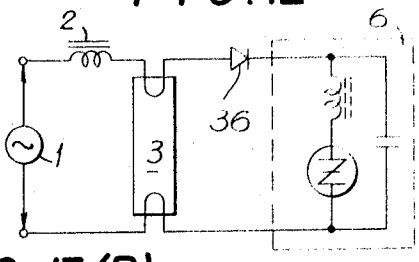


FIG. 13(A)

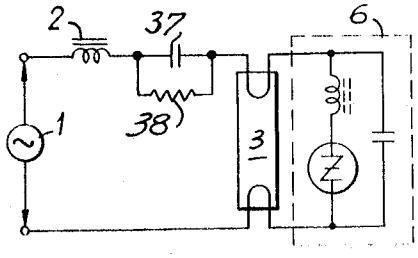


FIG. 13(B)

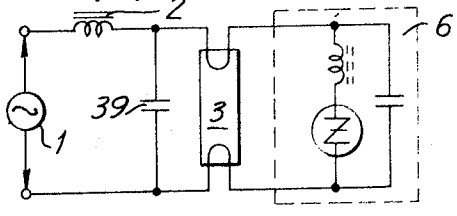
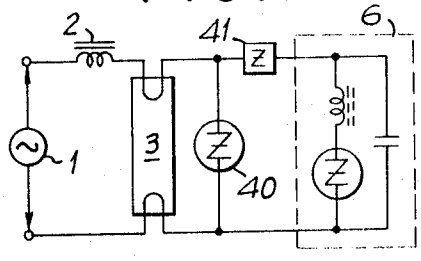


