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ARC LAMP SUPPLY WITH CONSTANT LIGHT REGULATION
AND OVER CURRENT PROTECTION
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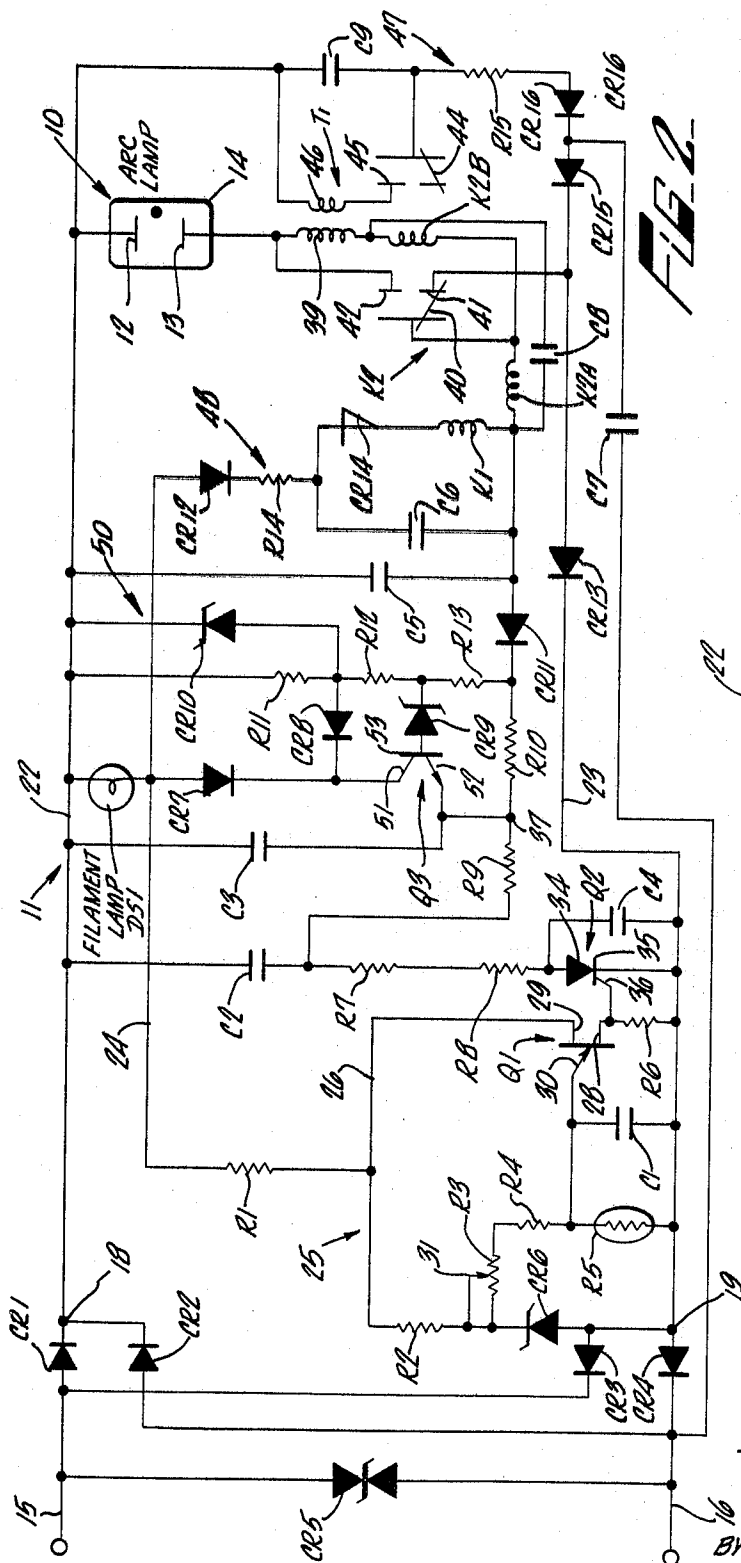


