

**July 5, 1966**

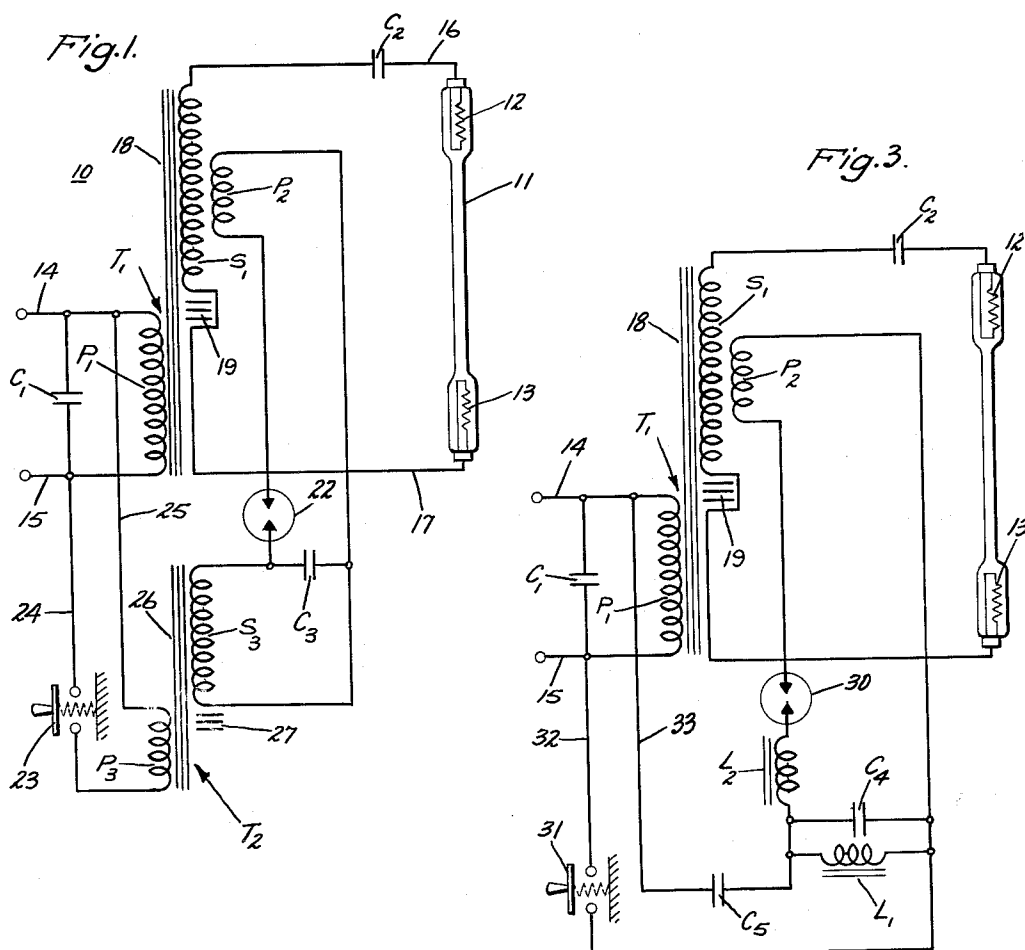
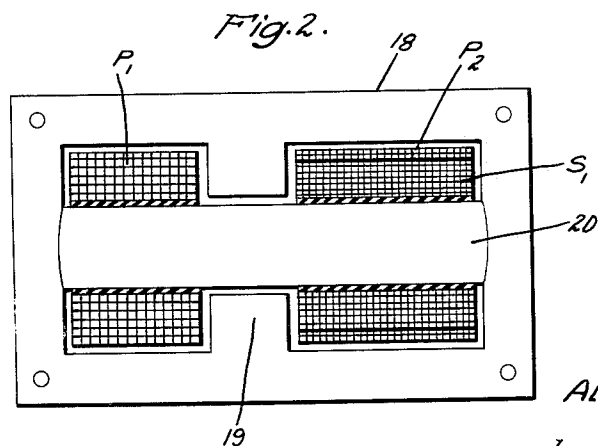
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**3,259,796**

