

United States Patent

Miller et al.

[15] 3,635,537

[45] Jan. 18, 1972

[54] MULTIPLE ANODE ARC LAMP SYSTEM

[72] Inventors: **Charles G. Miller**, Los Angeles; **Ralph E. Bartera**, La Canada, Calif.

[73] Assignee: **California Institute of Technology**, Pasadena, Calif.

[22] Filed: **Dec. 29, 1969**

[21] Appl. No.: **888,362**

[52] U.S. Cl. **315/145, 315/260, 315/334**

[51] Int. Cl. **H05b 41/16**

[58] Field of Search **315/145, 147, 260, 334**

[56] References Cited

UNITED STATES PATENTS

1,854,606 4/1932 Winograd 315/145 X

2,153,036 4/1939 Burt et al. 315/147 X
2,265,323 12/1941 Spanner 315/147 X
2,538,561 1/1951 Francis et al. 313/217 X
2,974,249 3/1961 Thouret 315/334 X

FOREIGN PATENTS OR APPLICATIONS

962,646 7/1964 Great Britain 315/147

Primary Examiner—Roy Lake

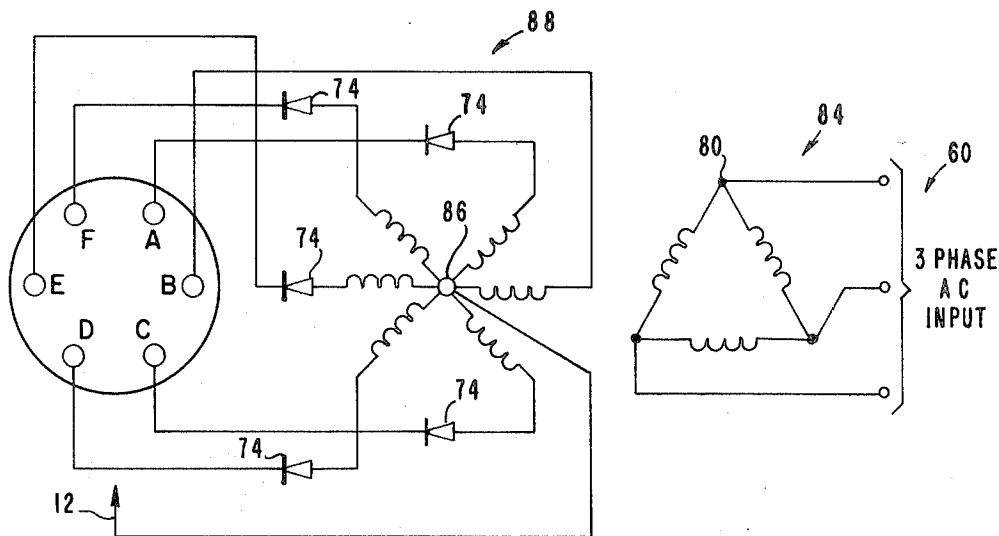
Assistant Examiner—Palmer C. Demeo

Attorney—Samuel Lindenberg and Arthur Freilich

[57] ABSTRACT

A high-intensity xenon arc lamp having a plurality of separate anodes axially disposed in a symmetrical pattern spaced a discharge gap from a common cathode.