FIG. 1

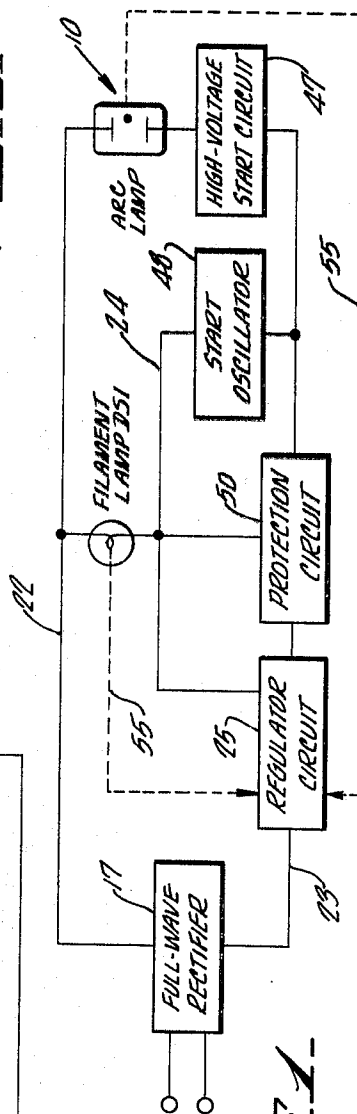


FIG. 2

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**ARC LAMP SUPPLY WITH CONSTANT
LIGHT REGULATION AND OVER
CURRENT PROTECTION**

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11 Claims

ABSTRACT OF THE DISCLOSURE

An arc-lamp power supply using optical feedback and a light-sensitive control system to maintain substantially constant light intensity by varying lamp power in response to intensity variations in light output from the lamp. Arc-lamp power is limited during lamp warm-up and in the event of lamp shorting, by a filament lamp arranged to shine on the light-sensitive control system with an intensity which increases as the arc-lamp power tends to exceed a maximum limit. A high-voltage pulse transformer is connected in series with the lamp to provide ignition voltage, and a circuit is actuated to bypass the transformer after ignition so the transformer does not carry the arc-lamp post-ignition operating current.

BACKGROUND OF THE INVENTION

This invention relates to a power supply for an arc lamp, and particularly to a power supply incorporating optical feedback for maintaining a constant-intensity light output from an enclosed arc lamp. Several types of arc lamps are commercially available for applications requiring a high-intensity light source. Such lamps include a pair of electrodes of a material such as tungsten, and produce illumination by an electrical discharge between the electrodes. A power supply for use with an arc lamp must provide a relatively high operating current, and must also provide a momentary high-voltage pulse across the lamp to initiate the electrical discharge between the electrodes.

In one style of arc lamp, the electrodes are surrounded by a transparent envelope, and the envelope is filled with a gas or easily vaporized metal to provide gaseous-discharge illumination of high intensity and having specific spectral characteristics. Such lamps are called compact-arc lamps or enclosed arc lamps, and are typically filled with xenon, or mercury and xenon, at relatively high pressures. Such lamps are quite small, and are especially useful in photographic recording oscillographs, for example, which require a compact source of high-intensity illumination with relatively high ultraviolet content.

When an enclosed arc lamp is used in a recording oscillograph or similar device, it is desirable to maintain the intensity of the lamp light at a relatively constant, controllable value. Arc lamps characteristically operate at a relatively constant voltage (after reaching normal operating temperature) in spite of variations in lamp current. However, this characteristic voltage has significant variations during lamp warm-up, and also varies considerably as the lamp ages. Known power supplies are designed to provide constant power to the lamp in an effort to maintain constant intensity. This approach does not produce optimum results because it does not compensate for variations in the characteristic operating voltage of the lamp. Furthermore, a true constant-power supply is difficult to design and expensive to manufac-

ture, and most available units do little more than compensate for line-voltage variations.

The power supply of this invention overcomes these problems, and employs optical feedback to provide the desired constant-intensity illumination from an enclosed arc lamp. A light-sensitive element in the power supply senses the light output of the lamp, and is arranged in feedback fashion to vary the power delivered to the lamp to provide a constant-intensity light output. Variations in line voltage or lamp characteristic voltage are thus automatically compensated, and the desired constant-intensity illumination is achieved.

A feature of the invention is that the optical-feedback approach provides faster warm-up of the arc lamp by increasing lamp power during the start-up cycle. A mercury-arc lamp, for example, does not reach full light intensity until the lamp has warmed up enough to vaporize the mercury. This stabilization takes one to two minutes with a constant-power supply. The use of optical feedback provides higher-than-normal current to the lamp during the warm-up cycle while light output is low, and the lamp stabilizes approximately twice as fast as when operated by a conventional constant-power supply. A protection circuit is included in the power supply to limit lamp current to a safe value during the warm-up cycle or in the event of a short-circuit failure of the arc lamp.