# APPARATUS FOR STARTING AND OPERATING ARC LAMPS

Filed June 10, 1963

3 Sheets-Sheet 1



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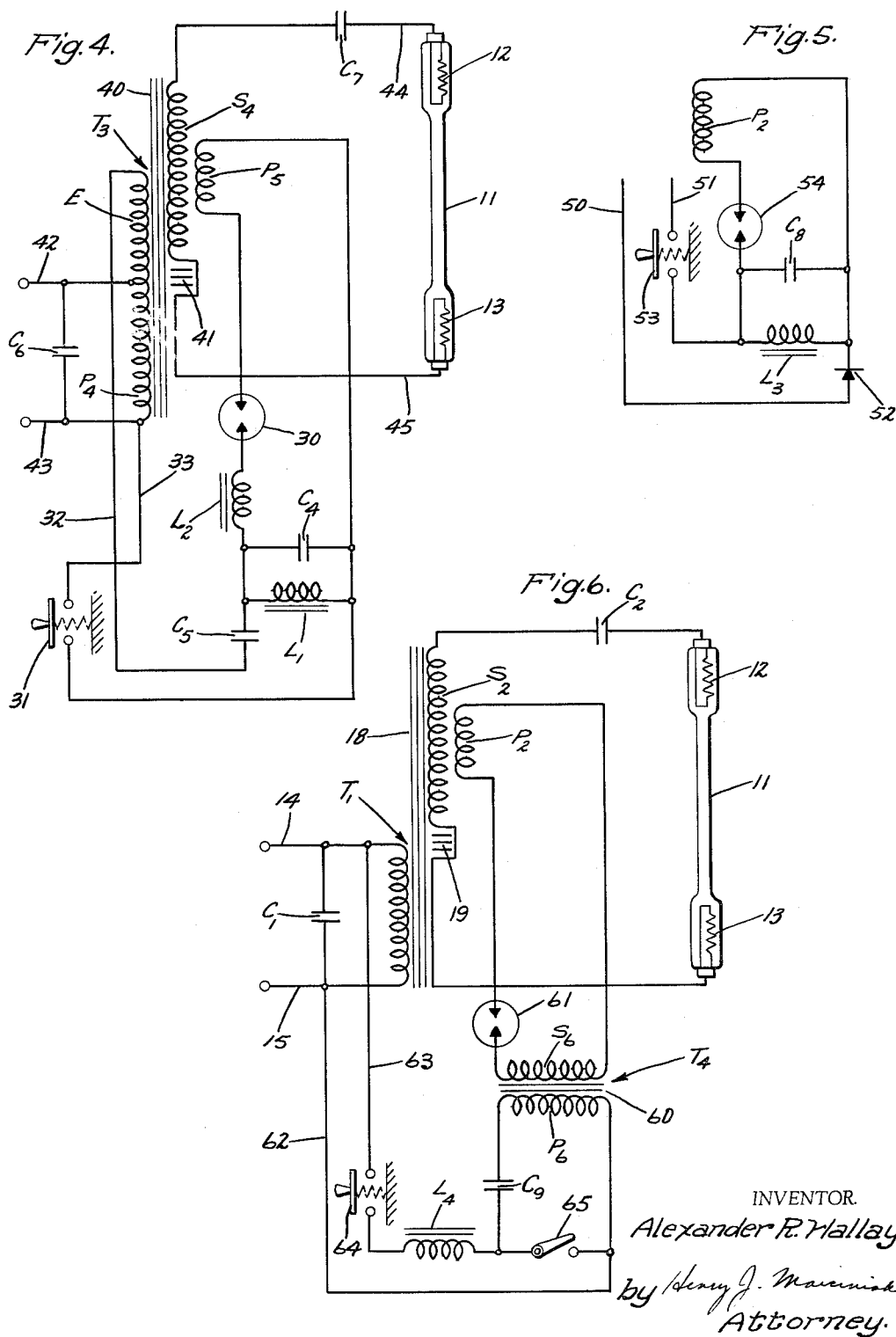
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APPARATUS FOR STARTING AND OPERATING ARC LAMPS

Filed June 10, 1963

3 Sheets-Sheet 2



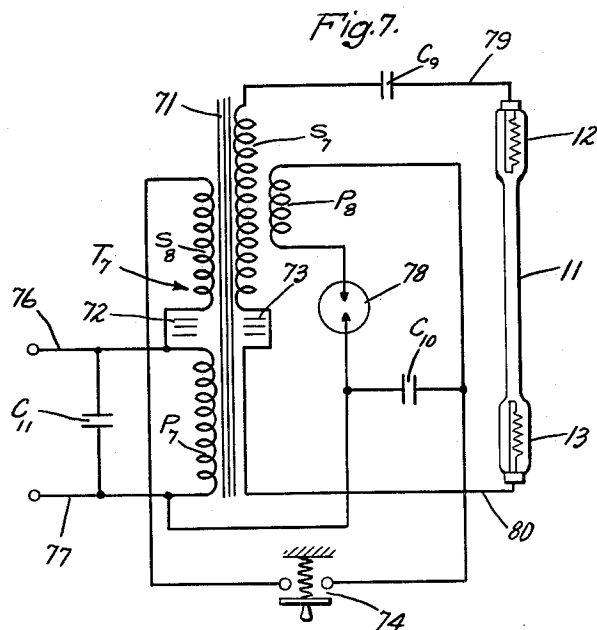
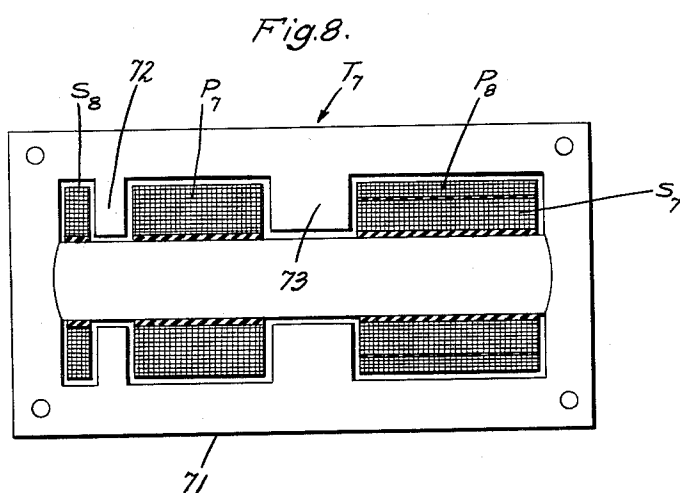
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# APPARATUS FOR STARTING AND OPERATING ARC LAMPS

Filed June 10, 1963

3 Sheets-Sheet 3



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3,259,796

## APPARATUS FOR STARTING AND OPERATING ARC LAMPS

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12 Claims. (Cl. 315-174)

This invention relates to apparatus for starting and operating arc lamps and more particularly to such apparatus wherein the starting or ignition of the lamp or lamps is accomplished by pulses superposed on the open circuit voltage of the apparatus. The present application is a continuation-in-part of application Serial No. 255,539, filed February 1, 1963, now abandoned.

