United States Patent [19]

Miller

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[54] **COMPACT, HIGH INTENSITY ARC LAMP WITH INTERNAL MAGNETIC FIELD PRODUCING MEANS**

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

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[21] Appl. No.: **385,059**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 173,178, Aug. 19, 1971, abandoned.

[52] **U.S. Cl.** **315/344;** 313/32; 313/161; 313/184; 313/224

[51] **Int. Cl.... H05b 31/06;** H05b 31/28; H05b 41/00

[58] **Field of Search** 313/32, 155, 153, 161, 313/184, 224; 315/344

[56] **References Cited**

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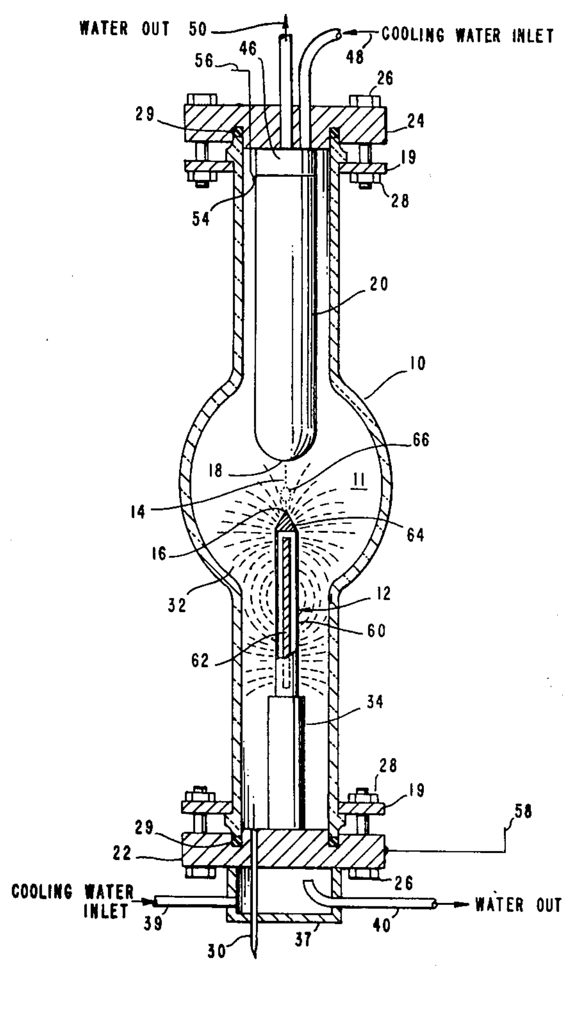
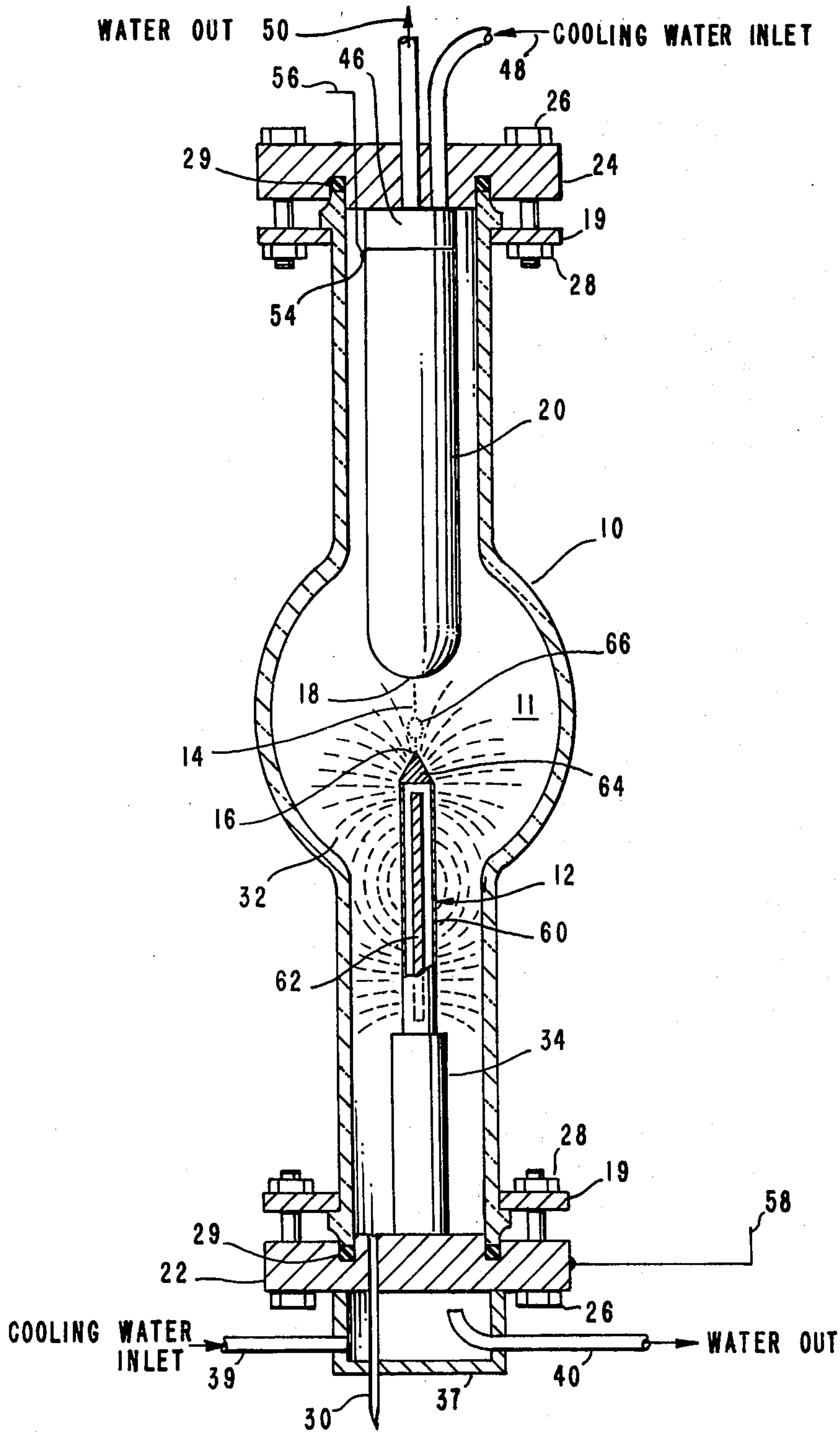
[57] **ABSTRACT**