10 Claims, 5 Drawing Figures



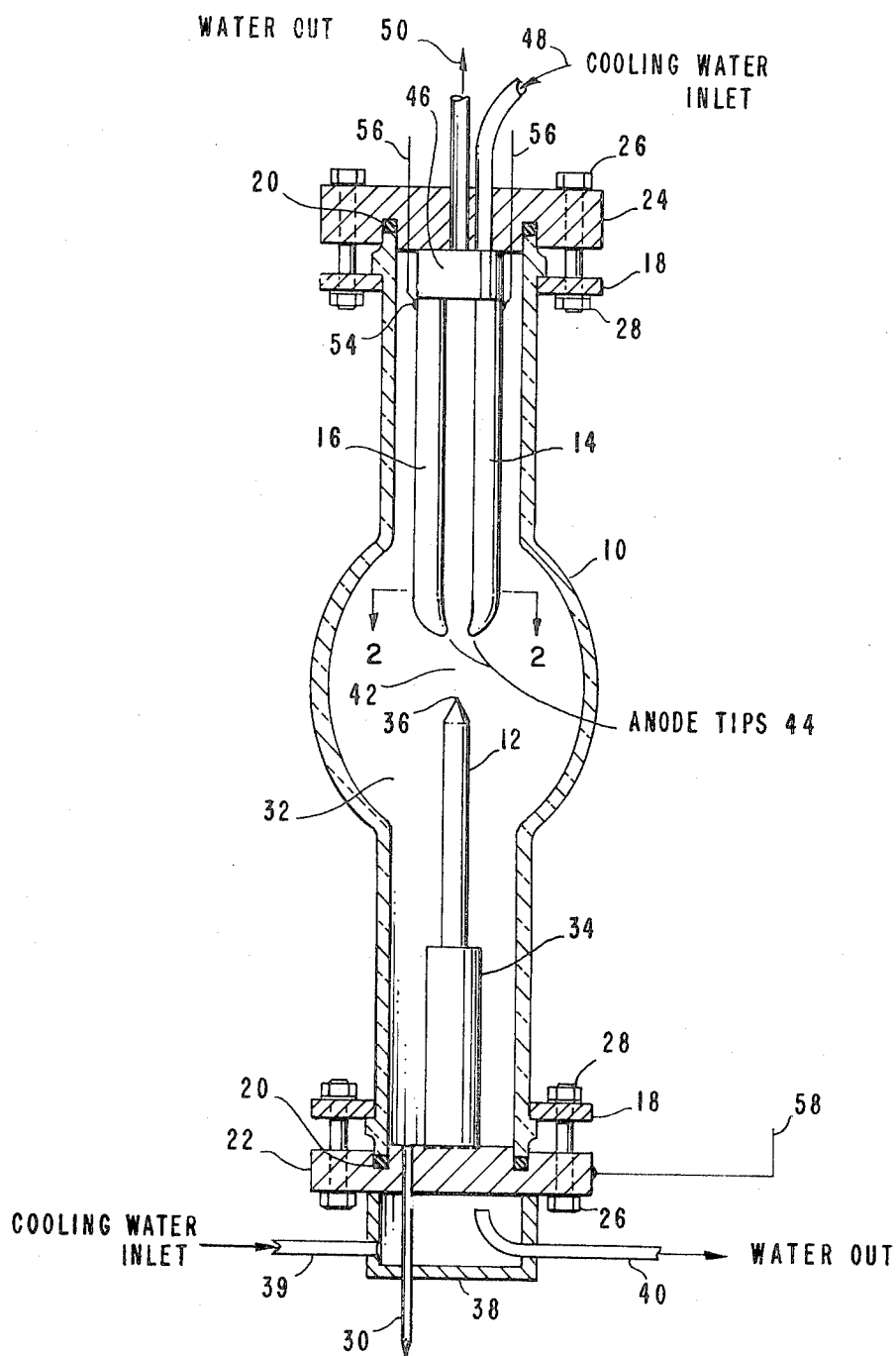


FIG. 1

INVENTORS
CHARLES G. MILLER
RALPH E. BARTERA

Indenberg & Fredrick
ATTORNEYS

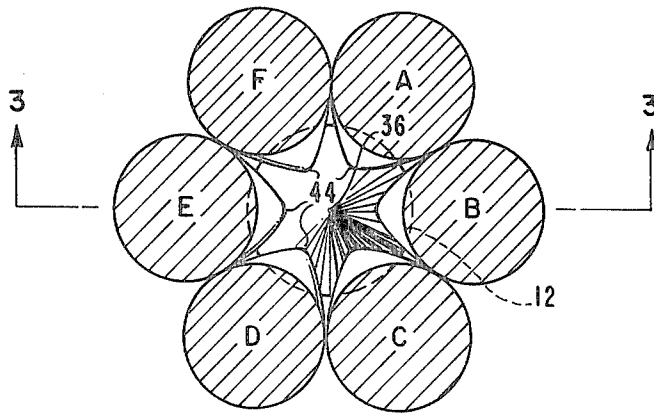


FIG. 2

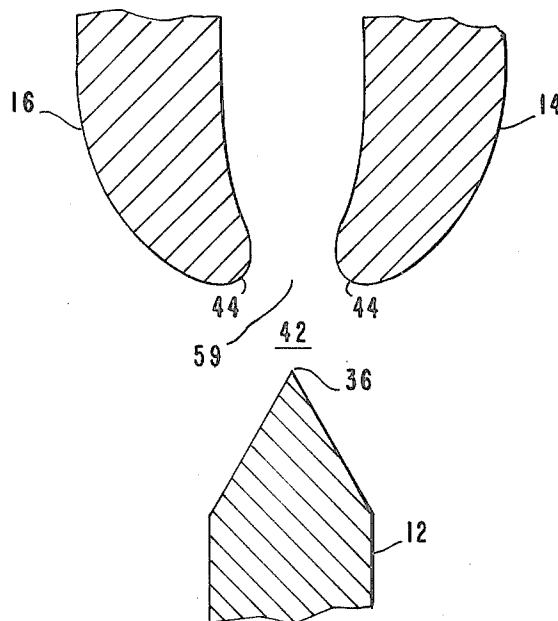


FIG. 3

INVENTORS
CHARLES G. MILLER
RALPH E. BARTERA

BY

Lindenberg & Freulich
ATTORNEYS

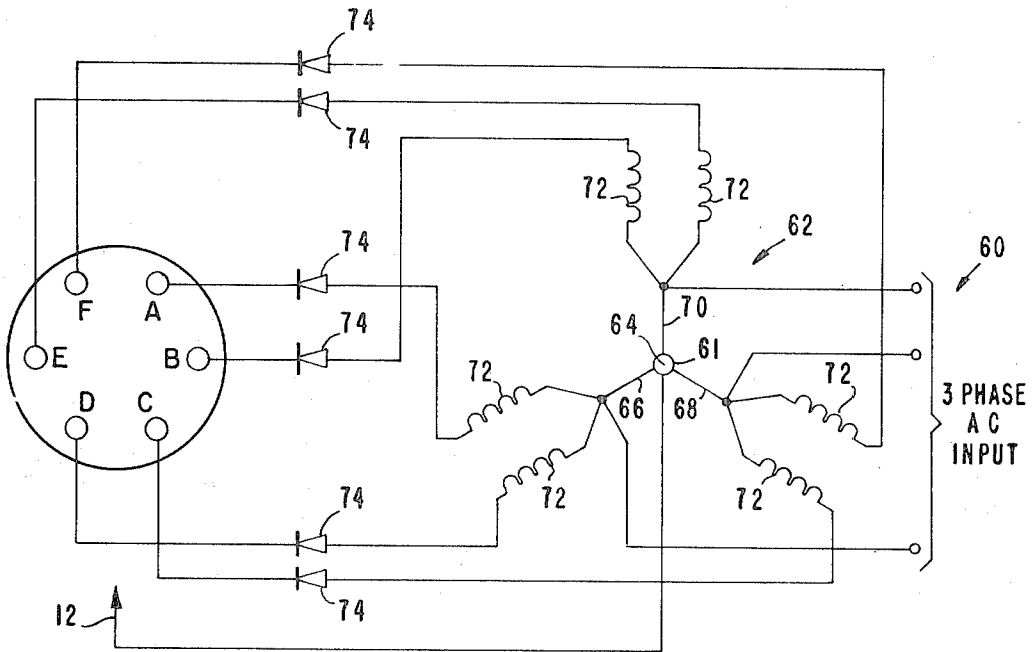


FIG. 4

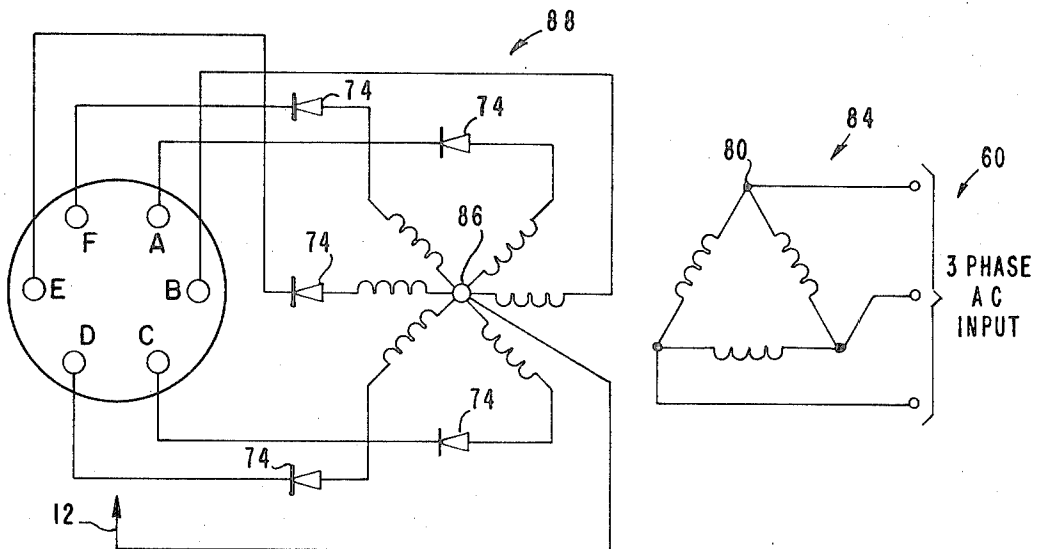


FIG. 5

INVENTORS
CHARLES G. MILLER
RALPH E. BARTERA
BY

Lundberg & Frellick
ATTORNEYS

MULTIPLE ANODE ARC LAMP SYSTEM

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to arc lamps and more particularly this invention relates to multiple anode xenon compact arc lamps.

2. Description of the Prior Art

Light sources with a continuum luminous output, whose spectral distribution and brightness approach that of the sun, are needed. The best present sources are direct current electric arcs in xenon gas under moderate pressure. However, the