Recently developed compact arc lamps, such as cesium and sodium metal vapor lamps, possess many desirable features among which are improved efficiency of operation and improved color characteristics. These lamps, however, require an extremely high peak voltage for ignition as compared with high pressure mercury vapor lamps, which generally have a peak starting voltage ranging from 200 to 300 volts. On the other hand, compact arc lamps usually require a peak starting voltage from 800 to 1,500 volts. The compact lamps are then operated at a voltage between 50 and 120 volts with an operating current ranging between 6 and 12 amperes.

For a given arc lamp the peak voltage required to start or ignite the lamp will generally depend upon factors such as vapor pressure, electrode spacing, electrode geometry and other lamp characteristics. Since conventional high reactance transformers designed to provide open circuit voltages above 800 volts are usually relatively inefficient, expensive and bulky, it is not desirable to design high reactance ballast transformers to supply such high starting voltages.

The high pressure compact arc lamp, which the apparatus of the invention is particularly suitable for starting and operating, is comprised of an envelope formed of a light transmissive material having a high melting point, such as quartz or polycrystalline alumina ceramic material. The inner diameter of the arc tube may be as small as 6 millimeters. For example, a typical arc lamp with an inner diameter of 6 millimeters and an electrode distance of 50 to 60 millimeters has a peak breakdown voltage of approximately 1800 volts. If the arc tube is filled with argon or xenon to a pressure of about 20 millimeters of mercury, the peak breakdown voltage may be reduced to approximately 1100 volts.

Accordingly, it is an object of the invention to provide an improved apparatus for starting and operating an arc lamp having a peak starting voltage of 800 volts or more.

A more specific object of the invention is to provide an improved apparatus for starting compact arc lamps wherein the main primary and secondary windings of the ballast transformer do not have to provide the peak voltage required to start the arc lamp.

It is another object of the invention to provide an improved apparatus for starting and operating compact arc lamps that will reliably start the lamp.

A further object of the invention is to provide an improved apparatus for starting and operating a compact arc lamp wherein high voltage pulses are used to start the lamp but are effectively prevented from being fed back into the supply lines.

According to one form of my invention I have provided an improved apparatus for starting and operating arc lamps of the type which may require, for example, a peak voltage between 800 and 1500 volts to start the lamps. The operating voltage is supplied by an operating transformer, which is of the high leakage reactance

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type and has a primary winding and a loosely coupled secondary winding. In order to provide the high peak voltage required to start or ignite the lamp, the improved arrangement includes an auxiliary winding which is inductively coupled with the secondary winding of the high reactance transformer and is preferably wound over the secondary winding. The auxiliary winding is coupled with a pulse generating means.

In one embodiment of my invention, the pulse generating means includes a second high reactance transformer having a primary and a secondary winding, a capacitor and a spark gap means. The capacitor is connected in parallel circuit with the secondary winding of the second high reactance transformer and also is connected to the auxiliary winding. The capacitor provides sufficient capacitance in the circuit as compared with the inductance of the secondary winding so that an oscillatory current or pulses will be supplied to the auxiliary winding. In order to increase the frequency of the current pulses supplied to the auxiliary winding a spark gap is connected in the auxiliary winding circuit. By employing a second high leakage reactance transformer in conjunction with a filter capacitor, feedback to the supply lines is minimized.

During the starting condition of the apparatus when pulses are supplied to the auxiliary winding, it and the secondary winding of the operating high reactance transformer effectively operate as a pulse transformer to supply a pulsed output voltage of sufficient magnitude to start the arc lamp. This arrangement permits a relatively smaller transformer to be used to operate the arc lamp. The subject matter which I regard as my invention is set forth in the appended claims. The invention itself, however, together with further objects and advantages thereof may be understood by referring to the following description taken in connection with the accompanying drawings in which:

FIGURE 1 is a schematic circuit diagram of an apparatus for starting and operating an arc lamp embodying one form of the invention;

FIGURE 2 is a diagrammatic illustration of the core and coil assembly of the operating transformer used in the embodiment of the invention shown in FIGURE 1;

FIGURE 3 illustrates another embodiment of the invention in which the pulse generating circuit includes a tank circuit without a high reactance transformer;

FIGURE 4 illustrates a modification of the embodiment of the invention shown in FIGURE 3 wherein an extension winding is used on the operating transformer to supply a stepped up voltage for the pulse generating circuit;

FIGURE 5 illustrates another modification of the pulse generating circuit shown in FIGURE 3;

FIGURE 6 is a schematic circuit diagram of an apparatus for starting and operating arc lamps in which an oscillatory circuit is included on the primary side of a high frequency transformer to provide the current pulses to start the arc lamp;

FIGURE 7 is a schematic circuit diagram illustrating a modification of the circuit shown in FIGURE 1 wherein an extension winding not only provides the stepped-up voltage for the pulse generating circuit but also provides the inductive reactance required for the pulse generating circuit; and

FIGURE 8 is a diagrammatic illustration of the core and coil assembly of the operating transformer used in the embodiment of the invention shown schematically in FIGURE 7.