A significant increase in brightness of the arc and a more focusable light-emitting region are provided in compact arc lamps by causing magnetic lines of force to diverge from the cathode tip from magnetic field producing means disposed within the cathode structure.

12 Claims, 5 Drawing Figures




WATER OUT 50
COOLING WATER INLET
46
48
56
26
29
24
19
28
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20
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64
16
12
32
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COOLING WATER INLET
WATER OUT
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37
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FIG. 1

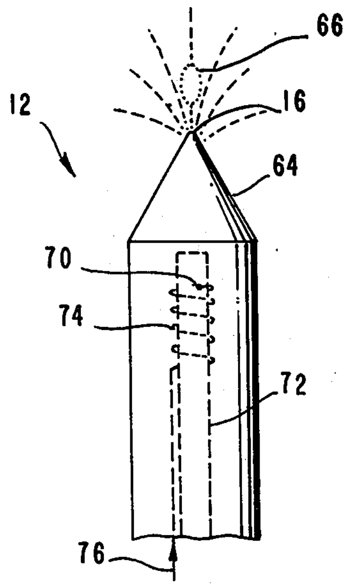

FIG. 2

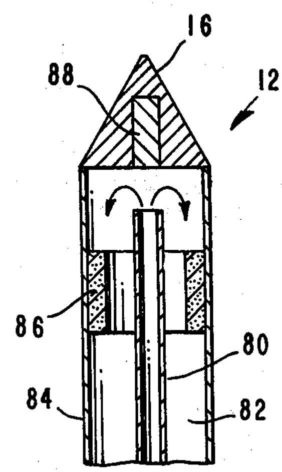

FIG. 3

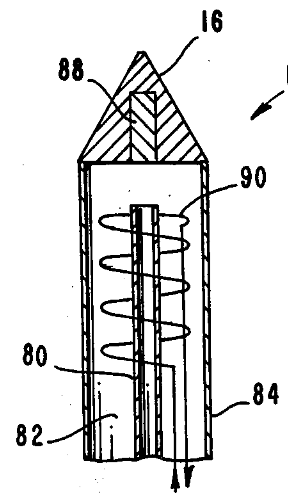

FIG. 4

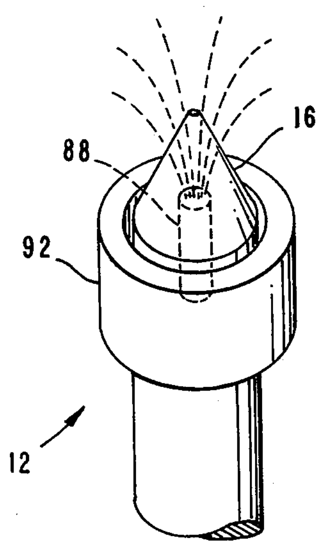

FIG. 5

COMPACT, HIGH INTENSITY ARC LAMP WITH INTERNAL MAGNETIC FIELD PRODUCING MEANS

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).