brightness, power-handling capacity and useful lifetime of these lamps are not satisfactory. Furthermore, in order to use line voltage, DC rectifiers and associated equipment are required.

Present sealed lamps operate with an electrical cathode and anode spaced in line across a small gap. These small separations raise the maximum brightness of the main emitting volume just off the cathode tip and increase the utilizable light efficiency of the lamp. An extreme heat load is applied to the anode due to the electron, or negative ion bombardment along the arc stream direction impinging on the anode tip plus the flow of hot gas flowing along the axial line joining the cathode and anode.

This causes a "fireball" about 6 mil in diameter which is disposed just above the apex of the cathode. The arc contacts the anode in a minute hot spot which while substantially larger than the fireball, imposes a considerable heat load on a relatively small area. The anodes fail under the sustained high heat and pressure loading probably because of creep of the copper material from which the anodes are made.

In a previous effort to improve the life expectancy of anodes, an anode is provided with an internal cooling water passageway which is so shaped that water flow is accelerated to a relatively high velocity as it flows past the hot spot of the anode. Such anodes are capable of handling peak heat fluxes in the range of 10×10^6 BTU/hr./ft.² which is equivalent to 3 kw./cm.². Greater loadings have been found to be unstable and lead to unpredictable sudden failure. The highest input power practicable obtainable is just under 30 kilowatts, even with the use of highest conductivity copper anodes and high efficiency water cooling.

OBJECTS AND SUMMARY OF THE INVENTION

It is therefore an object of this invention to improve the operating characteristics, efficiency, reliability and service life expectancy of high-intensity arc lamps.

