

[54] **CONTROL CIRCUIT FOR STARTING, SUSTAINING AND OPERATING ARC LAMPS**

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[52] U.S. Cl. ....**315/239, 315/200, 315/225, 315/274, 315/DIG. 5**

[51] Int. Cl. ....**H05b 41/14**

[58] Field of Search.....**315/236, 239, 240, 100, 101, 315/241, 199, 274, 276, 282, 306, 311, 354, DIG. 5**

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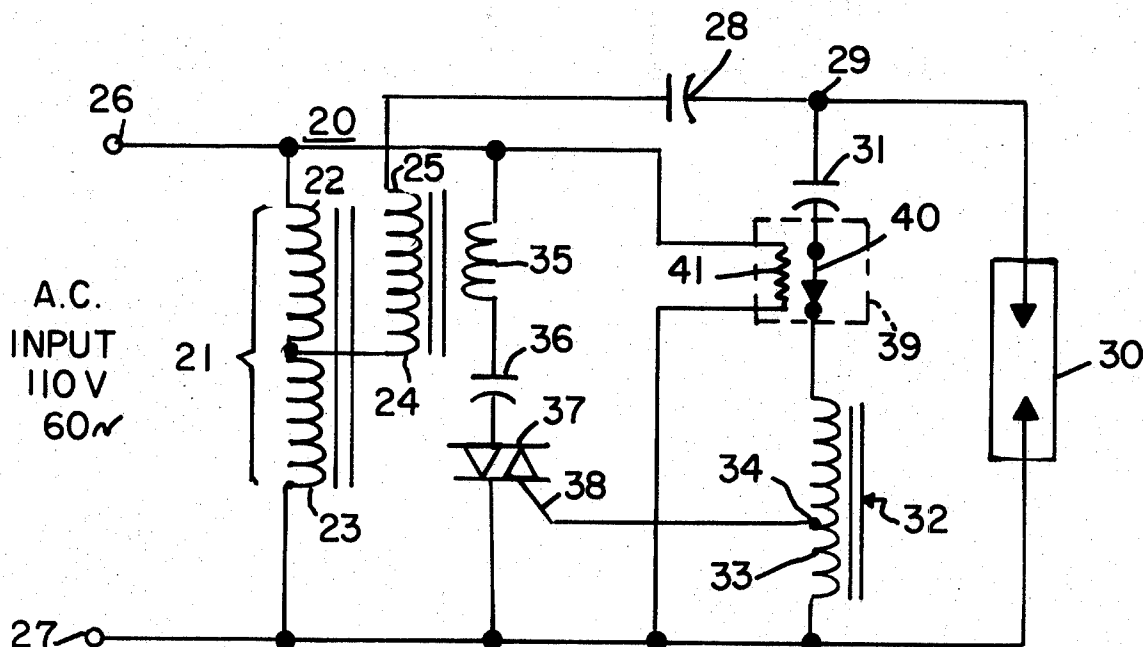
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[57] **ABSTRACT**

A control circuit for starting, sustaining and operating metal halide arc lamps comprising a bridged air gap ballast transformer having AC input terminals and output terminals for connection to an arc lamp. A differentiating circuit is connected across the output terminals for detecting voltage transitions in the lamp circuit and generating trigger signals in response thereto. Serially connected across the AC input terminals are a pulse winding magnetically coupled to the secondary winding of the ballast transformer, a capacitor, and a switch for discharging the capacitor through the pulse winding in response to the trigger signal from the differentiating circuit to thereby supply a voltage pulse of sufficient energy to ignite the arc lamp.