ORIGIN OF THE INVENTION

This application is a continuation in part of an application, Ser. No. 173,178, filed Aug. 19, 1971, entitled Magnetic Improvements For Compact Arc Lamps, and now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to arc lamps, and more particularly, to magnetic improvements in high pressure, xenon, compact arc lamps.

2. Description of the Prior Art:

Light sources with a continuous luminous output, and with a spectral distribution and brightness approaching that of the sun are needed. One of the best present sources of such light is a direct current electric arc produced in xenon gas under pressure. However, the brightness, power handling capacity and useful lifetime of these lamps are not great enough for many present needs.

Present lamps operate with an electrical cathode and anode spaced in line across a small gap. These small separations raise the maximum brightness of the very useful light 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 and ion bombardment along the arc stream direction impinging upon the anode tip, and due to the flow of hot gas, flowing in the axial direction from cathode to anode.

Such lamps develop a fireball about 30 mils in diameter disposed just above the apex of the cathode. The lamps are usually mounted in a collecting reflector and are focussed with respect to location of the fireball. The arc contacts the anode in a small hot spot which, while substantially larger than the fireball imposes a considerable heat load on a relatively small area of the anode. These conditions may cause erosion of the cathode tip by the fireball to a condition at which defocusing occurs. The mode fails under the sustained and concentrated load impinging always on the same spot.

A solar simulator lamp system has been constructed in which the light from a cluster of xenon, compact arc lamps is combined via an integrating lens system and a single piece collimator to give a large diameter beam of the intensity approaching true sunlight at earth orbit outside the atmosphere. Additional power can be provided by increasing the number of lamps in the cluster, resulting in an increased beam diameter but without improving the collimation angle, increasing the intensity or improving the spectral characteristics. Unless the radiation field of the lamp is changed, improvements in any of the last three characteristics can only be obtained at the expense of degrading other performance characteristics.

A net improvement in performance can only come from an increased intrinsic brightness of the emitting area of each arc. The peak brightness volume of each lamp comprises a cylinder approximately 2 mm in diameter by 3 mm long located just off the tip of the cathode which is the useful input area for the solar simulator system optics. An increase in the brightness of this specified area of the arc source, even if obtained by redistribution of the light in the remainder of the field, would be advantageous. A change in the brightness of the specified area of the arc source, can in general, be obtained by a change in the operating parameters of the lamp which leads to a redistribution of the energy in the arc area. Such a gain in the brightness of the imaged area does not necessarily mean increased efficiency, and does not necessarily imply increased overall luminosity.

The effect of increased power on brightness of the imaged area depends on a number of independent factors, the most important and pertinent ones being:

1. Gas composition and density;
2. Anode heat transfer;
3. Specific emission of cathode and arc resistance;
4. Spatial stability of cathode spot and overall stable operation of the lamp; and
5. Gas pressure in relation to container strength.

Anode heat loading has been a limiting factor in lamp operation. In Ser. No. 888,362, filed Dec. 29, 1969, now U.S. Pat. No. 3,635,537 which issued on Jan. 18, 1972, the limitations set by the power-handling capacity of a single anode is circumvented by arranging a plurality of anodes working with a common cathode. By sequentially firing the anodes with increased power and shortened duty cycle, each anode can handle its normal design maximum as a long time average load. While the operation is satisfactory, multiple anode lamps require careful alignment of the elements, and eleborate cooling circuits which add considerably to the cost of manufacturing each lamp.