Another feature of the invention is a novel start circuit for providing high voltage to the lamp to initiate an electrical discharge between the arc-lamp electrodes. A high voltage must be applied to the electrodes with sufficient energy to cause ionization of the gas surrounding the electrodes, and to heat the electrodes to a point where there is sufficient thermionic emission of electrons to support ionization of the gas in the envelope at a relatively low lamp operating voltage. The start pulse is typically in the range of 10,000 to 15,000 volts, whereas the characteristic operating voltage of the lamp is commonly in the range of 15 to 30 volts at perhaps 5 amperes of lamp current.

The need for a high-voltage ignition pulse presents the problem of coupling a high-voltage start circuit to a relatively high-current, low-impedance power supply. Some known supplies incorporate a large inductor in series with the lamp to prevent the low-impedance supply from loading the high-voltage circuit. The drawback of this design is that the inductor loads the high-voltage pulse to an extent that it is difficult to obtain the voltage level needed to insure reliable starting of an enclosed arc lamp. This deficiency is particularly acute when attempting to restart a hot lamp which has a substantially higher ionizing voltage than a cold lamp of the same type.

Another approach to the coupling problem is to use a high-voltage pulse transformer having a secondary winding in series with the lamp and low-voltage power supply. This design is unsatisfactory in many applications because an expensive and relatively bulky transformer is required to provide a secondary winding capable of carrying the relatively high current which the lamp requires after ignition.

The power supply of this invention incorporates a pulse transformer having a secondary winding coupled in series with the lamp during the start cycle. When ignition is achieved, a relay closes automatically to provide a low impedance path in parallel with the transformer secondary. The transformer can therefore be a small and inexpensive unit because its secondary winding need carry the full lamp current only during a very short

period (say 5 to 10 milliseconds) required for relay closure after lamp current begins to flow.

SUMMARY OF THE INVENTION

Briefly stated, the invention contemplates a regulated-intensity light source comprising an enclosed arc lamp and a power supply connected to the lamp, the power supply including a light-sensitive element disposed to receive light from the lamp and connected to vary the power delivered to the lamp inversely in response to variations in light intensity whereby a constant intensity is maintained. The power supply includes a protective circuit having a filament lamp disposed to illuminate the light-sensitive element and arranged in the protective circuit to increase in brightness as arc-lamp power tends to exceed a predetermined safe value whereby power delivered to the arc lamp is limited to the safe value. Preferably, the power supply further includes a high-voltage start circuit having a transformer winding connected in series with the lamp, and shorting means such as a relay for bypassing the secondary winding after the lamp is ignited.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in detail with reference to the attached drawings, in which:

FIG. 1 is a block diagram of an arc-lamp power supply according to the invention; and

FIG. 2 is a schematic circuit diagram of the power supply.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2, a regulated-intensity light source according to the invention includes an enclosed arc lamp 10 and a power supply 11 connected to the arc lamp. Lamp 10 is of a conventional type having a first electrode 12 and a second electrode 13, the electrodes being surrounded by an envelope 14 of a material such as fused quartz. The envelope is filled with xenon, mercury and xenon, or similar gases or easily vaporized metals under relatively high pressure.

The power supply includes a pair of input leads 15 and 16 for connection to an A-C power source in the range of say 100 to 130 volts. Connected across the input leads are four diodes CR1, CR2, CR3 and CR4 which form a conventional full-wave bridge rectifier circuit 17. The full-wave-rectified waveform of the A-C input voltage appears between a first output terminal 18 and a second output terminal 19 of the rectifier circuit. Protection of the power supply against high voltage spikes in the line voltage is provided by a pair of back-to-back breakdown or Zener diodes CR5 connected between input leads 15 and 16.

A lead 22 is connected between first output terminal 18 of the rectifier circuit and first electrode 12 of the arc lamp, and another lead 23 is connected from second output terminal 19 to the cathode of a diode CR13. A conventional tungsten-filament pilot lamp DS1 is connected between lead 22 and a lead 24. Coupled between leads 23 and 24 is a regulator circuit 25.