Another object of the present invention is the provision of a self-rectifying, arc lamp operable directly from AC line current.

A further object of the invention is to increase the brightness, power and useful lifetime of direct current arc lamps having a continuum luminous output.

These and other objects and many attendant advantages of the invention will become apparent as the description proceeds.

An improved, high-intensity continuum luminous output arc lamp is provided, according to the invention by providing a plurality of anodes, typically three or six, arranged axially and spaced from a common cathode. The tips of the anodes form a circle in a plane transverse to the cathode axis such that typical anode-cathode spacing is maintained. In a preferred embodiment of the invention an even number of anodes are provided and spaced opposed pairs of anodes are simultaneously fired to provide balanced positioning of the arc

fireball. Another feature of the invention resides in connecting the anodes and cathodes to a polyphase input such as a star-connected transformer to provide automatic sequential firing of each anode.

The invention will become better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of an arc lamp, according to the invention;

FIG. 2 is an enlarged view in section of the anode tip arrangement taking along the line 2—2 of FIG. 1;

FIG. 3 is a sectional view taken on the line 3—3 of FIG. 2;

FIG. 4 is a schematic wiring circuit illustrating one mode of connecting the electrodes to a polyphase power supply; and

FIG. 5 is another schematic wiring circuit illustrating another mode of connecting the electrodes to a polyphase power supply.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, an embodiment of a high-intensity arc lamp, according to the invention, generally includes an envelope 10, a single cathode 12 and a plurality of anodes, suitably six, two of which 14, 16 being shown for purposes of illustration. The envelope is formed of a transparent material suitably quartz. A flange 18 is attached to the envelope 10 adjacent each open end thereof. Lamp ends 22 and 24 having a plurality of apertures adjacent the outer periphery are attached to the lamp envelope 10 by means of a plurality of bolts 26 extending through the apertures and correspondingly located holes in flange 18 and are secured by means of nuts 28. A circular groove which receives an O-ring 20 is formed on the inner surface of each end plate 22, 24 and the grooves receive each end surface of the envelope. When the bolts 26 and nuts 28 are secured, the O-rings 20 form a gastight seal between the ends 22, 24 and the envelope 10.

Obviously, only the window portion of the lamp need be transparent while the other portions of the envelope may be constructed of higher structural strength material such as metal or ceramic. The multiple anode arc system of the invention is also applicable to lamp housings formed in a sealed beam configuration containing a cathode and a plurality of anodes axially supported within an envelope. The lamp contains an integral, internal aligned reflector and a transparent window portion disposed transverse to the axis of the electrodes. The cathode may be supported within a narrowed neck portion while the anodes may be supported by means of straps attached to the sidewall of the envelope. A suitable construction for such lamp is disclosed in copending application Ser. No. 841,278 filed July 14, 1969.

A gas inlet tube 30 penetrates through lamp end 22 into the interior 32 of the envelope 10. A cathode support 34 is attached to end plate 22. The cathode 12 is in the form of a cylinder, suitably formed of tungsten and terminates in a conical tip 36. A hollow cap 38 is attached to the exterior of end plate 22 and receives a flow of coolant through inlet 39 and outlet 40. If greater heat removal capacity is required or desired, the cathode may be hollow and water circulated through the support 34 and cathode 12.

The cathode is spaced a discharge gap 42 from the tips 44 of the anodes 14, 16. The anodes may be formed of copper tipped with tungsten. The base of the anode is attached to a hollow support 46 which receives a flow of coolant from an inlet member 48 and an outlet member 50 extending through the end plate 24. Higher operating temperatures and power inputs are again provided by forming a hollow coolant passageway within the anodes, preferably extending adjacent the tips 44 of the anodes. The passages may be similar to those provided in the high-efficiency water-cooled anode, described above. An electrical connection 54 is provided to each anode. An electrical lead 56 is attached to each connection and ex-

tends through the end plate 24. Electrical connection to the cathode may be provided by an electrical lead 58 connected to the end plate 22.