In Ser. No. 108,810, filed Jan. 22, 1971, by this and another inventor, the complexity of the electrostatic switching method described above is eliminated by rotating the arc in a circular path around the tip of a single watercooled anode by means of the interaction of a radial magnetic field with the longitudinal arc current. The attachment point then becomes a circle coaxial with the center line, part-way up the anode structure. Ser. No. 123,289 filed Mar. 11, 1971, filed by the inventor, discloses the application of longitudinal magnetic fields in the vicinity of the cathode tip applied from magnetic means external to the lamp envelope to stabilize the attachment of the arc discharge to the cathode tip in sequentially fired multiple anode lamps and to neutralize stray magnetic field produced by ferro-magnetic support for clusters of lamps. The latter applications were corrective in nature and utilized external magnetic field producing means to correct problems in already existing and assembled lamp systems.

SUMMARY OF THE INVENTION

The present invention relates to providing a significant increase in brightness and in improving the shape of the light emitting region of compact arc lamps. These improvements are provided by means of structure disposed within the lamp envelope and thus, are incorporated into the lamp during manufacture.

It was discovered in the course of stabilization of the arc in the multiple anode lamps and the clusters of lamps that an unexpected increase in lamp fireball brightness was realized when a magnetic field was provided with magnetic field lines radiating from the cathode due to a dimunition of the size of the emitting area at the tip of the cathode and to an effective increase in the arc column resistance. The increase in the arc column resistance requires an increased applied voltage to maintain a given current in the arc and this constitutes an increased power into the arc resulting in greater brightness and luminous output in the emitting area.

In the compact arc lamp of this invention magnetic field producing means are preferably provided within the cathode structure. This causes a maximum number of magnetic field lines to radiate from the cathode tip to thereby direct a maximum number of ions to the cathode, thereby increasing the arc column resistance and having a maximum constricting effect on the shape of the fireball into a longer spindle-shaped emitting area which is better suited to reflectors for lamp systems because of better focusability. This also provides a greater light yield for a given set of arc operating conditions and gas pressure. Furthermore, the internal magnetic means disposed adjacent the cathode and below the cathode tip do not interfere with or block emission of light from the fireball. The internally generated magnetic field also provides fireball stabilization and shielding against the effects of stray magnetic fields.

A high intensity arc lamp system in accordance with the invention comprises a sealed envelope for containing a discharge gas at greater than atmospheric pressure; a cathode having a tip extending into the envelope; an anode disposed within said envelope parallel to a line through the axis of said cathode and having a tip spaced an arc discharge gap from the tip of the cathode; electric discharge means connected to the anode and cathode for forming an arc discharge between said tips; and magnetic field means disposed within said cathode for providing a magnetic field with lines which radiate from the cathode tip during said arc discharge.

These and many other attendant advantages of the invention will become apparent as the invention becomes 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 view, partly in section, of an arc lamp, according to the invention including magnetic source means within the cathode for providing a magnetic field wherein a maximum number of field lines radiate from the cathode tip;

FIG. **2** is a partial view of an alternate form of internal magnetic cathode structure;

FIG. **3** is a partial, sectional view of a further cathode construction including an internal cooling circuit;

FIG. **4** is another partial view in section of another embodiment of a cathode structure including a cooling circuit;

FIG. **5** is a partial view of yet another cathode construction in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. **1**, a first embodiment of a high intensity arc lamp, according to the invention, generally includes an envelope **10**, a cathode **12** having a tip **16** axially spaced a discharge gap **14** from the tip **18** of an anode **20**. The envelope is formed of a transparent material, suitably quirtz, and contains a discharge gas **11** under pressure.

In one suitable type of lamp construction, a flange **19** 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 through correspondingly located holes in flange **19** and are secured by means of nuts **28.** A circular groove which receives an end O-ring **29** is formed on the inner surface of each end, **22, 24** and the grooves receive each end surface of the envelope. When the bolts **26** and nuts **28** are secured, the O-rings **29** form a gas-tight seal between the ends **22, 24** and the envelope **10.**

In another suitable type of lamp construction the O-rings **29** may be dispensed with, and metal-glass seals are used to join end caps to the envelope serving the same function as **22** and **24.**

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 lamp housing may contain an integral, internal, pre-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 anode may be supported by means of straps attached to the side walls of the envelope. A suitable construction for such a lamp is disclosed in my co-pending application, Ser. No. 841,278, filed July 14, 1969. The improvements cited in the present application are suitable for incorporation into such a sealed beam lamp configuration.