**13 Claims, 8 Drawing Figures**



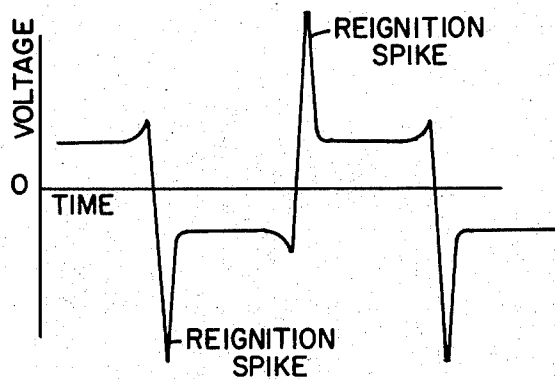


FIG. 1

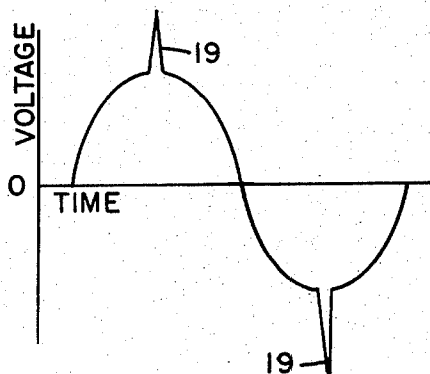


FIG. 4

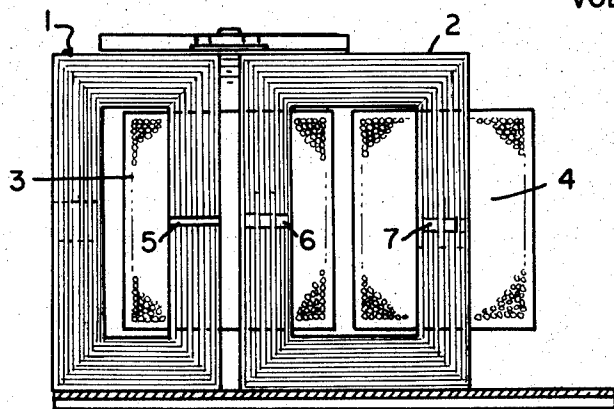


FIG. 2

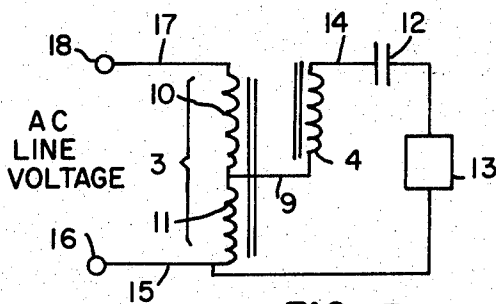


FIG. 3

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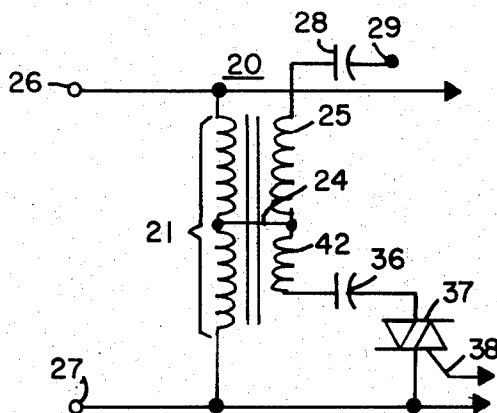
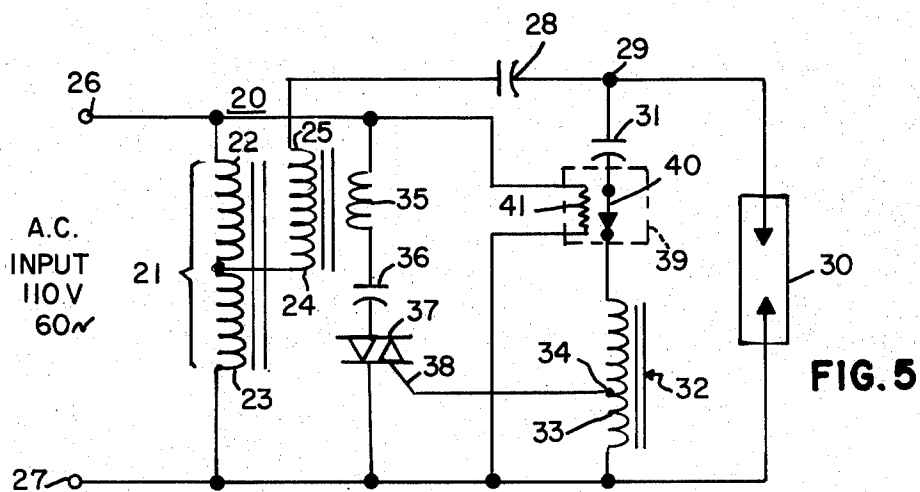