FIG. 14



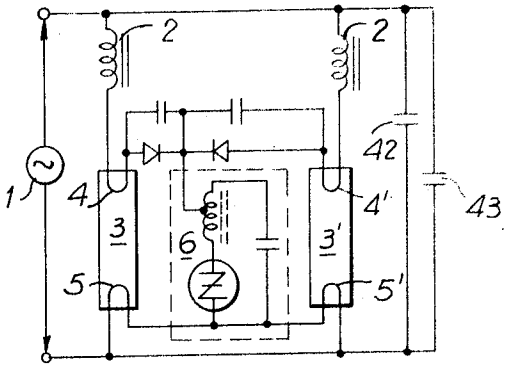


FIG. 15

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FIG. 16

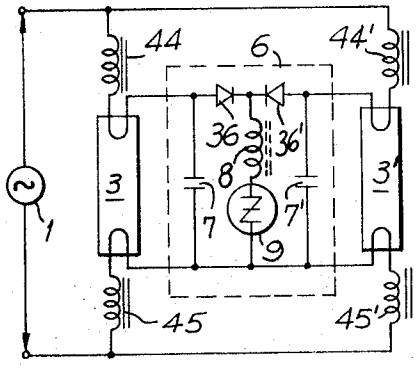


FIG. 17

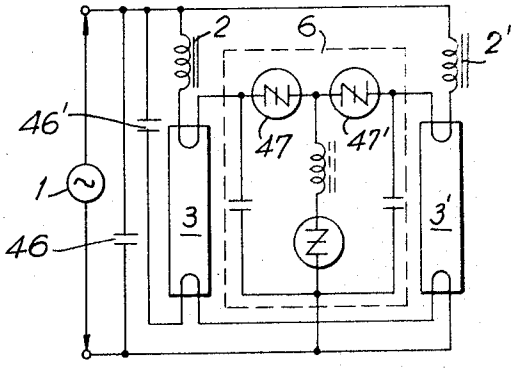


FIG. 18

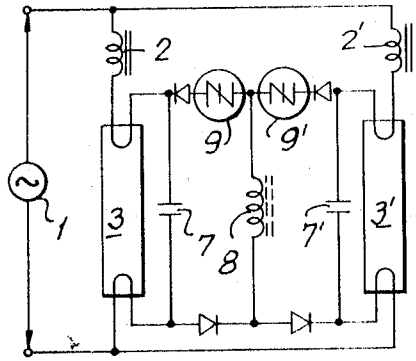


FIG. 19

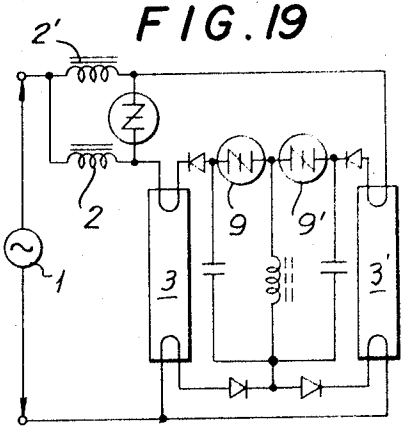


FIG. 20

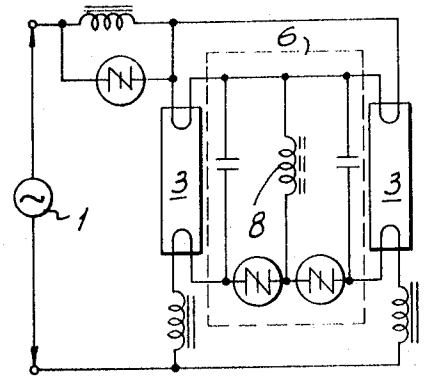
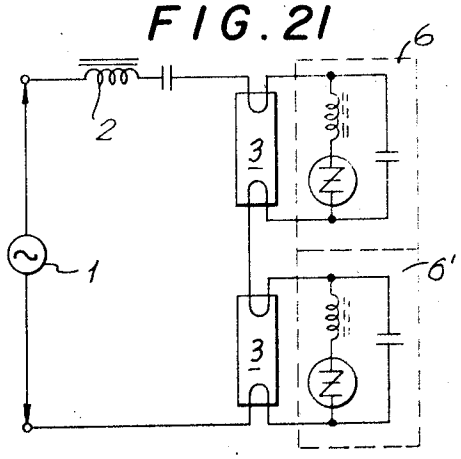


FIG. 21



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DISCHARGE-LAMP OPERATING DEVICE USING THYRISTOR OSCILLATING CIRCUIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to discharge-lamp starting devices and more particularly to structurally simple devices for reliably starting low-pressure discharge lamps, in which an oscillating high voltage produced at the beginning of starting operation by the use of a non-linear thyristor oscillator is applied between the electrodes of the discharge lamp.

2. Description of Prior Art

According to the prior art, part of a choke coil is utilized to generate a pulse voltage, and this pulse voltage is superposed on the power source voltage to initiate the operation of a discharge lamp. In this arrangement, however, it is difficult to generate the pulse voltage because magnetic saturation occurs in the associated iron core when current is supplied to the main coil of the choke for preheating the electrode. This requires the provision of an electrode-heater transformer, and the over-all structure becomes inevitably complicated. Also, it is difficult to terminate generation of the pulse voltage after starting of the discharge lamp. As a result, the life of the discharge lamp is curtailed and, as well, noise is introduced into the power circuit.

On the other hand, voltage amplification is not obtained sufficiently by the well-known pulse generator which uses a thyristor, so that a pulse-transformer is required in the starting of discharge lamps. Such starting device has the disadvantage that pulse energy is decreased due to the large winding ratio of the pulse-transformer used for voltage step-up.

SUMMARY OF THE INVENTION

It is an object of the invention to eliminate the above-noted and other drawbacks inherent in the prior art and to provide an improved discharge lamp operating device.

To achieve the above objects, there is provided in accordance with the invention an improved discharge-lamp operating device having a first circuit device comprising a power source connected in series with a discharge lamp and a choke device for stabilizing the arc discharge of the lamp, and a second circuit device for starting the lamp connected in parallel thereto. The circuit device for starting the lamp comprises a capacitance element connected across the electrodes of the lamp and a voltage responsive switching element having an inductance element connected in parallel with said capacitance element.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1(A) to (B) are circuit diagrams and FIG. 1 (C) is a signal chart illustrating the principles of operation of a device embodying this invention;

FIGS. 2(A) to (D) are circuit diagrams and signal charts in accordance with this invention;