In the particular type of lamp shown in FIG. **1**, a gas inlet tube **30** penetrates through lamp end **22** into the interior **32** of the envelope. A cathode support **34** is attached to the lamp end **22.** One suitable structure for a cylindrical cathode, as illustrated, comprises a body portion **60** having a central recess for receiving a permanent bar magnet **62** which is embedded within the cathode. The cathode is suitably manufactured from a high temperature metal, such as tungsten and terminates in a conical tip **64.** In lamps of relatively low power, the cathode does not require cooling but in higher powered lamps, the cathodes as well as the anode requires forced liquid cooling. For example, a hollow cap **37** is attached to the exterior of lamp end **22** and receives a flow of coolant liquid through the coolant inlet tube **39** and discharges the coolant liquid via coolant outlet **40.** If greater heat removal capacity is required or desired, the cathode **12** may be hollow and water circulated through the support **34** and cathode **12.** In that case, the magnet **62** would be disposed within the cathode structure in such manner that internal passageways for coolant would be available.

Electrical connections to the anode **20** and cathode **12** are provided by electrical leads **56, 58** connected to the respective lamp ends **22, 24** and a d.c. source, not shown. The anode **20** may be provided with an internal coolant passageway **38** by disposing an insert **44** within the hollow anode to form an annular coolant passage **38** which communicates with the coolant inlet **48** and coolant outlet **53.**

Sufficient operation gas which may be any of the gases chosen from the class 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 closed. Typical internal pressures are about 30–60 psig when non-operating at ambient temperature, which increases to about 70–180 psig when in operation.

During operation, water or other coolant fluid is circulated through the hollow electrodes. Typically, the cathode and anode are about ¾ inch in diameter and are separated by a discharge gap of about ½ inch. On application of a d.c. electrical power input to the anode and cathode, a negative ion or electron stream and a positive ion arc stream are established between the tip **18** of the anode **20** and the tip **16** of the cathode **12**. The arc contacts the anode tip **18** and a fireball **66** is disposed above the cathode tip **16**. The magnet **62** creates magnetic lines of force indicated by the dotted lines. Since the magnet **62** is placed within the cathode and adjacent to its very tip a maximum possible number of field lines or lines of force will radiate from the cathode tip for a given magnetic field. The lines of force adjacent the tip **16** of the cathode and surrounding the fireball **66** radiate from the cathode and serves to constrict the fireball a maximum amount in the vicinity of the cathode tip. However, the lines of force are reduced in intensity near the anode and do not apply much force in the vicinity of the anode tip. Therefore, they would not interfere or interact with any radially directed magnetic field from the anode which could be present to rotate the foot of the arc as disclosed in application, Ser. No. 108,810, filed Jan. 22, 1971.

An ion produced by arc discharge, in the absence of a magnetic field, may diffuse in any direction with the effect of widening the fireball **66**. In the presence of the magnetic lines of force, ions are constrained by the lines of force, do not diverge and are directed onto the cathode. This slows down ion diffusion across the magnetic field lines. In addition, the magnetic lines of force compress the electrons in the hottest portion of the arc, i.e., the fireball **66**, into the elongated cylindrical shape illustrated. The net result of these effects is a longer spindle-shaped and brighter emitting area which is better suited for focussing. A more focusable fireball in itself provides a greater light yield for a given set of arc operating conditions and gas pressure.

However, it has also been found that there is an increase in arc column resistance due to the shape and location of this particular magnetic field. Increased resistance requires an increased applied voltage to maintain a given current in the arc. This constitutes increased power input to the arc and consequently, a higher luminosity and brightness are obtained.

From experimental data, it has been determined that the increase in power, which is delivered to a typical 20 kw xenon arc lamp, is about 15 percent for a magnetic field having an intensity from 50 to 60 gauss. A magnetic field of about 50 gauss is a very practical field for use in compact arc lamps and may be generated safely and economically.

Referring now to FIG. **2**, a cathode **12** is illustrated which includes an electromagnet insert **70** capable of producing a maximum number of magnetic lines of force radiating from the tip **16** of the cathode **12** for the magnetic field provided. The insert **70** comprises a rod **72**, the upper end of which is provided with an electromagnetic coil **74**. An electrical lead **76** is connected to the coil and to a power supply, not shown.

In the variation illustrated in FIG. **3**, the cathode **12** may be cooled by means of coolant introduced through a central coolant inlet tube **80**. The coolant, such as water, flows down the annular channel **82** provided between the inlet tube **80** and the wall **84** of the cathode **12**. A magnetic field having the desired shape and location can be provided by forming the inlet tube **80** of soft iron and placing a permanent ceramic annular magnet **86** adjacent the upper end of the cathode casing **84** and by disposing a soft iron pole piece **88** within the conical tip **16** which can be made of tungsten.