FIG. 6

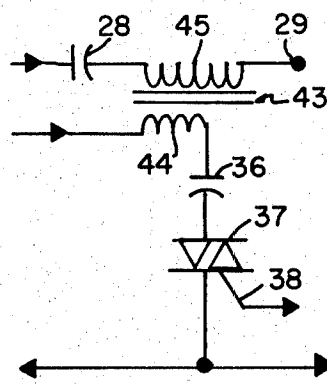


FIG. 7

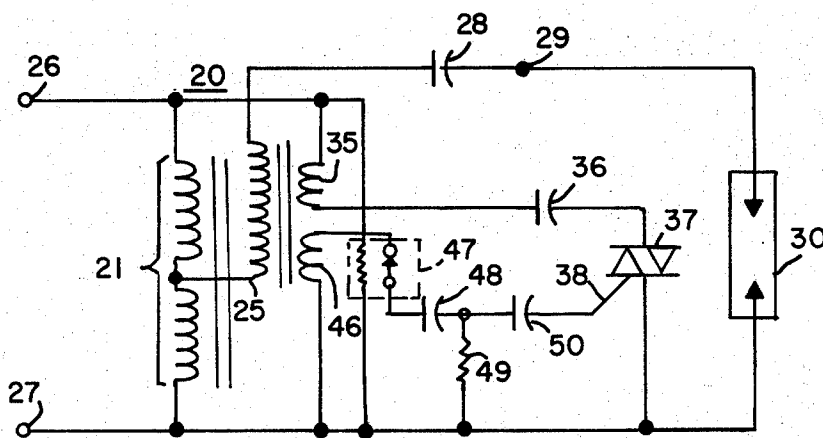


FIG. 8

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## CONTROL CIRCUIT FOR STARTING, SUSTAINING AND OPERATING ARC LAMPS

### BACKGROUND OF THE INVENTION

This invention relates generally to arc lamp control circuits and more particularly to an improved circuit for starting, sustaining and operating metal halide arc lamps.

Although applicable to a wide variety of arc discharge lamps, the present invention is particularly useful in connection with the metal halide type employing selected metal additives in the form of halogen compounds, generally known as iodide, to achieve desired alterations in the lamp discharge characteristics. It is well known in the art that arc lamps operate at a relatively low voltage but require a very high ignition or starting voltage. For example, a 400 watt metal halide arc lamp may operate with a nominal RMS lamp voltage of 130 volts and require a peak starting voltage of 510 volts. It is also well known that such lamps require a current limiting ballast. Due to the effect of iodine in the gas phase during warm-up, however, metal halide arc lamps also require a relatively high sustaining voltage during the critical period where a high reignition voltage is required, viz., 30 to 90 seconds after start. For example, the aforementioned 400 watt lamp requires a minimum RMS sustaining voltage of 250 volts.

An expanded discussion of the reignition characteristics of metal halide lamps is presented by A Franke et al., in volume 62 of the Journal of the Illuminating Engineering Society, pages 204-213 (1967). Briefly, the AC operation of an arc lamp inherently results in the disruption of current flow twice each cycle. Before the current flow can be reestablished, the applied voltage must (1) establish the electrode which was the anode during the previous half cycle as the cathode, and (2) reestablish a minimum conductivity to the plasma. The reignition voltage required to perform these functions is dependent upon the pressure and composition of the discharge.

For arc discharges operating at pressures of 1 to 2 atmospheres, thermodynamic equilibrium exists - the discharge will have a high heat capacity in comparison to its rate of heat loss. As a result, gas temperature and the associated plasma conductivity will exhibit only relatively small fluctuations even though the applied voltage is sinusoidal. At these pressures the applied voltage need only establish an electrode as cathode prior to conduction.

By contrast, a low pressure discharge operating on AC voltage is characterized by a fluctuation in conductivity.

The aforementioned article noted that the pressure of a metal iodide lamp upon initial ignition corresponds to that of the fill gas, about 20 torr. During the warm-up period of pressure build-up, two or three minutes, the metal iodide lamp exhibits characteristics of low pressure operation. Hence, during the period of AC voltage reversal, the instantaneous power dissipated in the plasma will go to zero. Accordingly, electrical conductivity will diminish, and the reignition voltage will increase. The waveform of FIG. 1 illustrates lamp voltage as a function of time for a metal halide lamp exhibiting the characteristic high reignition voltage peak at the beginning of each half cycle. If this peak voltage,

which is the voltage required to reignite the discharge in the period of low pressure, rises to a value higher than that available from the ballast, the lamp will extinguish and fail to operate.

In the case of a lead-peaked ballast, the secondary impedance is primarily capacitive, such that lamp current leads the open circuit voltage. Hence, the open circuit voltage opposes lamp reignition each half cycle, with the capacitor voltage being that which is in the proper phase to relight the lamp. Consequently, the above-referenced article observes that the net voltage available for reignition, i.e. the sustaining voltage, appears to be the instantaneous difference between capacitor voltage and open circuit voltage at the instant that lamp current goes through zero and the lamp voltage spike appears.