FIGS. 3 and 4 are circuit diagrams showing other embodiment relating to FIGS. 2 (A) — (D);

FIGS. 5(A) to 5(D) are a circuit diagram and signal charts showing other embodiment of the invention relating to FIG. 1(A);

FIG. 6 illustrates a modification of the embodiment of FIG. 5(A);

FIG. 7 is a circuit diagram showing another modification of the embodiment of FIG. 1(A);

FIG. 8(A) illustrates a modification of the embodiment of FIG. 2(C) and FIG. 8(B) shows the waveform of the tube voltage of the discharge lamp of FIG. 8(A);

FIGS. 9 through 11 are circuit diagrams having an improved pre-heating circuit in accordance with further embodiments of this invention;

FIG. 12 is a circuit diagram suitable for operation at low temperature;

FIGS. 13(A) and (B) are circuit diagrams using a condenser for high frequency heating and leading power-factor operations respectively;

FIG. 14 is another circuit diagram of a variation of FIG. 12;

FIGS. 15 through 20 are circuit diagrams of still further embodiments for the operation of a plurality of parallel discharge lamps; and

FIG. 21 is a circuit diagram showing an embodiment for the operation of a plurality of series discharge lamps.

DETAILED DESCRIPTION

The invention will hereinafter be explained in detail with reference to the appended drawings.

FIG. 1(A) illustrates an embodiment of the invention wherein an AC power source **1**, a choke coil **2** and a discharge lamp **3** having electrodes **4** and **5** are connected in series. Also shown is a starting circuit **6** including a condenser **7** and an inductor **8** thyristor **9** connected across the discharge lamp **3** in parallel.

FIG. 1(B) is a modification wherein starting circuit **6'** includes a high frequency transformer **10** having a primary winding **11** and a secondary winding **12**. In this embodiment, a bidirectional element (for example, a silicon symmetrical switch) is used as the thyristor switching element which turns on at a voltage below the power source voltage and above the tube voltage of the discharge lamp. Instead of this element, a unidirectional element may be used.

The electrode preheating starting circuit is designed so that this circuit will have a high impedance with respect to the power source frequency by virtue of the capacitor **7** when the thyristor switching element **9** is in its non-conducting state, or will have a low impedance when the switching element **9** is in its conducting state, namely when the capacitor **7** is in its short-circuiting state.

The operation of this circuit will next be described below. When power from the AC source **1** is supplied to the circuit, the capacitor **7** is not charged at the beginning of each half cycle. In this state, the impedance of this capacitor is zero. Accordingly, a small current flows in a closed circuit including elements **1-2-4-7-5-1**. As a result, the electrodes **4** and **5** of the discharge lamp **3** are heated slightly and charging of the capacitor **7** starts. When the voltage across the capacitor **7** reaches a certain definite value at time t_1, the thyristor switching element **9** turns on and the capacitor **7** releases its charge rapidly into closed circuit including elements **7-8-9-7**. Repeating the above cycles, inductance voltage e_1 across the terminals of the inductor **8** is developed into a value nearly equal to that of condenser voltage e_c across the condenser **7**, and the condenser voltage e_c becomes higher than the break-over voltage V_{bo} of the thyristor **9**. As a result, an oscillating voltage is applied to the discharge lamp **3**. When a current passing through the thyristor is decreased and cancelled by the current flowing into the elements **1-2-4-8-9-5-1**, it is impossible for the thyristor switching element **9** to sustain its holding current and the switching element turns off.

In this way, a series of the above described operations occurs several times whereby an oscillating voltage is generated out successive times. In the course of this operation, the instantaneous value of the current is increased gradually. Thus, when the thyristor switching element **9** turns on at time t_2 and becomes able to sustain its holding current, the switching element **9** maintains its conducting state whereby generation of the oscillating voltage is stopped at times as described hereinafter in FIG. 2(D), and the current for heating the electrodes **4** and **5** is increased to a normal value. Since the oscillation frequency is significantly high, the second closed circuit is deemed to be a short-circuit with respect to the source voltage having the frequency of a commercial power source.