The regulator circuit includes a resistor R1 connected between lead 24 and a lead 26, and a pair of parallel circuit branches are connected between leads 23 and 26. The first circuit branch includes a resistor R2 connected in series with a breakdown or Zener diode CR6, the anode of the diode being connected to lead 23. The second circuit branch includes a unijunction transistor Q1 having a base-one electrode 28 connected to lead 23 through a resistor R6, and a base-two electrode 29 connected to lead 26. The unijunction transistor has an emitter electrode 30, and a capacitor C1 is connected between the emitter electrode and lead 23.

A pair of series-connected resistors R3 and R4 are connected between the cathode of Zener diode CR6 and the junction of emitter electrode 30 and capacitor C1. Resistor

R3 is variable to provide intensity control for the arc lamp, and has an arm 31 connected to the cathode of diode CR6. A light-sensitive, variable-impedance element such as a light-sensitive resistor R5 is connected across capacitor C1 between lead 23 and the junction of resistor R4 and emitter electrode 30. Resistor R5, tungsten-filament lamp DS1, and arc lamp 10 are positioned with respect to each other such that a portion of the light emitted by the lamps illuminates the light-sensitive resistor. The resistance of resistor R5 varies inversely with the intensity of the light received from the lamps, and this element is a conventional type such as a cadmium sulfide photoconductive cell.

The regulator circuit also includes a power-control element such as a silicon controlled rectifier Q2 having an anode 34 coupled to lead 23 through a capacitor C4, a cathode 35 connected to lead 23, and a control or gate electrode 36 connected to the junction of resistor R6 and base-one electrode 28 of the unijunction transistor. Three series-connected resistors R7, R8 and R9 are connected between anode 34 and an output terminal 37 of the regulator circuit. A pair of filter capacitors C2 and C3 are connected between lead 22 and the opposite ends of resistor R9 to form a smoothing filter for the pulsating output of the regulator. An isolation diode CR11 has its cathode connected to output terminal 37 through a resistor R10.

Second electrode 13 of the arc lamp is connected to one end of a secondary winding 39 of a high-voltage pulse transformer T1, and a pull-in coil K2B and a holding coil K2A of a relay K2 are connected in series between the other end of the secondary winding and the anode of diode CR11. Relay K2 is of the high-voltage contactor type, and includes a movable contact 40 connected to the junction of coils K2A and K2B, a first fixed contact 41 connected to lead 23 through diode CR13, and a second fixed contact 42 connected to second electrode 13 of the arc lamp. A capacitor C8 is connected across coils K2A and K2B. Movable contact 40 is in contact with fixed contact 41 when the coils of relay K2 are not energized, and is moved into contact with fixed contact 42 when the relay is energized.

Relay K2 is of the high-voltage type as it must withstand the high-voltage start pulse applied to the arc lamp for ignition. A substantial gap (of say about one-half inch) is therefore provided between the relay contacts, and considerable power is required to move the movable contact quickly when the relay coils are energized. Pull-in coil K2B therefore has a large number of turns to develop a strong magnetic field needed to close the relay. Holding coil K2A includes only a few turns of heavy wire, and this coil supplies the relatively small amount of force needed to hold the movable contact closed once it has been moved against fixed contact 42. The pull-in coil is shorted out of the circuit when the relay closes to form a short-circuit bypass path around secondary winding 39 and the pull-in coil, and lamp current flows only through holding coil K2A after the lamp is ignited. This technique permits very rapid contact closure without the need for a large relay coil which is capable of providing a high magnetic force for rapid closure while at the same time handling the full lamp current continuously.

A capacitor C5 is connected between lead 22 and the anode of diode CR11. An energy-storage means such as a start capacitor C9 is connected in series with a resistor R15 between first electrode 12 of the arc lamp and the anode of a diode CR16. The cathode of diode CR16 is connected to the anode of a second diode CR15, and the cathode of diode CR15 is connected to fixed contact 41 of relay K2. A capacitor C7 is connected between the junction of diodes CR15 and CR16 and input lead 16.

A switch means such as a start relay with a coil K1 has a movable contact 44 connected to the junction of start capacitor C9 and resistor R15, and also has a fixed contact 45 which is spaced from the movable contact

when the relay is not energized. A primary winding 46 of pulse transformer T1 is connected at one end to fixed contact 45 and at the other end to first electrode 12 of the arc lamp. Transformer T1, capacitors C5, C7, C8 and C9, resistor R15, diodes CR15 and CR16, contacts 44 and 45, and relay K2 form a high-voltage start circuit 47 for the arc lamp.