Referring now more particularly to FIGURE 1 of the drawings, the apparatus 10 is intended for starting and operating an arc lamp 11 consisting of a tubular envelope of light transmissive material and electrodes 12, 13 dis-

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posed at opposite ends. The operating circuit includes a pair of input leads 14, 15 adapted for connection to a suitable alternating current supply, a filter capacitor C<sub>1</sub>, a high leakage reactance transformer T<sub>1</sub>, a series capacitor C<sub>2</sub>, and a pair of output leads 16, 17. The high reactance transformer T<sub>1</sub> is comprised of a primary winding P<sub>1</sub>, a secondary winding S<sub>1</sub> loosely coupled with the primary winding P<sub>1</sub> on a magnetic core 18, an auxiliary winding P<sub>2</sub> and magnetic shunts 19. A predetermined amount of leakage reactance is provided by the inclusion of a high reluctance flux leakage path or the shunts 19 in the magnetic core between the primary winding P<sub>1</sub> and the secondary winding S<sub>1</sub>. It will be understood, of course, that depending upon the particular transformer design and application, a flux leakage path may be formed either through magnetic material, such as by the provision of shunts or through nonmagnetic material such as air. As is well known, a shunt construction such as is shown schematically in the drawings, results in a high leakage reactance type of transformer and serves to limit the current flow in the lamp circuit. Since arc lamps have a negative resistance characteristic, it is necessary, of course, to provide some means for limiting the lamp current.

As is shown in FIGURE 2, the auxiliary winding P<sub>2</sub> is wound over the secondary winding S<sub>1</sub>, which is mounted on the winding leg 20 of the magnetic core 18. The primary winding P<sub>1</sub> is mounted on another portion of the winding leg 20 and is separated from the coil assembly, which includes the secondary winding S<sub>1</sub> and the auxiliary winding P<sub>2</sub>, by the magnetic shunts 19. In order to minimize the leakage inductance of the auxiliary winding P<sub>2</sub> the width of the winding P<sub>2</sub> is preferably the same as that of the winding S<sub>1</sub>. Also, preferably the winding P<sub>2</sub> is spirally wound.

In accordance with the invention, under starting conditions, the auxiliary winding P<sub>2</sub> and the secondary winding S<sub>1</sub> operate effectively as a pulse transformer to superpose a pulsed voltage on the open circuit voltage of transformer T<sub>1</sub>. It will be noted that the auxiliary winding P<sub>2</sub> is not connected in the lamp operating circuit but is electrically connected in the pulse generating circuit, which will now be more fully described.

The pulse generating circuit includes a high leakage reactance transformer T<sub>2</sub>, a capacitor C<sub>3</sub>, a spark gap 22, a switch 23 and input connections 24, 25. Preferably, a high reactance type of transformer T<sub>2</sub> is employed in the starting circuit since the high reactance transformer T<sub>2</sub> limits the current in the auxiliary winding circuit to a relatively safe value when spark gap 22 breaks down.

High reactance transformer T<sub>2</sub> is comprised of a magnetic core 26, a primary winding P<sub>3</sub> and a secondary winding S<sub>3</sub>, and magnetic shunts 27, which provide the desired leakage reactance. If desired, the input connections 24, 25 may be connected to the input leads 14, 15 so that only a pair of leads need be connected across a power supply to energize the apparatus 10. The switch 23 is a push button type of switching means and during the starting condition is closed to momentarily energize the pulse generating circuit. After the arc lamp 11 is ignited or ionized switch 23 is released and is normally in the open position during operation.

In order to start or ignite the arc lamp 11, the input leads 14, 15 are connected in circuit with a suitable power supply, such as a 115 volt, 60 cycle source, and switch 23 is closed to energize the high reactance transformer T<sub>2</sub>. The capacitor spark gap 22 is fired when the voltage across the capacitor C<sub>3</sub> reaches a preselected value, which in the exemplification of the invention was 1000 volts. When the capacitor C<sub>3</sub> discharges, a pulsed oscillatory voltage is provided across the auxiliary winding P<sub>2</sub> of transformer T<sub>1</sub>. By transformer action this pulsed voltage is superposed upon the open circuit voltage of the transformer T<sub>1</sub> and is applied across the arc lamp 11 thereby igniting it. Preferably, it was found that the arc lamp 11 reliably ignited if a series of pulses are applied in each half cycle of the 60 cycle power supply. With

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a hermetically sealed isotope stabilized spark gap 22 having a spacing of  $\frac{3}{16}$  of an inch, it was possible to generate 20 pulses in a half cycle of the 60 cycle power supply.

When the arc lamp 11 was ignited, the switch 23 was released to cut off the power to the starting circuit. The high leakage reactance transformer T<sub>1</sub> provides the requisite operating voltage for the arc lamp 11, and the transformer T<sub>1</sub> and capacitor C<sub>2</sub> provide sufficient impedance in the lamp circuit to limit the current during operation.