In the same way, a series of the above operations is repeated at each half cycle and, as a result, the electrodes **4** and **5** are sufficiently heated and thus the discharge lamp **3** is appropriately illuminated. suppresses

When the discharge lamp **3** is once illuminated, the semiconductor switching element cannot remain in the conducting state since the conduction starting voltage of the switching element **9** is higher than the tube voltage of the

discharge lamp 3. Accordingly the oscillating voltage generator circuit automatically stops generating the oscillating voltage. Under this condition, the circuit 6 has a high impedance against the power source frequency. This means that power consumption is decreased and the electrode 4 and 5 of the discharge lamp 3 are operated normally at all times.

In other words, this device is operated in such manner that the semiconductor switching element S becomes conducting due to the voltage across the capacitor C, the charge stored in the capacitor C being rapidly discharged into the series circuit consisting of L and S, and a parallel resonance is brought about in the L–C circuit, thereby initiating ignition of the discharge lamp. During the oscillation, the current i_c flowing in the capacitor C and also the current i_s flowing in the semiconductor switching element S take continuous oscillation waveforms respectively as shown in FIG. 1(C). In FIG. 1(B), oscillating voltage induced in the primary winding 11 of the high-frequency transformer 10 is stepped up by the secondary winding 12 and is applied to the lamp 3.

The embodiment of FIG. 2(C) is an improved circuit suitable particularly for a discharge lamp wherein emission is decreased (i.e. when the life of the lamp is terminating) or wherein the mercury vapor pressure is lowered due to use of the lamp in a frigid environment, or wherein an electrode filament is almost broken due to the condition in which the discharge start voltage is extremely large due to a failure such as leakage in the discharge lamp. In such discharge lamp, it is inevitable that a large current (such as more than 3 amperes in a 20 watt lamp) is kept flowing. This serves to produce a considerable amount of heat in the capacitor C due to dielectric loss. This means that the capacitor used for this device must be a high-frequency capacitor whose tanδ is small. Furthermore, the diameter of the winding of the high-frequency coil L must be large enough to cope with this large current. Also an expensive material producing little high-frequency loss must be used for the magnetic core. In addition, the semiconductor switching element must have a large current capacity.

FIG. 2(C) also shows an improvement with respect to discoloration of the discharge lamp caused by applying the high-frequency voltage generated by the starting circuit device, and with respect to short life of the lamp which is caused by keeping said high voltage impressed for a period of about 100 cycles to initiate turn-on after the power switch has been closed.

Namely, the embodiment of FIG. 2(C) is characterized in that said oscillation is stopped at an arbitrary phase angle before $\pi/2$ in each half-cycle of the AC power supply. The principle of said oscillation stop at an arbitrary point will next be described relative to FIG. 2(A) in which two coils L_1 and L_2 are provided for a magnetic core T, a low-frequency power source EL is connected to the coil L_1 by way of a low-frequency impedance ZL, and a high-frequency power source EH is connected to the coil L_2 via a high-frequency impedance ZH. In this circuit, it is assumed that the high-frequency voltage is kept constant, and the low-frequency voltage is used as a kind of bias . Then, as shown in FIG. 2(B), since the magnetic core T has a hysteresis characteristic, the flux density B is largely varied by the low-frequency current I_1 during the period a'—b'–c' At c', the magnetic core is saturated. The flux density B is nearly constant for the period c'–d'. Hence, it becomes possible to oscillate the circuit only during the periods a'–c' and d'–f' of the low-frequency current I_1 whereby a high-frequency voltage is obtained and the oscillation can be stopped during the periods c'–d' and f'–a'. Similarly, an oscillation is produced during the periods a''–c'' and d''–f'' of a larger low-frequency current I_2 whereby high-frequency voltage is obtained, and the oscillation is stopped during the periods c''–d'' and f''–a''. (Strictly speaking, the B–H curve varies with a variation of the low-frequency current; however, FIG. 2(B) shows only one B–H curve for simplicity of explanation.)

In the above operation, it is arranged to vary the low-frequency current. Instead, the high-frequency current may be varied. Also keeping the current constant, a magnetic core having a different hysteresis characteristic may be used.