A start oscillator circuit 48 serves to actuate the high-voltage start circuit periodically until the arc lamp ignites. The start oscillator circuit includes a conventional four-layer diode CR14 having its cathode coupled to the anode of diode CR11 through relay coil K1. A capacitor C6 is coupled across the series combination of four-layer diode CR14 and relay coil K1. The anode of a diode CR12 is connected to lead 24, and the cathode of this diode is connected to the anode of four-layer diode CR14 through a resistor R14.

A protection circuit 50 functions to protect the components in the power supply by limiting arc-lamp power during warm-up or in the event of a shorted lamp. The protection circuit includes filament lamp DS1 which, as already described, is connected between leads 22 and 24, and is physically positioned to illuminate light-sensitive resistor R5. An isolation diode CR7 has its anode connected to lead 24 and its cathode connected to a collector electrode 51 of a variable-impedance element such as a transistor Q3. An emitter electrode 52 of transistor Q3 is connected to output terminal 37. Diode CR7 and transistor Q3 form a path for current flowing through the filament lamp when the transistor is conducting.

Three series-connected resistors R11, R12 and R13 are connected between lead 22 and the cathode of diode CR11 to form a voltage divider. A Zener diode CR9 has its anode connected to a base electrode 53 of transistor Q3 and its cathode connected to the junction of resistors R12 and R13. Another Zener diode CR10 has its anode connected to the junction of resistors R11 and R12 and its cathode connected to lead 22. An isolation diode CR8 has its anode connected to the junction of resistors R11 and R12 and its cathode connected to collector electrode 51 of transistor Q3.

A power supply as just described has been built from components having values as indicated in the following table:

Component:	Description
Resistor R1 -----	9000 ohm, $\pm 1\%$, 3 watt.
Resistor R2 -----	200 ohm, $\pm 5\%$, $\frac{1}{2}$ watt.
Potentiometer R3 --	5000 ohm, $\pm 5\%$, 1 watt.
Resistor R4 -----	3000 ohm, $\pm 5\%$, $\frac{1}{2}$ watt.
Resistor R5 -----	Photoconductive cell, 1000 ohms at 2 footcandles illumination of 2854° K. light, Clairex Corp. part No. CL602.
Resistor R6 -----	20 ohm, $\pm 5\%$, $\frac{1}{2}$ watt.
Resistor R7, R8 ---	0.2 ohm, $\pm 3\%$, 50 watt.
Resistor R9 -----	0.2 ohm, $\pm 3\%$, 25 watt.
Resistor R10 -----	1 ohm, $\pm 3\%$, 50 watt.
Resistor R11 -----	1600 ohm, $\pm 5\%$, $\frac{1}{2}$ watt.
Resistor R12 -----	1300 ohm, $\pm 5\%$, $\frac{1}{2}$ watt.
Resistor R13 -----	910 ohm, $\pm 5\%$, $\frac{1}{2}$ watt.
Resistor R14 -----	43,000 ohm, $\pm 5\%$, $\frac{1}{2}$ watt.
Capacitor C1 -----	0.47 microfarad, $\pm 10\%$, 100 volt.
Capacitor C2, C3 --	9000 microfarad, $+75\%$ – 10% , 50 volt.
Capacitor C4 -----	0.01 microfarad, $\pm 10\%$, 600 volt.
Capacitor C5 -----	10 microfarad, $+75\%$ – 10% , 200 volt.
Capacitor C6 -----	5 microfarad, $+75\%$ – 10% , 150 volt.
Capacitor C7 -----	0.068 microfarad, $\pm 10\%$, 400 volt.