By way of a more specific exemplification of the invention, the apparatus 10 shown in FIGURE 1 was reduced to practice, and the following components are given by way of illustration:

|    |                                       |                                                                                                 |
|----|---------------------------------------|-------------------------------------------------------------------------------------------------|
| 15 | Arc lamp 11 -----                     | 600 watt Xenon PXA lamp.                                                                        |
|    | Primary winding P <sub>1</sub> ----   | 192 turns of .0427 of an inch in diameter wire.                                                 |
|    | Secondary winding S <sub>1</sub> ---  | 441 turns of .0538 of an inch in diameter wire.                                                 |
| 20 | Auxiliary winding P <sub>2</sub> ---- | 40 turns of .0201 of an inch wire.                                                              |
|    | Primary winding P <sub>3</sub> -----  | 460 turns of .0201 of an inch in diameter wire.                                                 |
| 25 | Secondary winding S <sub>3</sub> --   | 6000 turns of .0071 of an inch in diameter wire.                                                |
|    | Spark gap 22 -----                    | 3 kilovolt, isotope stabilized, hermetically sealed with $\frac{3}{16}$ of an inch gap spacing. |
| 30 | Capacitor C <sub>1</sub> -----        | 2.0 microfarads 300 volts (A.C.).                                                               |
|    | Capacitor C <sub>2</sub> -----        | 30 microfarads 350 volts (A.C.).                                                                |
|    | Capacitor C <sub>3</sub> -----        | .05 microfarad 3000 volts (A.C.).                                                               |

35 In FIGURES 3, 4, 5 and 6 I have illustrated exemplifications of pulse generating circuits which may be coupled on the operating transformer in accordance with the invention. Since the operating circuit for the arc lamp 11 shown in FIGURES 3 and 6 is essentially the same as the operating circuit of FIGURE 1, I have employed the same reference symbols to identify the corresponding parts.

Referring now more particularly to the starting circuit shown in FIGURE 3, it will be seen that the pulse generating circuit includes a tank circuit which is comprised of a capacitor C<sub>4</sub> and an inductor L<sub>1</sub>. Further, the pulse generating circuit includes a current limiting capacitor C<sub>5</sub>, an inductor L<sub>2</sub>, a spark gap 30, a starting switch 31 and input connections 32, 33. The capacitor C<sub>5</sub> isolates the tank circuit from the power supply and provides the finite time interval required to charge the capacitor C<sub>4</sub> when the switch 31 is initially closed to ignite the arc lamp 11. The inductance and capacitance of the tank circuit are selected to provide a condition near resonance in the circuit at line frequency. The inductor L<sub>2</sub> is essentially an impedance matching device.

In order to start the arc lamp 11 with the starting arrangement shown in FIGURE 3, the starting switch 31 is momentarily depressed to energize the tank circuit. Initially, energy is being stored in the capacitor C<sub>4</sub> of the tank circuit until the charge on the capacitor C<sub>4</sub> reaches the breakdown voltage of the spark gap 30. At this point the spark gap 30 fires thereby discharging the capacitor C<sub>4</sub> through the auxiliary winding P<sub>2</sub> to provide a damped oscillatory pulse that is superposed upon the open circuit voltage of the operating transformer T<sub>1</sub> to ignite the arc lamp 11.

In the circuit shown in FIGURE 4, I have illustrated a modification of the starting circuit of FIGURE 3 in which the input connection 32 of the starting circuit is connected to an extension winding E of an operating transformer T<sub>3</sub>. Since the starting circuit illustrated in FIGURE 4 is essentially the same as the starting circuit of FIGURE 3, the same reference symbols are used to identify the corresponding parts.

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As is shown in FIGURE 4, the input connection 33 is joined to the lower end of a primary winding  $P_4$ , and input connection 32 is joined to the end of the extension winding E thereby placing the starting circuit across the primary winding  $P_4$  and the extension winding E. The operating transformer  $T_3$  includes a loosely coupled secondary winding  $S_4$  and an auxiliary winding  $P_5$  which are inductively coupled on a magnetic core 40 having magnetic shunts 41. The auxiliary winding  $P_5$  is wound over the secondary winding  $S_4$ , and during the starting condition the auxiliary winding  $P_5$  and the secondary winding  $S_4$  operate as a pulse transformer to superpose the high voltage pulses generated by the pulse generating circuit on the open circuit voltage of the transformer  $T_3$ . The primary winding  $P_4$  and the loosely coupled secondary winding  $S_4$  function as a high reactance transformer to provide the requisite operating voltage and to perform the ballasting function for the arc lamp 11. During the starting condition the extension winding E and the primary winding  $P_4$  function as an autotransformer to provide a stepped up voltage across the tank circuit comprised of the inductor  $L_1$  and capacitor  $C_4$ . An advantage of this arrangement is that the need for a separate transformer in the pulse generating circuit as used in the apparatus 10 of FIGURE 1 is eliminated.

A capacitor  $C_6$  is connected across the input terminal leads 42, 43 to prevent a feedback from the apparatus under starting conditions. A capacitor  $C_7$  introduces a capacitive reactance in the lamp circuit. The output of the apparatus is supplied to the arc lamp 11 by means of the output leads 44, 45.

Referring now more particularly to FIGURE 5, I have shown therein a schematic diagram of a pulse generating circuit which is similar to the circuit shown in FIGURES 3 and 4 except that the tank circuit is adapted for D.C. operation. The input connections 50, 51 are intended for connection to an alternating current supply; and the auxiliary winding  $P_2$  corresponds to the auxiliary winding  $P_2$  of the transformer  $T_1$  as shown in FIGURES 1, 3 and 6.