Referring now to FIGS. 2 and 3, six anodes, A-F, are symmetrically arranged around cathode 12. The tips 44 of the anodes are canted toward and face the conical tip 36 of the cathode 12, and are spaced a discharge gap 42 from the tip 36 of the cathode 12.

The disposition of the anodes in a pattern surrounding the cathode removes them from the direct line of the hot-gas cathode jet. Although the electron or negative ion stream flows to each anode in turn, the hot-gas cathode jet is electrically neutral and does not depart from its axial flow direction. In the arrangement, according to the invention, this jet with its initial velocity of several hundred feet per second can pass through the central opening 59 between the ring of anode tips 44, and gradually slows and spreads as it moves in the flow direction. It is eventually stopped and cooled by the water-cooled end 24 of the lamp. The cathode jet, thus, does not add its head load to that of the electron stream which is being applied to each anode tip 44.

The lamps are assembled by bolting the end plates 22 and 24 to the flanges 18. Electrical leads 56 and 58 are connected to a power source, as shown in FIGS. 4 and 5. Sufficient operating gas which may be any of the gases chosen from the glass comprising neon, argon, krypton, xenon or their mixtures is introduced into the evacuated and moisture-free interior of the envelope 10 through the gas inlet tube 30 which is then pinched off, or a pressure-indicating gauge is installed at that location. Typical internal pressures are greater than atmospheric pressure, suitably about 30 to 100 p.s.i.g. at ambient temperature which increases to about 70 to 250 p.s.i.g. at operating temperature.

During operation, water is circulated through both of the hollow electrode supports or through the electrodes if they are provided with cooling passages. Typically the cathodes and anodes are about three-fourths inch in diameter and are separated by a discharge gap of about one-half inch. On application of an electrical power input to the anodes and cathode, a negative ion or electron stream and a positive ion arc stream is created between the anode and cathode.

The arc lamp of the invention is operated from a suitable polyphase input. One mode of connecting the anodes and electrodes is illustrated in FIG. 4. A three-phase AC input 60 is connected in a star configuration 62. The cathode 12 is connected to the common ground 61 of the star connection 62. In the configuration of FIG. 4 opposed pairs of anodes such as AD, CF, and BE are connected to common legs 66, 68 and 70 respectively, of the star connection 62. Each anode connection contains a current-limiting resistor 72 and a diode 74 as a rectifying element in series with the anode.

Current will flow to each pair of anodes in turn during the passage of an electrical cycle, and only to that pair of opposed anodes that has the momentary maximum (positive) potential. The other pairs of anodes are inoperative during the part of the cycle when they do not have maximum positive potential. Each anode thus, has a duty cycle of one-third for the three-phase input, but each anode can handle its normal design maximum as a long-time average load. Thus, the single cathode with three pairs of anodes has a power capability of three times that of a single anode lamp, although the luminous emitting area and location are little changed from that of a single-anode lamp. The use of opposed pairs of anodes which are simultaneously fired preserves symmetrical location of the hot spot.

The pair of opposed anodes could be connected to the terminals of a three-phase 60-cycle, star-connected, current-limiting transformer with the cathode return connected to the neutral point of the transformer. As illustrated in FIG. 5, the anodes may also be separately connected to the terminals of a six-phase transformer. In this case the three-phase AC input 60 is connected to the terminals 80 of the primary 84 of the transformer. The cathode 12 is connected to the common

return 86 of the star-connected secondaries 88 of the transformer. The line connecting each secondary to each anode again contains a diode 74 in series with each anode as a rectifying element to prevent a reverse discharge from anode to cathode during polarity reversal of the AC line supply.

The three-phase input will produce a six-phase output and the anodes will be sequentially fired in turn by the half-wave outputs. With this arrangement, the lamp is self-rectifying and each anode operates at full power for a duty cycle of one-sixth. With a sixty cycle supply and six-phase output, the power input duration for each anode is 2.8 milliseconds and the quiescent period for each anode is 13.8 milliseconds. For all practical purposes, the slight dip between phase outputs will have no appreciable effect on the light output of the lamps since the dips occur at 360 cycles per second.