Capacitor C8 -----	0.082 microfarad, $\pm 10\%$, 400 volt.
Capacitor C9 -----	0.27 microfarad, $\pm 10\%$, 400 volt.
Diode CR1–CR4 --	Type 1N3493.
Diode CR5 -----	Type 6RS20SP5B5.
Diode CR6, CR9 --	Type 1N3021A (Zener), 11 volts.
Diode CR7, CR12–13, CR15–16 ---	Type 1N4004.
Diode CR8 -----	Type 1N4002.
Diode CR10 -----	Type 1N3028A (Zener), 22 volts.
Diode CR11 -----	Type 1N3493.
Diode CR14 -----	Type 1N3846 (four-layer).
Transistor Q1 ----	Type 2N1671B (unijunction).
SCR Q2 -----	Type C30B.
Transistor Q3 -----	Type 2N3054.
Lamp DS1 -----	Pilot lamp No. 53.
Relay K1 -----	Phillips Advance Control Co. Type 16.
Arc Lamp -----	PEK Labs Inc. Type 110.

T1 is a high-voltage pulse transformer having a secondary winding with a D-C resistance of about 15 ohms. The transformer is wound such that a 0.27 microfarad capacitor charged to 300 volts and suddenly discharged through the transformer primary winding will produce a gradually decaying A-C output voltage across the transformer secondary winding, the first positive and negative peaks of this output voltage being at least plus and minus 12,000 volts respectively. This measurement is made with the secondary winding unloaded except for a conventional oscilloscope high-voltage probe (such as a Tektronix type P6015 probe). The period of the first half cycle of the output voltage is preferably less than 1.5 microseconds. Relay K2 is a dual-coil high-voltage contactor with a holding coil K2A having a D-C resistance of about 0.1 ohm, and a pull-in coil K2B having a D-C resistance of about 6 ohms.

In operation, input leads 15 and 16 are connected to a source of A-C power at about 100 to 130 volts. The input power is full-wave rectified by the rectifier circuit, and a voltage having a peak value of say 160 volts is presented between leads 22 and 23. Start capacitor C9 charges to about twice this voltage through the voltage-doubler circuit formed by diode CR15 and CR16 and capacitor C7. Start oscillator 48 functions as a relaxation oscillator, and a pulse of current periodically flows through relay coil K1 to close movable contact 44 against fixed contact 45.

When relay K1 closes, start capacitor C9 discharges through primary winding 46 of pulse transformer T1. The high-voltage pulse appearing across secondary winding 39 of transformer T1 is applied to the lamp, and this or a succeeding pulse will cause ignition of the lamp. A substantial current then flows through the arc lamp and series-connected secondary winding 39 and pull-in coil K2B. Relay K2 is thus energized and movable contact 40 is closed against fixed contact 42 to bypass secondary winding 39 and pull-in coil K2B so the arc-lamp current now flows only through holding coil K2A to terminal 37 of the regulator through diode CR11 and resistor R10. When the lamp ignites, the voltage across capacitor C6 is clamped to the lamp voltage, and the start oscillator ceases to function whereby relay K1 is actuated only until ignition is achieved.

During each half cycle in the voltage waveform appearing at output terminals 18 and 19 of the rectifier circuit, capacitor C1 in the regulator circuit is charged to a value which depends on the resistance or conductance of light-sensitive resistor R5. When the voltage across capacitor C1 equals the emitter peak-point voltage of unijunction transistor Q1, the transistor turns on to pass a current through resistor R6 which in turn provides a

firing pulse at gate 36 of silicon controlled rectifier Q2. The unijunction transistor is turned on at some point after the rectified voltage waveform passes ninety degrees to decrease the interbase voltage of the unijunction transistor whereby the peak-point voltage of the transistor is lowered until the turn-on point is reached.

The resistance or conductance of resistor R5 thus controls the firing angle of silicon controlled rectifier Q2, and hence controls the amount of power delivered to the arc lamp. A change in the setting of variable resistor R3 will vary the value to which capacitor C1 charges for a constant value of resistor R5, and resistor R3 hence varies the firing angle of the silicon controlled rectifier and serves as an intensity control for the arc lamp. Capacitor C4 decouples silicon controlled rectifier Q2 from noise spikes in the circuit. Zener diode CR6 clips the peak of the voltage waveform applied to the voltage divider formed by resistors R3, R4 and R5, and limits the charge accumulated in capacitor C1.

The arc lamp normally operates at a relatively low voltage of say 20 volts, but this operating voltage is considerably higher while the lamp is warming up. Voltage is limited during the warm-up phase by protection circuit 50. Zener diode CR9 determines the turn-on point of transistor Q3, and Zener diode CR10 sets the turn-on voltage of the transistor with respect to the voltage appearing across the lamp. The circuit is arranged such that about twice the normal operating power is delivered to the lamp during the warm-up cycle, and heating is thereby accelerated to bring the arc lamp to full brilliance quickly.