It will be appreciated that the inductor  $L_3$  of the tank circuit will store energy when it is operated from a D.C. source. In the starting circuit shown in FIGURE 5, a half wave D.C. voltage was supplied to the tank circuit by connecting a diode 52 in circuit with the input lead 50. If desired, a bridge connection may be used to provide a full wave D.C. voltage. When the switch 53 is closed to energize the pulse generating circuit, energy is essentially stored in the inductor  $L_3$ , and when the switch 53 is released, the tank circuit will oscillate thereby transferring energy from the inductor  $L_3$  to the capacitor  $C_8$ . When the breakdown voltage of the spark gap 54 is reached, the capacitor  $C_8$  will discharge through the gap 54 and the auxiliary winding  $P_2$ . In this manner the peak voltage required to start the arc lamp as in the other illustrated starting circuits, is superposed on the open circuit voltage of the high reactance transformer used to operate and ballast the lamp.

In the starting circuit illustrated schematically in FIGURE 6, I have provided an oscillatory circuit on the primary side of a high frequency transformer  $T_4$ . The high frequency transformer  $T_4$  includes a primary winding  $P_6$  and a secondary winding  $S_6$  which are inductively coupled on a magnetic core 60. The secondary winding  $S_6$  is connected in circuit with the auxiliary winding  $P_2$  and the spark gap 61. Although the starting circuit is energized by the connections 62, 63 to the input leads 14, 15 of the transformer  $T_1$ , it will be appreciated that the connections 62, 63 may be made directly to an alternating current supply. A normally open switch 64 is provided to energize the starting circuit when it is desired to ignite the arc lamp 11. The inductance of the primary winding  $P_6$  and the capacitance of the capacitor  $C_9$  are adjusted so the circuit will be nearly resonant at the line frequency.

The operation of the starting circuit shown in FIGURE

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6 is initiated by closing the line switch 64. With the switch 64 closed and switch 65 in the open position, capacitor  $C_9$  is charged. When switch 65 is closed and switch 64 opened, capacitor  $C_9$  discharges through the primary winding  $P_6$  to develop an oscillatory voltage thereacross. A corresponding stepped-up voltage is induced in the secondary winding  $S_6$  and causes the spark gap 61 to fire. This secondary voltage applied across the auxiliary winding  $P_2$ , and the pulsed voltage is superposed on the open circuit voltage of the transformer  $T_1$  by virtue of the transformer coupling between the auxiliary winding  $P_2$  and the secondary winding  $S_2$ . This, the required peak starting voltage for the arc lamp 11 is provided. It will be appreciated that the spark gap 61 may be eliminated, if desired, in certain applications.

In FIGURE 7 I have illustrated an embodiment of my invention wherein the reactance for the starting or pulse generating circuit is contributed by a high leakage reactance extension or secondary winding  $S_8$  connected in autotransformer relation with primary winding  $P_7$ . It was found that the need for one or more separate inductors in the starting circuit, such as are shown in FIGURE 4, may, if desired, be eliminated.

Having specific reference now to both FIGURES 7 and 8, it will be seen that the ballast transformer  $T_7$  is provided with a magnetic core 71 having magnetic shunts 72 interposed between the primary  $P_7$  and the loosely coupled secondary winding  $S_8$ . Also, magnetic shunts 73 are interposed between the primary  $P_7$  and the isolated loosely coupled secondary winding  $S_7$ . As in the other embodiments of the invention, an auxiliary winding  $P_8$  is inductively coupled with the secondary winding  $S_7$  to provide a transformer type of coupling with the secondary winding  $S_7$ . When the push button switch 74 is closed to start lamp 11, the auxiliary winding  $P_8$  and the secondary winding  $S_7$  effectively function as a pulse transformer to superpose high voltage pulses on the open circuit voltage of the transformer  $T_7$ . The lamp 11 is a compact arc lamp having a pair of electrodes 12, 13 disposed in an envelope of light transmissive material such as quartz.

As in the other illustrated operating circuits, I have employed a series capacitor  $C_9$  connected in circuit with the secondary winding  $S_7$  to provide a net capacitive reactance in the lamp circuit. Also, a filter capacitor  $C_{11}$  is connected across input terminal leads 76, 77 to minimize possible radio interference that might be caused by the feedback of frequencies resulting from the electric discharge in the lamp 11 to the power supply lines.

The operation of the circuit shown in FIGURE 7 is initiated by closing the push button switch 74 to energize the pulse generating circuit. When the capacitor  $C_{10}$  is charged to a predetermined value, the spark gap 78 is fired, and capacitor  $C_{10}$  discharges to produce an oscillatory voltage across the auxiliary winding  $P_8$ . By virtue of the transformer coupling between the auxiliary winding  $P_8$  and the secondary winding  $S_7$ , a pulsed or peaking voltage is introduced into the lamp circuit. This pulsed voltage is superposed upon the open circuit voltage across the output terminal leads 79, 80 to cause ignition of the arc lamp 11. After the arc lamp 11 is ignited, the push button switch 74 is released to cut off the supply of power to the pulse generating circuit. During the operating condition of the arc lamp 11, the secondary winding  $S_8$  and the auxiliary winding  $P_8$  do not come into play, and the transformer  $T_7$  functions as a high reactance isolated type of ballast transformer to provide the ballasting action and the operating potential for the proper operation of arc lamp 11.

From the foregoing description of several illustrative embodiments of the invention, it will be apparent that an improved arrangement is provided for starting high pressure arc lamps wherein the operating transformer does not have to provide the extremely high peak voltages required to start such lamps. It is possible with the im-

proved arrangement of the invention to employ relatively smaller and less expensive high reactance transformers as compared with transformers adapted to provide the peak open circuit voltage required for such high pressure arc lamps. Although in the illustrative exemplifications of the invention I have shown circuits for operating a single arc lamp, it will be appreciated that these circuits are equally suitable for starting and operating one or more arc lamps.