Heretofore, the requisite high sustaining voltage and other operating requirements for metal halide arc lamp have been provided by inductive capacitive ballasts with a high open circuit voltage and a high inductive reactance offset by a high capacitive reactance to give a net ballasting effect which controls the lamp current. In order to provide such performance, however, conventional ballasts become quite bulky, heavy and expensive.

An improved ballast transformer of reduced size and cost is described in U.S. Pat. No. 3,360,753, assigned to the assignee of the present invention. This ballast has a bridged air gap construction which provides a peaked pulse for starting the lamp during part of each half cycle. The bridged air gap transformer, however, must still be large enough to provide the required sustaining voltage and, thus, exhibits disadvantages in size, weight, and cost as compared to the control circuit of the present invention.

### SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved control circuit for starting, sustaining and operating arc lamps.

It is another object of the invention to provide a control circuit for a metal halide arc lamp which enables use of a ballast which is smaller, lighter and more economical than ballasts heretofore required for a like application.

It is a further object of the invention to provide a control circuit which extends and enhances advantages of the bridge air gap type ballast transformer.

Briefly, these objects are attained in a control circuit comprising a ballast transformer having output means for connecting an arc lamp in a lamp operating circuit loop, means for detecting a voltage transition in the lamp operating loop and generating a trigger signal in response thereto, and means responsive to the trigger signal for introducing a voltage pulse of sufficient energy to ignite the arc lamp. More specifically, when employing a bridged air gap type ballast transformer, the lamp circuit voltage transitions are detected by a differentiating circuit connected across the ballast output, and the voltage pulse for igniting the lamp is provided by a circuit comprising a pulse winding magnetically coupled to the ballast secondary, a capacitor, and a switching means serially connected in that order across the ballast input terminals, the switching means responding to a trigger signal from the differentiating circuit.

## BRIEF DESCRIPTION OF THE DRAWINGS

This invention will be more fully described hereinafter in conjunction with the accompanying drawing, in which:

FIG. 1 shows the lamp voltage waveform for a metal halide arc lamp having a high reignition voltage to which previous reference has been made;

FIG. 2 is a profile section of a bridged air gap ballast transformer;

FIG. 3 is a circuit schematic showing the transformer of FIG. 2 connected to a lamp;

FIG. 4 shows the open circuit secondary voltage wave form of the transformer of FIGS. 2 and 3;

FIG. 5 is a schematic diagram of a control circuit in accordance with the invention;

FIG. 6 is a schematic diagram of an alternative pulse transformer arrangement for use in the control circuit of FIG. 5.

FIG. 7 is a schematic diagram of another alternative pulse transformer arrangement for use in the control circuit of FIG. 5; and

FIG. 8 is a schematic diagram of a control circuit in accordance with the invention which employs an alternative differentiating circuit arrangement to that used in FIG. 5.

## DESCRIPTION OF PREFERRED EMBODIMENT

In accordance with the present invention, electronic circuitry is employed in combination with a ballast transformer to enhance the performance and capabilities of the ballast, thereby enabling the use of a smaller, lighter and lower cost ballast for a given application. Various types of ballast transformers may be used in the control circuit of the invention; however, a particularly useful and advantageous embodiment employs a bridged air gap type ballast transformer.

The construction and operation of a ballast transformer having a bridged air gap is disclosed in the previously referenced U.S. Pat. No. 3,360,753, however, for convenience, the more significant aspects are described hereinafter, with reference to FIGS. 2-4.

The transformer construction is illustrated in FIG. 2 as comprising a first magnetic core 1, closed except for an air gap 5, and a second magnetic core 2, closed except for bridged air gaps 6 and 7. The air gap 6 can be omitted. A portion of one core is close to but spaced from a portion of the other core, and a primary winding 3 encircles each of the juxtaposed portions of the cores and overlies air gap 5 and bridged air gap 6. A secondary winding 4 encircles a portion of core 2 only and overlies the bridged air gap 7 therein.

In core 2 the bridging pieces are staggered, with the bridging pieces under the primary winding 3 extending upwardly as the bridging pieces under the secondary winding 4 extend downwardly.

A diagram of the electrical circuit of the transformer and lamp is shown in FIG. 3. The primary winding 3 has an intermediate tap 9 which divides it into winding 10, which is in the primary circuit only, and winding 11 which is common to both primary and secondary. More specifically, secondary winding 4 is connected in series with portion 11 of the primary winding to form an autotransformer.