The permanent magnet **86** may suitably be replaced with an equivalent electromagnetic winding. In the electromagnetic embodiment illustrated in FIG. **4**, the collant inlet water tube **80** is surrounded by a coil **90** which is supported within the annular coolant return channel **82**. A soft iron pole piece **88** is again embedded within the conical cathode tip **16**.

In the cathode embodiment illustrated in FIG. **5**, a permanent magnet in the form of an annular ceramic cylinder **92** surrounds the upper portion of the cathode just below the cathode tip **16**. The magnetic field lines are concentrated by means of the soft iron pole piece **88** placed immediately behind the cathode tip, and then the field lines are caused to diverge from the cathode tip.

All the embodiments of cathodes have in common a magnetic structure which is incorporated within the lamp envelope, placed within the cathode and with a pole adjacent the very tip of the cathode. Compact arc lamp may be manufactured incorporating these features to provide an automatic and inherent increase in lamp fireball brightness, focusability and stability.

It is to be realized that only preferred embodiments of the invention have been described and that numerous substitutions, alternations and modifications 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 high-intensity arc lamp comprising in combination:

a sealed envelope for containing a discharge gas at greater than atmospheric pressure;

a cathode having a tip extending into the envelope;

an anode disposed within said envelope parallel to a line through the axis of the cathode and having a tip spaced an arc discharge gap from the tip of the cathode;

electric power means connected to the anode and cathode for forming an arc discharge between said tips including a highly luminous fireball disposed above the cathode tip; and

magnetic field producing means disposed internally within said cathode and adjacent the cathode tip for establishing a magnetic field having the maximum possible number of field lines radiating from said cathode tip for said magnetic field for increasing lamp brightness and for improving the shape of said arc.

2. An arc lamp according to claim **1** in which said magnetic field producing means includes a ferromagnetic pole piece axially disposed within the structure of the cathode tip.

3. An arc lamp according to claim **2** in which an annular, permanent magnet is supported below the cathode tip for magnetizing the pole piece to develop the longitudinal lines of force.

4. An arc lamp according to claim 3 in which the pole piece is formed of soft, magnetic iron and the annular magnet is disposed within the structure of the cathode.

5. An arc lamp according to claim 2 in which said magnetic field producing means includes an electrical winding within said cathode and means for energizing said winding.

6. An arc lamp according to claim 1 in which said cathode is hollow and further includes means for flowing coolant through the hollow cathode.

7. An arc lamp according to claim 6 wherein said hollow cathode includes a soft iron inlet tube for flowing coolant through said cathode, and

said magnetic field producing means includes an electrical winding wound around said inlet tube, and

means for energizing said winding.

8. An arc lamp according to claim 6 wherein said hollow cathode includes a soft iron inlet tube for flowing coolant through said cathode, and

said magnetic field producing means includes an annular magnet disposed within the structure of said cathode and enclosing said soft iron inlet tube.

9. A high-intensity arc lamp comprising in combination:

a sealed envelope for containing a discharge gas at greater than atmospheric pressure;

a cathode having a tip extending into the envelope;

an anode disposed within said envelope parallel to a line through the axis of the cathode and having a tip spaced an arc discharge gap from the tip of the cathode;

electric power means connected to the anode and cathode for forming an arc discharge between said tips including a highly luminous fireball disposed above the cathode tip; and

a magnet positioned within said cathode,

said cathode having a magnetic pole piece adjacent said cathode tip.

10. In an arc lamp of the type comprising a cathode having a tip and an anode spaced therefrom enclosed in a gas filled envelope which upon the application of voltage between anode and cathode produces a fireball adjacent the cathode, a method of increasing the lamp brightness output and improving the shape of the light emitting region thereof comprising:

generating a magnetic field from within and adjacent the tip of the cathode of said arc lamp to cause a maximum possible number of field lines to radiate from said cathode for said magnetic field.

11. A method as called for in claim 10 wherein said step of generating a magnetic field from within and adjacent the tip of said cathode comprises:

placing an elongated magnet within said cathode and below the tip thereof to provide a magnetic field.

12. A method as called for in claim 10 wherein said step of generating a magnetic field from within and adjacent the tip of said cathode comprises:

placing a soft iron pole piece within the tip of said cathode; and

placing annular magnet around the periphery of said cathode and adjacent to the tip thereof.

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