FIG. 2(C) shows such an embodiment wherein an AC power supply 1 of commercial frequency, a choke coil 2, and a discharge lamp 3 having electrodes 4 and 5 are connected in series and wherein there is provided a starting device 6 including a capacitor 7 having a high impedance against said commercial frequency, and a semiconductor switching element 9 operatable according to the voltage across the capacitor 7. This device is different from the embodiment shown in FIG. 1 in that a high-frequency coil 14 is provided which has an intermediate tap via which power is supplied thereto.

The operation of the circuit of this embodiment will be explained below. When the AC power is supplied, the capacitor 7 is charged by way of part 15 of the high-frequency coil 14 and the semiconductor switching element 9 becomes conducting according to the voltage across the capacitor 7. As a result the charge across the capacitor 7 is rapidly released via the coil 14 whereby the capacitor 7 and coil 14 effect a resonance and a high-frequency voltage is thus obtained. In this operation, the direction of current flowing in the part of coil 15 in the charging turn is the reverse of that in the discharging turn. Accordingly, the magnetic core of the high-frequency coil 14 is excited by the low-frequency current which represents the difference between these mutually reversed currents. Thus, when the core is saturated at an arbitrary phase angle before $\pi/2$ in each half-cycle of the AC power supply, the flux density of the high-frequency coil 14 is no longer varied and the oscillation is stopped. As a result, the current i_c flowing in the capacitor 7 becomes zero, the current i_s flowing in the semiconductor switching element 9 becomes a low-frequency current, and this state is maintained to the end of the half-cycle. A series of such operations is repeated in each half-cycle of the AC power supplied and thus an intermittent oscillation voltage as shown in FIG. 2(D) is applied to the discharge lamp 3. When the electrodes 4 and 5 are sufficiently heated, the discharge lamp 3 is illuminated. When the discharge lamp 3 has been illuminated, the semiconductor switching element 9 cannot stay in its conducting state and the oscillation is stopped precisely as required. In this way, the discharge lamp 3 receives no undesirable influence.

FIG. 3 shows another embodiment of the invention wherein a capacitor 17 having a small capacity is connected in parallel with the high-frequency coil 8. According to this circuit, the capacitor 17 connected in parallel with the inductor 8 varies the back-swing characteristic of the inductor 8 so as to make a smaller back-swing variation. Therefore, oscillation can be stopped at a small current i_2 by using the capacitor 17, at the time the voltage across the thyristor 9 reaches the break-over voltage V_{bo} thereof. In this embodiment, it may be so arranged that a secondary coil is provided for the high-frequency coil 8, and the capacitor 17 is connected to this secondary coil.

FIG. 4 shows another embodiment of the invention wherein a resistor 18 having a high resistance is connected in parallel with the capacitor 7. According to this embodiment, the current flowing in the resistor 7 serves to excite the high-frequency coil 8 in the direction against the flow of the discharge current. This circuit operates with the same effect as in the arrangements of FIGS. 2(C) and 3, which make it possible to turn on the discharge lamp quickly and securely with the aid of oscillation on the initial drive. Furthermore, the oscillation period can be reduced to less than $\pi/2$ and, as a result, the oscillation current can be set at an arbitrary value which is ¼th to 1/20th of that required according to the embodiment of FIG. 1.

FIG. 5(A) shows a further embodiment which eliminates varying light at low level at the beginning of a starting operation.

In FIG. 5(A), a starting device 6 includes a capacitor 7, a semiconductor switching element 9 and a high-frequency coil 19 having a pair of windings 20 and 21. The capacitor 7 has a high impedance with respect to power source frequency. The core of the high frequency coil 19 consists of toroidal ferrite or the like, and is provided with a pair of windings 20 and 21 disposed in the oscillation circuit to be operated demagnetizingly or in bucking relation.