A lead capacitor 12 and arc discharge lamp 13 are connected in series between an end 14 of the secondary

winding and an end 15 of the primary winding, end 15 also being connected to one side of the AC line voltage source represented by terminal 16. The other end 17 of the primary winding is connected to the other side of the AC line voltage source represented by terminal 18.

Before the lamp starts, the reluctance of the air gap 5 will be much greater than that of the bridged gaps 6 and 7 because the flux in the bridging pieces has not yet become saturated. Nearly all the flux produced appears in the secondary core 2, and very little in the other core 1. The voltage across the secondary will thus be the turnsratio voltage, and rise to a sharp maximum. In this manner the bridged gaps provide a high voltage peak during each half cycle for starting the lamp. Once the bridges saturate, the flux is forced into the air spaces between the bridges, resulting in operation like an air gap, thereby increasing the reluctance so that the flux is shared with the air gap core, and the voltage induced in the secondary is reduced. The time-width of the pulse increases with the amount of bridging.

FIG. 4 shows the waveform of the voltage across the output terminals of the transformer, with the sharp pulse 19, which is for starting, occurring about midway in each half cycle. The voltage across the lamp will be somewhat different because of the series capacitor; i.e., the sharp pulse 19 will not be at the middle of each half cycle voltage wave across the lamp, but will be phased displaced near to the initial zero crossing of the lamp waveform, and may even be negative across the lamp. Since the pulse occurs at substantially open circuit, it will always be in the same phase with the induced transformer voltage, whereas the phase of the voltage across the lamp will change with the values of the capacitive and inductive reactances used. The height of the voltage peaks is important during the lamp starting phase; however, arc discharge lamps do not generally need to be restarted each half cycle, but only during the first few starting cycles.

FIG. 5 shows a control circuit in accordance with the invention. The circuit includes a ballast transformer 20 of the bridged air gap type described above. Primary winding 21 of the ballast is analogous to winding 3 in that it encircles each of the juxtaposed portions of the magnetic cores and overlies the air gap in the first magnetic core. Also, primary 21 may be divided into portions 22 and 23, with a tap at point 24. The ballast secondary winding 25 is analogous to winding 4 of FIGS. 2 and 3 in that it encircles a portion of the magnetic core 2 only and overlies the bridged air gap therein. Further, secondary winding 25 is connected in series with portion 23 of the primary winding via tap 24 to thereby form an autotransformer. An AC input terminal 26 is connected as shown to one end of the primary winding 21, and a common terminal 27 is connected to the other end of the primary. To complete the lead-peaked ballast arrangement, a capacitor 28 is series connected to the end of secondary winding 25 opposite that connected to tap 24. Hence, the secondary output of the ballast is provided across common terminal 27 and a terminal 29 on the output side of the capacitor 28.

A metal halide arc lamp, or in general any other type arc lamp, may be connected between terminals 29 and 27, in which case a lamp operating circuit loop is provided. More specifically, the lamp circuit loop includes

lamp 30, capacitor 28, secondary winding 25, and portion 23 of the primary winding.

A differentiating circuit is connected across the output of the ballast for detecting abrupt voltage transitions in the lamp operating circuit loop and generating a trigger signal in response to each of the transitions. In FIG. 5, this differentiating circuit includes a capacitor 31 and a step-down autotransformer 32 serially connected between output terminal 29 and common terminal 27. The entire winding of the autotransformer comprises its primary, and the winding portion 33 between tap 34 and common terminal 27 comprises the secondary of the autotransformer. Hence, any voltage transition occurring in the lamp circuit is differentiated by capacitor 31 and stepped down in voltage by autotransformer 32 to appear as a trigger signal at tap 34.

A switch controlled energy storage circuit coupled to the lamp operating circuit loop is responsive to the trigger pulse from the autotransformer for introducing a voltage pulse of sufficient energy to ignite the arc lamp 30. In the embodiment of FIG. 5 this circuit comprises a pulse primary winding 35 magnetically coupled to the secondary winding 25 of the ballast transformer, a capacitor 36, and a semiconductor switch 37 serially connected between input terminal 26 and common terminal 27. Switch 37 has a trigger input terminal 38 connected to the autotransformer tap 34 and is operative to discharge capacitor 36 through the pulse primary winding 35 in response to each trigger signal from the autotransformer 32.