A voltage proportional to arc-lamp current appears across resistor R10, and this voltage also controls the conduction of transistor Q3. If the arc lamp should short, a high current flows through resistor R10 and turns on transistor Q3, connecting filament lamp DS1 to lead 23 through diode CR7, resistors R7, R8 and R9, and silicon controlled rectifier Q2. The pilot light then burns very brightly to illuminate light-sensitive resistor R5 which reduces its resistance to in turn increase the firing angle of the silicon controlled rectifier and reduce the current delivered to the shorted lamp. The components in the power supply are thereby protected against a high-level, short-circuit current which would otherwise flow through the lamp. Filament lamp DS1 thus emits a medium-intensity light during the warm-up cycle of the lamp, and a very high-intensity light in the event of arc-lamp shorting, but emits little or no light during normal operation of the arc lamp.

As suggested by dashed lines 55 in FIG. 1, the arc lamp and the filament lamp are optically coupled in feedback fashion to the regulator unit whereby the power delivered to the lamp is varied to maintain a constant-intensity light output from the arc lamp. If the arc-lamp output decreases slightly during normal operation, the resistance of resistor R5 is increased and the firing angle of the silicon controlled rectifier is correspondingly retarded to increase the power delivered to the lamp. If the arc-lamp output increases, the illumination of light-sensitive resistor R5 is increased and the firing angle of the silicon controlled rectifier is increased to decrease the power delivered to the lamp. A desired constant intensity of the light output of arc lamp 10 is thus maintained.

The power supply is also protected against a runaway condition which might occur if the arc lamp shorted and filament lamp DS1 burned out. This is because operating voltage for the regulator circuit (as well as the start oscillator) are derived from lead 24 which is connected to the rectifier circuit output through the filament lamp. If the filament lamp opens, operating voltages are removed from the regulator circuit, the silicon controlled rectifier is not fired, and no current is delivered to the shorted arc lamp.

The amount of light reaching the light-sensitive re-

sistor from filament lamp DS1 is important as it serves to limit the lamp power during the warm-up cycle, and also controls the current-limiting function of the regulator in the event of a shorted lamp. The light reaching the light-sensitive resistor from the filament lamp can be adjusted by varying the spacing of these components, or by incorporating a variable opening or filter between the components. This factor is readily determined for any particular type of tungsten lamp which may be selected for use in the power supply.

There has been described a novel constant-intensity light source incorporating an enclosed arc lamp and a power supply which controls light intensity rather than lamp power. The power supply is flexible in that it can operate mercury lamps, mercury-xenon lamps, and other types of enclosed arc lamps, and is capable of restarting such lamps while they are hot. The design of the regulator circuit and protection circuit cuts lamp stabilization time in half, and also extends lamp life because the useful voltage range is wider than in conventional supplies. Furthermore, the power supply can be constructed from conventional, readily available components, and is lightweight and small in size.

While the invention has been described in terms of a presently preferred form, variations and modifications of the basic optical-feedback technique and circuit philosophy may be suggested to those skilled in the art. All such variations and modifications are intended to be encompassed within the scope of the following claims which define the invention.

What is claimed is:

1. A regulated-intensity light source, comprising an enclosed arc lamp and a power supply connected to the lamp, the power supply including a light-sensitive element disposed to receive light from the lamp and connected to vary the power delivered to the lamp inversely in response to variations in light intensity whereby a constant intensity is maintained, the power supply further including a protection circuit connected in series with the lamp to sense lamp current and arranged to limit lamp power during lamp warm-up and in the event of a short circuit in the lamp, the protection circuit having a filament lamp disposed to illuminate the light-sensitive element and arranged in the protection circuit to increase in brightness as arc-lamp power tends to exceed a predetermined safe value whereby power delivered to the arc lamp is limited to the safe value.

2. The light source defined in claim 1 in which the power supply further includes a high-voltage start circuit having a transformer secondary winding connected in series with the lamp, and means for bypassing the secondary winding after the lamp is ignited.