While I have illustrated and described several specific embodiments of the invention, further modifications and improvements will occur to those skilled in the art. It is understood, therefore, that this invention is not limited to the specific forms of the invention shown and it is intended in the appended claims to cover all such modifications that come within the true spirit and scope of this invention.

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

1. An apparatus for starting and operating an arc lamp having a peak starting voltage greater than 800 volts, said apparatus comprising: a high reactance transformer having a primary winding for connection to a source of alternating current, a secondary winding inductively coupled with said primary winding, and an auxiliary winding inductively coupled with said secondary winding; a pulse generating source having voltage breakdown means connected in circuit with said auxiliary winding; and an output means including at least a pair of output terminal leads connected to said secondary winding for connection to the arc lamp, said auxiliary winding and said pulse generating source causing a series of voltage pulses to be superposed upon the output voltage of said secondary winding of said high reactance transformer thereby to start the arc lamp.

2. An apparatus for starting and operating an arc lamp, said apparatus comprising: a high reactance transformer having a primary winding for connection to a source of alternating current, a secondary winding, and an auxiliary winding inductively coupled with the secondary winding of said high reactance transformer; output means including a pair of output terminal leads connected in circuit with the secondary winding and adapted for connection to the arc lamp; and a pulse generating source including a voltage breakdown device connected in series circuit with said auxiliary winding for supplying pulses thereto, said auxiliary winding and said secondary winding operating as a pulse transformer during the starting condition of the apparatus to apply a voltage at the output terminal leads for starting the arc lamp.

3. An apparatus for starting and operating an arc lamp, said apparatus comprising: a high reactance transformer having a primary winding for connection to a source of alternating current, a secondary winding loosely coupled with said primary winding and an auxiliary winding inductively coupled with the secondary winding; a pair of output terminal leads adapted for connection with the arc lamp and connected in circuit with said secondary winding of said high reactance transformer for applying the output thereof across the arc lamp; a capacitor connected in series circuit relation with one of said output terminal leads; and a pulse generating circuit having an energy storage device and a voltage breakdown device, said pulse generating circuit being connected with said auxiliary winding for supplying pulses thereto in response to said voltage breakdown device conducting current from said storage device, said auxiliary winding and said secondary winding of said high reactance transformer operating as a pulse transformer during the starting condition to supply a peaked output voltage at said output terminal leads thereby to start the arc lamp.

4. An apparatus for starting and operating an arc lamp comprising: a first high reactance transformer having a primary winding adapted for connection to a source of

alternating current and having a secondary winding loosely coupled therewith and an auxiliary winding inductively coupled with the secondary winding of said first high reactance transformer; a pair of output terminal leads connected in circuit with said secondary winding and adapted for connection to the arc lamp; and a pulse generating source comprising a second high reactance transformer having a primary winding for connection to an alternating current supply and a secondary winding, a capacitor connected in parallel circuit relation with said secondary winding, and a spark gap means; said auxiliary winding and said spark gap means being connected in series circuit relation across said capacitor, and said auxiliary winding of said pulse generating source and said secondary winding of said first high reactance transformer operating as a pulse transformer to provide a peaked voltage at said output terminal leads to start said arc lamp.

5. An apparatus for starting and operating an arc lamp from an alternating source, said apparatus comprising: a first high reactance transformer having a primary winding adapted for connection to a source of alternating current, a secondary winding inductively coupled with said primary winding, and an auxiliary winding wound over said secondary winding; output means including at least a pair of output terminal leads for connection to the arc lamp and for supplying the output of said apparatus thereto; and a pulse generating circuit including a second high reactance transformer having a primary winding for connection to the alternating current source and having a secondary winding inductively coupled with said primary winding, a capacitor connected in parallel circuit relationship with the secondary winding of said second high reactance transformer, and a spark gap means; said spark gap means and said auxiliary winding of said first high reactance transformer being connected in series circuit relation with each other and in parallel circuit relation with said capacitor, and said auxiliary winding and said secondary winding of said first high reactance transformer operating as a pulse transformer during the starting condition to supply the peak output voltage at said output terminal leads for starting the arc lamp.

6. An apparatus for starting and operating an arc lamp peak starting voltage of 800 volts or more, said apparatus comprising: a transformer means having a primary winding for connection to a source of alternating current, a secondary winding loosely coupled with said primary winding and an auxiliary winding coupled to said secondary winding; a pulse generating means having a voltage breakdown device coupled to said auxiliary winding; and an output means including at least a pair of output terminal leads connected to said secondary winding for connection to the arc lamp and for supplying the output of said apparatus thereto, said auxiliary winding and said secondary winding of said transformer means operating as a pulse transformer during the starting condition to supply a pulsed output voltage at said output terminal leads in response to conduction by said voltage breakdown device for starting the arc lamp.

7. An apparatus for starting and operating an arc lamp from an alternating current source, said apparatus comprising: an operating transformer having a primary winding disposed on a magnetic core and adapted for connection to the alternating current source, an extension winding connected to said primary winding, a secondary winding loosely coupled with said primary winding on the magnetic core and an auxiliary winding coupled to said secondary winding; and an output means including at least a pair of output terminal leads for connection to the arc lamp and for supplying the output of the apparatus to the arc lamp; a pulse generating circuit including a tank circuit coupled with said auxiliary winding and circuit means including a switch for connecting said tank circuit across said primary winding and said ex-

tension winding of said operating transformer, said extension winding and said primary winding of said transformer providing a stepped-up voltage for said pulse generating circuit during the starting condition, and said auxiliary winding and said secondary winding of said transformer operating as a pulse transformer during said starting condition to provide the peak starting voltage at said output leads required to ignite the arc lamp.