FIG. 5 illustrates controlled switch 37 as comprising a bilateral semiconductor device known as a triac. A triac is triggered into conduction in either direction between its primary electrodes when a voltage pulse of either polarity is applied to its gate electrode. An equivalent network is two silicon controlled rectifiers connected in parallel in opposite polarity. Other bidirectional switching devices triggered externally or internally may be substituted. For example a silicon controlled rectifier in a bridge rectifier circuit or even a triggered spark gap might be employed.

In operation, the bridged gap ballast transformer 20 provides its usual functions of current limiting and, in the starting phase, voltage spikes 19 (see FIG. 4) for initiating the lamp starting process. The balance of the control circuit detects high rates of  $dv/dt$  and applies a high energy voltage pulse, at the instant of the high  $dv/dt$ , to the lamp 30. More specifically, upon applying AC power to the circuit input circuits 26 and 27 (which usually comprises 110 volts at 60 hertz), the bridged air gap ballast transformer 20 will generate across secondary winding 25 a voltage waveform similar to that illustrated in FIG. 4. The sudden voltage change 19 when the bridged air gap saturates is differentiated in the circuit comprising capacitor 31 and autotransformer 32 to provide a good trigger signal at tap 34 for gating switch 37. This first trigger signal occurs at a point of high input line voltage across the series circuit comprising winding 35, capacitor 36, and triac switch 37. Thus, the resultant triggering of switch 37 to thereby discharge capacitor 36 through winding 35 causes maximum energy to be coupled into the lamp circuit via ballast secondary 25 in the form of a voltage pulse. Hence, even though the ballast provided voltage spike 19 in itself may not be sufficient for lamp ignition,

the high energy voltage pulse produced by the transformer comprising primary 35 and secondary 25 will be more than adequate to start the arc lamp 30. Accordingly, the control circuit of the invention readily permits the use of a ballast transformer having reduced size and weight requirements as compared to that normally required for an equivalent application.

Once lamp 30 conducts, a lamp voltage of the general wave shape shown in FIG. 1 will be generated in the lamp operating circuit loop, the amplitude of the lamp voltage waveform steadily increasing during the lamp warm-up period. The sharp transition at the end of each half cycle of the lamp voltage waveform, at the moment of lamp extinction when the discharge stops, provides an equally good pulse trigger signal upon being differentiated. As previously discussed, in usual operation, the lamp reignites and the open circuit voltage just previous to reignition appears as a sharp spike on the oscillogram of lamp voltage. This spike is known as a "reignition spike." It is this reignition spike 19 which provides a excellent trigger signal for switch 37 at the instant it is needed. That is, after the initial starting pulse, the differentiating circuit, including capacitor 31 and autotransformer 32, detects each of the lamp voltage transitions represented by the reignition spikes 19 to provide a trigger signal for gating switch 37 into conduction. As a result, capacitor 36 is discharged to generate via windings 35 and 25 a high energy pulse for reigniting the arc lamp 30.

The trigger pulses from reignition spikes occur later in time than the peak of line voltage due to the previously mentioned phase displacement of the lamp voltage (FIG. 1) with respect to the ballast secondary voltage output (FIG. 4), but there is still appreciable energy storage in the series pulse circuit prior to the discharge of capacitor 36. As lamp current decreases until it reaches its quiescent level and a "hot lamp," lamp voltage phase shift becomes greater and the point of firing of the triac switch 37 occurs later in time with respect to the line voltage. Consequently, a smaller voltage is available to charge and discharge the series capacitor at the instant of trial firing. Therefore, as the lamp warms up, pulse energy decreases to a minimum.

Even through the pulse energy from the control circuit diminishes during the warm-up period operation, it has been found desirable in the interest of extending lamp life, to cut off pulse generation after the starting phase of lamp operation. Accordingly, the differentiating circuit includes a normally closed switch operative to provide an open circuit after predetermined period of operation of the control circuit to thereby inhibit the further generation of voltage pulses. In FIG. 5, this delayed switching means comprises a thermal relay 39 having normally closed switch contacts 40 serially connected between capacitor 31 and autotransformer 32. As illustrated, the delay feature may be provided by using a bimetallic element in the relay contacts 40 and a resistive element 41 connected between terminals 26 and 27 for generating heat pursuant to the current flowing therethrough.

As described, winding 35 of the energy storage and switching circuit of FIG. 5 is employed as the primary of a pulse transformer, for which ballast winding 25 serves as a secondary in addition to its function as secondary winding of the ballast transformer. Physi-

cally, this arrangement may be accomplished by winding primary coil 35 over the ballast transformer core winding 25.