The operation of the above circuit will next be explained. When power is supplied thereto from the AC power source **1**, the capacitor **7** is charged. Due to this, the semi-conductor switching element **9** becomes conducting, and the capacitor **7** and high-frequency coil **19** oscillate. Thus, a high-frequency high voltage is applied to the discharge lamp **3**. At the same time, the electrodes **4** and **5** are heated by the current supplied to the starting device **6**. When the electrodes are sufficiently heated, the discharge lamp is appropriately discharged for lighting and, after starting, the oscillation is automatically stopped in the manner according to the above-described embodiments of FIGS. **2** to **4**. In this embodiment, the starting operation is effectively carried out since the windings **20** and **21** are connected demagnetizingly with each other.

More specifically, when the number of turns of the winding **21** is zero, the oscillation voltage will take a waveform as shown in FIG. **5**(B). When the winding **21** has its turn ratio 1 : 1 with respect to the winding **20**, the oscillation voltage will take the waveform shown in FIG. **5**(C). If the turn ratio between the two windings is 3 : 1, the waveform will be as shown in FIG. **5**(D). In any case, the oscillation frequency becomes about ten times that in FIG. **5**(B). Furthermore, its instantaneous value is reduced and the envelope does not reach zero. Accordingly, the light intensity is increased steadily during the beginning of the starting operation. In other words, visibly comfortable starting can be realized according to this arrangement.

The windings **20** and **21** are connected demagnetizingly with each other and, hence, the combined inductance L of the ferrite core is varied with respect to each instantaneous value. The value of *di/dt* is remarkably increased and the oscillation frequency is accordingly increased. At the same time, the value of L (*di/dt*) is decreased and the instantaneous value is accordingly decreased.

FIG. **6** shows a modification of this embodiment wherein the winding **21** is connected in series with the oscillator circuit consisting of a capacitor **7** and a series circuit of the semiconductor switching element **9** and winding **20**. In this arrangement, the winding **21** through which current is supplied to the oscillator circuit is connected demagnetizingly to the winding **20** through which the discharge current from the capacitor **7** flows whereby the same effect as shown in FIG. **5**(A) is obtained.

FIG. **7** is another embodiment in which the supply of high-frequency voltage can be automatically stopped after starting of the lamp. This embodiment is characterized by the adding of a voltage responsive switching element **22** connected in series with the oscillating voltage generator for starting discharge lamps as shown above. As shown in FIG. **7**, a starting circuit including switching element **22** which is effective in operation at low temperatures to eliminate defects due to the elevated tube voltage is connected to a discharge lamp such as a fluorescent lamp having a hot cathode. The same components as shown in FIG. **1** are indicated by the common references. The voltage generator **6** is constituted of a capacitor **7**, a voltage responsive switching element **9** and a coil **8**.

In this embodiment, when power is supplied to the circuit from the power source **1**, the power source voltage is applied to the element **22** by way of the capacitor **7**. Due to this, the element **22** becomes conducting, and the capacitor **7** is charged. When the voltage across the capacitor **7** reaches the operating voltage of the element **9**, the element **9** becomes conducting, and the charge across the capacitor **7** is rapidly discharged into the closed circuit consisting of elements **7-9-8-7**. As a result, a voltage is induced in the coil **8** and is applied to the discharge lamp **3**. Accordingly, the electrodes **4** and **5** are heated. A series of such operations is repeated at each half-cycle of the power source. When the electrodes **4** and **5** are sufficiently heated, the discharge lamp **3** turns on. When the lamp **3** is illuminated, it becomes impossible for the element **22** to stay in the conducting state any longer because the operating voltage of the element **22** is higher than the tube voltage of the lamp **3**. As a modification of FIG. **7**, a circuit consisting of a condenser and a parallel resistor can be connected in parallel to the switching element **22** in order to prevent radio noise.

When said resonance is utilized in the arrangement, a discharge lamp (e.g., a 40 watt fluorescent lamp) can be ignited reliably even at a low temperature such as −20° C. Thus, a high-frequency voltage is applied to the circuit thereby initiating ignition of the discharge lamp and, once the lamp is illuminated, supply of the high-frequency or pulse voltage is terminated. In addition, the discharge lamp can be ignited at a very low temperature.

FIG. **8**(A) shows another embodiment which improves on the embodiment of FIG. **2** and permits stable starting even at low temperature.