8. An apparatus for starting and operating a high pressure arc lamp from an alternating supply, said apparatus comprising: a high reactance transformer having a magnetic core, a primary winding, a secondary winding inductively coupled with the primary winding on said magnetic core, and an auxiliary winding wound over said secondary winding, said primary winding being adapted for connection to the alternating current supply; a spark gap means connected in series circuit with said auxiliary winding; a tank circuit including a capacitor and an inductor connected in parallel circuit relation, said tank circuit being connected in circuit with said serially connected auxiliary winding and said spark gap means; said tank circuit being tuned to provide an oscillatory voltage sufficient in magnitude to break down said spark gap means, and input means connected with said tank circuit for connection to the alternating current supply, said input means including switching means for energizing said tank circuit during the starting condition, and said auxiliary winding and said secondary winding operating as a pulse transformer during the starting condition to supply the peak voltage for starting the arc lamp.

9. An apparatus for starting and operating a high pressure arc lamp from an alternating current supply, said apparatus comprising: input terminals for connection to said alternating current supply; a first transformer having a first magnetic core, a primary winding disposed on said first magnetic core and connected to said input terminals, a secondary winding loosely coupled with said primary winding on said first magnetic core, and an auxiliary winding inductively coupled with said secondary winding; circuit means including output leads for connection across the arc lamp and connected to said secondary winding for supplying the operating potential for the lamp; a second transformer having a second magnetic core, a primary winding and a secondary winding inductively coupled with said second magnetic core, said secondary winding of said second transformer being connected across said auxiliary winding, a capacitor connected in series circuit relationship with said primary winding of the second transformer, said primary winding and said capacitor forming an oscillatory circuit, means for connecting said oscillatory circuit to said input terminals, said oscillatory circuit providing a damped oscillation across said primary winding of the second transformer during the starting condition of the circuit to provide a pulsed output across the secondary of the second transformer and the auxiliary winding coupled with the secondary winding of said first transformer, and said auxiliary winding and said secondary winding of said first transformer operating as a pulse transformer during the starting condition to supply the peak voltage required for ignition of the lamp.

10. An apparatus for starting and operating a high pressure arc lamp from an alternating supply, said apparatus comprising: a ballast transformer having a primary winding for connection to a source of alternating current, a secondary winding and an auxiliary winding inductively connected with said secondary winding; an oscillatory circuit connected in circuit with said auxiliary winding; a spark gap means coupled with said oscillatory circuit and said auxiliary winding, said oscillatory circuit when energized being arranged to provide an oscillatory voltage sufficient in magnitude to break down said spark gap means to cause said oscillatory voltage to be

applied across said auxiliary winding, said auxiliary winding and said secondary winding operating as a pulse transformer during the starting condition of the apparatus to cause said oscillatory voltage to be superposed on the output voltage of the ballast transformer thereby to start the arc lamp.

11. An apparatus for starting and operating an arc lamp, said apparatus comprising: a high reactance transformer having a primary winding for connection to a source of alternating current, a first secondary winding loosely coupled with said primary winding, a second secondary winding loosely coupled with said primary winding, and an auxiliary winding inductively coupled with said second secondary winding; a spark gap means connected in series circuit with said auxiliary winding; a capacitor connected in circuit across said spark gap means and said auxiliary winding; circuit means connecting said capacitor across said primary winding and said first secondary winding of said high reactance transformer; and an output means including leads for connection to the arc lamp and connecting at least the second secondary in circuit with said leads to supply the operating potential for the arc lamp, said auxiliary winding and said second secondary winding of said high reactance transformer operating as a pulse transformer for the purpose of starting the arc lamp.

12. An apparatus for starting and operating a high pressure arc lamp from an alternating power source, said apparatus comprising: a ballast transformer having a magnetic core, a primary winding disposed on said core for connection to the alternating power source, a first secondary winding loosely coupled with said primary winding on said magnetic core and connected in autotransformer relation with said primary winding, a second secondary winding loosely coupled with said primary winding on said magnetic core and connected in isolated transformer relation with the primary winding, and an auxiliary winding disposed on said core to provide transformer coupling with said second secondary winding; output means including output leads for connection to the high pressure arc lamp and connecting at least said secondary winding in circuit with the arc lamp for supplying the operating potential thereto; and a pulse generating circuit including spark gap means connected in series circuit with said auxiliary winding, a capacitor connected in circuit across said spark gap means and said auxiliary winding, and circuit means connecting said capacitor in circuit across said primary winding and said first secondary winding, said circuit means including a switching means for disconnecting said pulse generating circuit from the power source, said primary winding and said first secondary winding operating as an autotransformer to charge the said capacitor to a preselected voltage to breakdown said spark gap means, said first secondary winding and said capacitor forming an oscillatory circuit to provide a pulsed oscillatory voltage across said auxiliary winding when said capacitor discharges, and the transformer coupling between said auxiliary winding and said second secondary winding causing a pulsed voltage to be superposed on the voltage at the output leads for igniting the arc lamp.

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