An alternative construction for magnetically coupling the pulse primary winding to the secondary winding of the ballast transformer is shown in FIG. 6. In this case, the pulse winding, denoted as element 42, is connected between capacitor 36 and the interconnection 24 of the ballast transformer primary and secondary windings. In this manner, pulse winding 42 is connected in series with secondary winding 25 (on the same core) to form an autotransformer. The balance of the circuit is as shown in FIG. 5, with capacitor 28 being connected to junction 29, terminal 26 being connected to resistance element 41, the trigger input 38 of switch 37 being connected to autotransformer tap 34, and common terminal 27 also being connected as shown in FIG. 5.

FIG. 7 illustrates another alternative pulse coupling arrangement wherein a separate pulse transformer 43 is employed, independent of the ballast windings. The primary winding 44 of pulse transformer 43 is connected in the same manner as pulse winding 35 of FIG. 5 except, of course, it is not magnetically coupled to ballast winding 25. The secondary 45 of pulse transformer 43, on the other hand, comprises winding serially connected in the lamp operating circuit loop between the ballast transformer secondary winding 25 and terminal 29. Preferably winding 45 is connected on the output side of lead capacitor 28 as shown in FIG. 7. The remainder of the control circuit connections are as shown in FIG. 5.

A variety of circuit arrangements for detecting lamp circuit voltage transitions and providing trigger signals are also contemplated. For example, FIG. 8 shows a control circuit similar to FIG. 5 except for the use of an alternative differentiating circuit configuration employing a pick-off winding for sensing voltage transitions. More specifically, pick-off winding 46 is wound about a portion of the core wound ballast secondary 25, with one end of winding 46 being connected to common terminal 27 and the other end being connected via thermal relay 47 to a high pass filter, comprising capacitor 48 and resistor 49. Relay 47 may be arranged, as shown, to operate in the same manner as the relay 39 of FIG. 5. Filter 48, 49 is followed by a differentiating capacitor 50 for providing a trigger signal to the gate 38 of triac switch 37.

In FIG. 8, therefore, ballast secondary 25 has two overlying windings, namely, the pulse primary winding 35 and the pick-off winding 46.

The open circuit voltage waveform in the pick-off is the open circuit voltage of the ballast secondary, as shown in FIG. 4. After the lamp 30 is started, the voltage waveform sensed by pick-off winding 46 comprises a composite of the lamp voltage waveform of FIG. 1 plus a 60 hertz sine wave component which varies as the lamp warms up. At the initial ignition, the 60 hertz component predominates, but as the lamp warms up, the lamp voltage component builds up to about 50 percent of the total voltage produced by the pick-off winding when the lamp is "hot." The high pass RC filter 48, 49 connected at the output of winding 46, restores the pick-off wave shape to a semblance of the lamp voltage. Subsequent differentiation by capacitor 50 then

provides a suitable trigger signal for gating the triac switch 37. The balance of the control circuit operation is the same as that described with respect to FIG. 5. Accordingly, the pick-off arrangement of FIG. 8 provides means for detecting voltage transitions in the lamp operating circuit loop and generating trigger signals therefrom without the need for making direct connections to the arc lamp 30. In addition, a significant cost reduction is provided by dispensing with a separate core wound autotransformer 32.

In summary, the present invention combines a differentiating network and pulse generating circuit with a smaller, lighter, and more economical ballast to provide lamp starting, sustaining and operating functions by detecting starting and reignition spikes in the lamp circuit and immediately responding to apply voltage pulses to ignite and reignite the arc lamp. Further, the phase shifts involved in the combination with a lead-peaked ballast provide a reduction in spike energy after the lamp is "hot." In addition to the advantages in ballast construction, there is also some evidence that the control circuit of the invention can give a longer lamp life and higher lamp yield by starting and sustaining lamps that would not do so with conventional ballasts.

What I claim is:

1. A control circuit for starting, sustaining and operating an arc lamp from a source of alternating current comprising, in combination, a ballast transformer having input means for connection to said source of alternating current and output means for connecting said arc lamp in a lamp operating circuit loop, differentiating circuit means coupled across the output means of said ballast transformer for detecting a voltage transition in said lamp operating circuit loop and generating a trigger signal in response thereto, and means coupled to said lamp operating circuit loop and responsive to said trigger signal for introducing a voltage pulse of sufficient energy to ignite said arc lamp.

2. A control circuit in accordance with claim 1 wherein said differentiating circuit means includes a normally closed switching means operative to provide an open circuit after a predetermined period of operation of said control circuit.