3. A power supply for an enclosed arc lamp having first and second electrodes, comprising:

- a rectifier circuit adapted to be coupled to an A-C power source and having first and second output terminals, the first output terminal being connected to the first lamp electrode;

- a regulator circuit being having a first input terminal connected to the second output terminal of the rectifier circuit, and having a third output terminal, the circuit including a power-control element having a control electrode and being connected in series between the first input terminal and the third output terminal for regulating output of the regulator circuit, the circuit further including light-sensitive means disposed to receive light from the arc lamp and coupled to the control electrode to vary the regulator-circuit output inversely in response to variations in light intensity; and

means connected between the third output terminal and the second lamp electrode for completing the circuit between the power supply and lamp.

4. The power supply defined in claim 3 in which the power-control element is a controlled rectifier, and the

light-sensitive means is arranged to vary a firing angle of the controlled rectifier in response to variations in light received from the arc lamp, whereby a variable amount of power is delivered to the arc lamp to maintain the light intensity constant at a predetermined level.

5. The power supply defined in claim 3 and further comprising a start circuit for initiating operation of the arc lamp and including energy storage means connected between the first and second output terminals of the rectifier circuit for accumulating an electrical charge, a step-up transformer having a primary winding and a secondary winding, the secondary winding being connected in series with the arc lamp, and switch means for intermittently connecting the primary winding across the energy storage means whereby the storage means is discharged into the transformer to deliver a high-voltage start pulse to the lamp.

6. The power supply defined in claim 5 in which the start circuit includes a relay having a pull-in coil, a holding coil and a pair of contacts, the coils being connected in series with each other and in series with the arc lamp and transformer secondary winding whereby the coils are energized to close the contacts when current flows through the arc lamp, the contacts being connected to form a low-resistance bypass path around the secondary winding and pull-in coil after ignition of the arc lamp.

7. The power supply defined in claim 6 in which the start-circuit switch means comprises a second relay having a coil, and further comprising a start oscillator connected to the coil to deliver intermittent current pulses to the coil for intermittent discharge of the storage means.

8. The power supply defined in claim 4 and further comprising a protection circuit having a filament lamp disposed to illuminate the light-sensitive means in the regulator circuit, sensing means for monitoring arc lamp current and including a variable-impedance element connected in series with the filament lamp, and means for connecting the series-connected filament lamp and variable-impedance element between the first terminal of the rectifier circuit and third output terminal of the regulator circuit, the sensing means being adapted to decrease the impedance of the variable-impedance element as the arc-lamp current tends to exceed a predetermined safe value whereby an increasing current flows through the filament lamp to provide increased illumination of the light-sensing means and a resulting decrease in arc-lamp current.

9. The power supply defined in claim 8 in which the sensing means includes a resistor connected in series with the third output terminal of the regulator circuit and the second arc-lamp electrode, and the variable-impedance element is a transistor, the sensing means further including means for coupling the transistor to the resistor whereby filament-lamp current flowing through the transistor is controlled by a voltage appearing across the resistor.

10. The power supply defined in claim 8 in which the regulator circuit includes a means connected to the filament lamp between the filament lamp and the variable-impedance element for providing an operating voltage to the regulator circuit from the first output terminal of the rectifier circuit, whereby the regulator circuit is disabled and the arc lamp is extinguished in the event of burnout of the filament lamp.

11. The power supply defined in claim 8 and further comprising a start circuit for initiating operation of the arc lamp and including energy storage means connected between the first and second output terminals of the rectifier circuit for accumulating an electrical charge, a step-up transformer having a primary winding and a secondary winding, the secondary winding being connected in series with the arc lamp, and switch means for intermittently connecting the primary winding across the energy storage means whereby the storage means is discharged into the transformer to deliver a high-voltage start pulse to the arc lamp; the start circuit further including shorting means connected in series with the arc lamp and actuable by arc lamp operating current to short circuit the secondary winding after ignition of the arc lamp.

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JAMES W. LAWRENCE, Primary Examiner

C. R. CAMPBELL, Assistant Examiner

U.S. Cl. X.R.

250—205; 315—159, 308; 323—21

PO-1050
(9/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,483,428 Dated December 9, 1969
Inventor(s) Dale E. LaPlante

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the specification, column 1, line 45, delete "is" second occurrence. Column 8, line 15 "xeon" should read --xenon--; line 50 "tin" should read --in--. Column 9, line 32, Claim 8, "claim 4" should read --claim 3--.

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Attest:

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Attesting Officer

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Commissioner of Patents