A three-anode structure was built and operated. A tungsten cathode was utilized with three one-quarter inch diameter, tungsten-tipped water-cooled copper supports as anodes. The lamp was pressurized at 75 p.s.i.g. with argon gas. The lamp was first operated as a single-cathode, single-anode lamp by connecting all three transformer outputs to one anode and operating the lamp. The anodes were raised to the melting point at 60 amperes. This would normally be the operating limit of such a single-cathode, single-anode lamp.

The three transformer outputs were then connected separately to each of the three anodes and the current needed to raise the tips of the tungsten anodes to the melting point was then 150 amperes (50 amperes in each anode leg) and 150 amperes through the single cathode. The 150 amperes would then be the operating limit for the lamp as a single-cathode, three-anode lamp. The inability to achieve an operating limit of 180 amperes was attributed to the hot radiation from the anode tips radiating additional heat load to adjacent neighboring anodes. With the use of water-cooled copper-tipped anodes, the copper would not reach its melting point of 1,083° C. and the additional heat load would not cause a reduction in the attainable operating limit of 180 amperes.

The lamp operated, as expected, with the cathode light spot being timed-modulated to the extent of 16 percent which corresponds to the current modulation in a three-phase current. A six-phase operation would give a 4.2 percent modulation and presumably a 4.2 percent light modulation. Such modulations with fractional second periods are far faster than any conceivable time constant of elements to be tested in simulators and thus are acceptable.

It is to be realized that only preferred embodiments of the invention have been disclosed and that numerous modifications, substitutions and alterations are all permissible without departing from the spirit and scope of the invention, as defined in the following claims.

What is claimed is:

1. A system for operating a high-intensity, arc discharge lamp comprising in combination:
 - a plurality of anode electrodes disposed axially and symmetrically with respect to a common axis, each anode electrode terminating in a tip disposed in a plane normal to the axis;
 - a single cathode disposed on said axis and having a tip spaced from said plane and spaced an equal discharge gap distance from each of said anode tips;
 - a sealed envelope surrounding said electrodes containing a discharge gas consisting essentially of at least one gas selected from the group consisting of neon, argon, xenon and krypton at a pressure greater than atmospheric at room temperature, at least a portion of the envelope being transparent to emitted radiation; and
 - polyphase power input means connected to said cathode and to each of said anodes for sequentially firing said anodes and for developing across said gap an arc discharge having a stationary, small, maximum brightness fireball disposed just above the apex of the cathode tip a neutral gas jet stream flowing axially from said fireball into the volume between the anode tips and an ion stream

5

6

between said stationary fireball and sequentially rotating across the tip of the anode having the momentary maximum positive potential.

2. A system according to claim 1 in which the tip of each anode is canted toward said cathode.

3. A system according to claim 1, in which said anodes are provided in multiples of three and said polyphase input means contains three phases.

4. A system according to claim 1 in which the gas is xenon and the pressure of the discharge gas within the envelope at ambient temperature is from 30 p.s.i.g. to 100 p.s.i.g.

5. A system according to claim 1 wherein $2n$ anodes are provided, said polyphase input has n phases and each opposed pair of anodes in a line in said plane through said axis is connected to a single phase of said polyphase input.

6. A system according to claim 1 wherein said polyphase input comprises a three-phase alternating current line supply and each connection to said anode from said supply contains a current-limiting device and a rectifying element in series with said anode.

7. A system according to claim 6 in which said rectifying element is a diode.

8. A system according to claim 6 in which said current-limiting device is a resistor.

9. A system according to claim 6 in which said current-limiting device is a transformer.

10. A system according to claim 1 in which said electrodes contain hollow passageways for receiving a flow of coolant.

* * * * *

20

25

30

35

40

45

50

55

60

65

70

75