3. A control circuit in accordance with claim 1 wherein said differentiating circuit means comprises a capacitor and an autotransformer serially connected across the output means of said ballast transformer, said trigger signal being available at a tap on said autotransformer.

4. A control circuit for starting, sustaining and operating an arc lamp from a source of alternating current comprising, in combination: a ballast transformer having input means for connection to said source of alternating current and output means for connecting said arc lamp in a lamp operating circuit loop; means for detecting a voltage transition in said lamp operating circuit loop and generating a trigger signal in response thereto; and means coupled to said lamp operating circuit loop and responsive to said trigger signal for introducing a voltage pulse of sufficient energy to ignite said arc lamp; said means for detecting a voltage transition comprising a pickoff winding magnetically coupled to the output means of said ballast transformer, a high pass filter connected to the output of said pick-off winding, and a differentiating capacitor connected at the output of said filter for providing said trigger signal.

5. A control circuit for starting, sustaining and operating an arc lamp from a source of alternating current comprising, in combination: a ballast transformer comprising a first magnetic core, closed except for an air gap, a second magnetic core, closed except for at least one bridged air gap, a portion of one core being close to but spaced from a portion of said other core, a primary winding encircling each of said portions of said cores and overlying the air gap in said first magnetic core, and a secondary winding encircling a portion of said second magnetic core only and overlying a bridged air gap therein, said secondary winding being connected in series with at least a portion of said primary winding to form an autotransformer; input means for connection to said source of alternating current comprising an input terminal connected to one end of said primary winding and a common terminal connected to the other end of said primary winding; ballast output means for connecting said arc lamp in a lamp operating circuit loop comprising said common terminal, said secondary winding, and an output terminal coupled to one end of said secondary winding; means for detecting a voltage transition in said lamp operating circuit loop and generating a trigger signal in response thereto; and means coupled to said lamp operating circuit loop and responsive to said trigger signal for introducing a voltage pulse of sufficient energy to ignite said arc lamp.

6. A control circuit in accordance with claim 5 wherein said means for introducing a voltage pulse to ignite the arc lamp comprises a pulse winding magnetically coupled to the secondary winding of said ballast transformer, a capacitor, and switching means for discharging said capacitor through said pulse winding in response to said trigger signal, said pulse winding, capacitor and switching means being serially connected in that order between said input terminal and said common terminal.

7. A control circuit in accordance with claim 5 wherein said means for introducing a voltage pulse to ignite wherein said means for introducing a voltage pulse to ignite the arc lamp comprises a pulse winding magnetically coupled to the secondary winding of said ballast transformer, a capacitor, and switching means for discharging said capacitor through said pulse winding in response to said trigger signal, said switching means, capacitor and pulse winding being serially connected in that order between said common terminal and the interconnection of said ballast transformer primary and secondary windings, said pulse winding

thereby being connected in series with the secondary winding of said ballast transformer to form an autotransformer.

8. A control circuit in accordance with claim 5 wherein said means for introducing a voltage pulse to ignite the arc lamp comprises a pulse transformer having primary and secondary windings, a capacitor, and switching means for discharging said capacitor through the primary winding of said pulse transformer in response to said trigger signal, said pulse transformer primary winding, capacitor, and switching means being serially connected in that order between said input terminal and said common terminal, and said pulse transformer secondary winding being serially connected in said lamp operating circuit loop between said ballast transformer secondary winding and said output terminal.

9. A control circuit in accordance with claim 5 wherein said means for detecting a voltage transition comprises a pick-off winding magnetically coupled to the secondary winding of said ballast transformer, a high pass filter connected to the output of said pick-off winding, and a differentiating capacitor connected at the output of said filter for providing said trigger signal.

10. A control circuit in accordance with claim 5 wherein said means for detecting a voltage transition comprises differentiating circuit means coupled between said output terminal and said common terminal.

11. A control circuit in accordance with claim 10 wherein said differentiating circuit means comprises a capacitor and a step-down autotransformer serially connected between said output terminal and said common terminal, said trigger signal being available at a tap on said step-down autotransformer.

12. A control circuit in accordance with claim 11 wherein said means for introducing a voltage pulse to ignite the arc lamp comprises a pulse winding magnetically coupled to said ballast transformer secondary winding, a capacitor, and a switching means serially connected in that order between said input terminal and said common terminal, said switching means having a trigger input terminal connected to the tap on said step-down autotransformer.

13. A control circuit in accordance with claim 11 wherein said differentiating circuit means further includes a thermal relay having normally closed switch contacts serially connected between said capacitor and said step-down autotransformer.

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