Generally, when a discharge lamp is initiated by AC power of commercial frequency, the tube voltage takes a square waveform as shown in FIG. **8**(B). The leading edge of the wave is steep. This is because the arc is first extinguished and glow discharge is formed in the reverse direction and then another arc discharge is started. The width of this rise portion or leading edge is in the order of milliseconds. The width increases with an increase in the capacity of the noise preventing capacitor usually connected in parallel with the lamp. In low temperature atmospheres, the rise is remarkably steep.

On the other hand, the break-over voltage V_{bo} of the semiconductor switching element (e.g. thyristor) in the starting circuit **6** is lower than the maximum instantaneous value of the power source voltage and higher than the maximum instantaneous value of the tube voltage of the discharge lamp. This breakover voltage V_{bo} has a sufficient amount of margin covering almost all kinds and capacities of fluorescent lamps under normal operating conditions. However, when the discharge lamp is operated in low temperature atmosphere or at a high tube voltage, or when the capacity of the capacitor **7** in the starting circuit **6** is large, said margin is not always sufficient, and the tube voltage will have a very high rise portion in its waveform as indicated by the dotted line in FIG. **8**(B). In some cases, the value of this rise portion ΔV_b is more than **20** V. Hence, in some discharge lamps, the value ΔV_b exceeds the break-over voltage V_{bo} of the semiconductor switching element **9**. As a result, it may often be the case that an oscillation is brought about at the beginning of each half-cycle whereupon the lighting flickers or the arc discharge cannot be maintained.

The starting circuit **6** of this embodiment has an element such as a discharge tube **23** which allows current flow prior to turn-on of the thyristor **9** and which has a suitable impedance and is connected substantially in parallel with the thyristor **9**.

In the operating circuit arrangement shown in FIG. **8**(A), the reference **24** denotes a noise preventing capacitor. The capacitor **7** acts as a noise preventing capacitor, if the part of coil **14** has a small impedance. The ignition voltage at which the discharge starts in the discharge tube **23** is lower than the breakover voltage V_{bo} of the semiconductor switching element **9**.

The operation of this circuit will next be described. When power is supplied thereto from the AC power source **1**, the capacitor **7** and high-frequency coil **14** of the starting circuit device **6** oscillate to turn on the discharge lamp. When the rise portion ΔV_b becomes large due to, for example, a low temperature environment, the discharge tube **23** releases its charge. Most of the energy due to V_b is absorbed by this circuit. As a result, the thyristor becomes inoperative. Even if the thyristor **9** is operated, this will not bring about oscillation. Thus, a stable discharge operation is maintained for the discharge lamp **3**.

Instead of the discharge tube **23**, a semiconductor switching element such as a Diac which has a relatively large operating resistance may be used, or a resistor may be used. By such means, a stable discharge condition can be maintained even at a low temperature such as −5° to −10° C.

For increasing current to pre-heat the filament of a discharge lamp of pre-heat type during the starting period,

various operating circuit arrangements are possible in accordance with the invention.

FIG. 9 is an embodiment characterized by a current-increasing circuit 30 for pre-heating the filament. This arrangement essentially comprises a closed circuit of a condenser 31 and a diode 32 connected in series with the condenser 31. The current-increasing circuit 30 is connected between the electrode 4 and the starting circuit device 6 described in the fundamental embodiment of this invention shown in FIG. 1(A). In order to adjust the charge and discharge period of the condenser 31 and to control the preheating current for the lamp 3, a resistor may be connected to the condenser 31 in parallel or in series. It is also possible to use a thermistor as a resistance element as part of all of the resistance component.

FIG. 10 is another embodiment. In this embodiment, increasing circuit 30 comprises a coil section 33 of the choke coil 2 and a semiconductor switching element 34 connected in parallel with the divided coil section 33. When the first high oscillating voltage is produced by the starting circuit device 6, the semiconductor switching element 34 is conducting due to the effect of dV/dt, and the pre-heating current can thus be increased.

FIG. 11 shows another embodiment of this invention. This arrangement, a current-increasing circuit 30'' for pre-heating the filament of the lamp comprises a coil winding 5 connected demagnetizingly with the choke coil 2. Circuit 30'' is connected between the electrode 4 of the lamp 3 and the starting circuit device 6, thereby eliminating the use of the semiconductor switching element 34 in the embodiment of FIG. 10.

For improvement of the tube voltage as described in the embodiment of FIG. 8(B), a diode 36 can be connected between the electrode 4 of the lamp and the starting circuit as shown in FIG. 12. The diode 36 supresses the peak voltage caused by charging the condenser 7 on reversing the current.

FIG. 13(A) shows a further embodiment for a leading power factor, in which a condenser 37 is connected in series between the choke coil 2 and one filament of lamp 3. A resistor 38 is usually used to protect against capacitor failure.

FIG. 13(B) shows a still another embodiment for pre-heating the filament by both high and low frequency. The circuit arrangement includes a condenser 39 in the first closed circuit, which is connected in parallel across the lamp 3. The capacitor 39 can pass the current i_2 in the second closed circuit through the filament because of the high frequency. On the other hand, the current i_1 from the power source 1 flows through the filaments of the lamp during the pre-heating period. Therefore, both the high and low frequency currents can heat the filaments of the lamp 3. As a result, ignition of the lamp is achieved rapidly by increasing filament currents.

FIG. 14 shows a further modification of FIG. 12 in which a thyristor 40 having a break-over voltage higher than the starting voltage of the lamp is connected in parallel with the lamp 3. An impedance means, which is originally used for reducing the current flowing into the thyristor 40 and which also acts as a stabilizer against an abnormal oscillation, is connected in series with the starting circuit device 6.

FIGS. 15 through 20 are circuit arrangements for a plurality of parallel discharge lamps. FIG. 15 shows a circuit arrangement having a single starting circuit and a pair of lamps. This circuit is considered as combination of embodiments in FIGS. 1(B) and 9. A condenser 42 for power-factor improvement and a condenser 43 for preventing noise are connected in parallel with the power source 1.

FIG. 16 illustrates a modification of the circuit arrangement of FIG. 15 in which the choke coil is divided into two portions 44 and 45 and the pair of diodes 36 and 36' are connected between the capacitor 7 or 7' and the thyristor 9. In the circuit arrangement of FIG. 17, one of a pair of condenser 46 and 46' for power-factor improvement can be used in a pre-heating circuit and semiconductor switching elements 47 and 47' are used in substitution for diodes 36 and 36' in FIG. 16. Further modifications are disclosed in FIGS. 18, 19 and 20, in which the references are the same as the hereinbefore described embodiments.

FIG. 21 shows a typical embodiment for the sequence circuit which is based on the embodiment of FIG. 1(A).

What is claimed is:

1. Apparatus comprising a first closed circuit including a power supply, a choke and a discharge lamp connected in series in said closed circuit; and a second closed circuit including a semiconductor switching element, a capacitor and an inductance element separate from said choke, said switching element and inductance element being connected in series with each other and in parallel with said lamp, said capacitor also being in parallel with said lamp, the lamp being adapted for being ignited and in discharging state having a characteristic tube voltage, said switching element being characterized by a conduction starting voltage which is higher than said tube voltage, said capacitor and inductance element forming a resonant circuit adapted for generating an oscillating voltage which is applied to said lamp, said lamp including electrodes respectively connected between said power supply and capacitor, said power supply charging said capacitor through said electrodes which are thereby heated, said switching element conducting when the capacitor achieves a charge equal to said conduction starting voltage whereupon said oscillating voltage is developed by said resonant circuit, the heating of said electrodes and the developing of said oscillating voltage igniting said discharge lamp, the tube voltage of which prevents the switching element from conducting.

2. Apparatus as claimed in claim 1 comprising a further capacitor connected across said inductance element.

3. Apparatus as claimed in claim 1 comprising a resistor connected across said capacitor.

4. Apparatus as claimed in claim 1 comprising a further capacitor for leading power factor connected in series with said choke and lamp.

5. Apparatus as claimed in claim 1 comprising a further capacitor connected in parallel with said lamp at the side opposite to said second closed circuit.

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