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(54) Metal halide lamp

(57) A highly efficient discharge lamp (10) has a color rendering index greater than 75, a lumens per watt rating greater than 90, a correlated color temperature of between 3500 and 4040°K, and a wall loading greater than 17 W/cm^2. The lamp (10) comprises an outer glass envelope (12) and a pair of electrical conductors (26,28) extending thereinto. A quartz discharge tube (14) is disposed within the outer envelope (12) and includes a pair of spaced electrodes which are electrically connected to the electrical conductors (26,28) for creating an electrical discharge during operation of the lamp. The discharge tube (14) has an arc chamber or arc cavity with the configuration of a prolate spheroid having a major diameter and a given arc distance as measured by the linear distance between the interior terminations of the electrodes, the ratio of the major diameter to the arc distance being less than 1 and greater than 0.9. An arc generating and sustaining medium within the arc chamber comprises the halides of sodium, scandium, lithium, thulium, in a ratio of 48:1:10:16, and a thallium amalgam. A fill gas selected from argon and xenon, and a given quantity of mercury to achieve a desired lamp voltage completes the chemical dose.

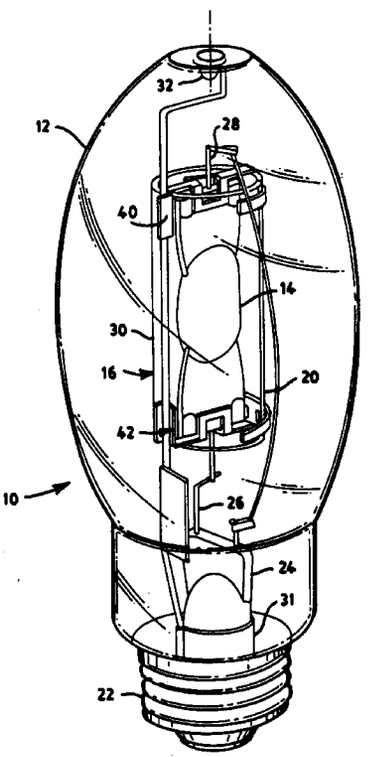

FIG. 1

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Description

TECHNICAL FIELD

This invention relates to high intensity discharge (HID) lamps and more particularly to such lamps having increased efficacy.

BACKGROUND ART

HID lamps are among the most efficient light sources currently available. When first introduced in 1934 as mecury lamps, such lamps had an arc length of 158 mm, a bore diameter of 33 mm and a power input of 400 W, resulting in a power loading of 2 W/cm^2. Efficacy was about 40 lumens per watt (LPW) and the color rendering index (CRI) was less than 20.

With the introduction in 1939 of the quartz arc tube, bore diameter was reduced to 22 mm and the arc length to 70 mm. For a 400 W input, the power loading reached 6 W/cm^2. An efficacy of 50 LPW was achieved and the life was increased to 6000 hours.

By the early 1960's improved quartz manufacturing techniques made possible the introduction of metal halides to augment the sparse mercury spectrum. This resulted in lamps with additives of scandium and sodium which provided for LPW of 80 and CRI of 65 for a 400 W power input. These lamps had a bore diameter of 20 mm and an arc length of 45 mm to satisfy the vaporization requirements of the metal halide additives. Power loading increased to 12 W/cm^2 for the 400 W input power.

Still more recent activity in this area has included the development of lithium iodide enhancements to the scandium-sodium chemistry (see, for example, U.S. Patent No. 5,057,743, Keeffe et al.). These lamps further improved the CRI to 75 at a correlated color temperature (CCT) of 3200°K with LPW of 85 and average wall loadings of 15.5 W/cm^2 in low wattage lamps.

These lamps are noted for their long life and good color rendering properties. These lamps comprise arc discharge envelopes of quartz having complex fills of metal halides, mercury and an inert gas. The arc discharge chamber is usually enclosed within an outer envelope of a hard glass such as an aluminosilicate having good UV absorbing properties. However, in an era of high energy costs, it would be advantageous to provide a metal halide HID lamp having even better and more efficient luminating qualities.

DISCLOSURE OF INVENTION

It is, therefore, an object of the present invention to obviate the disadvantages of the prior art.

It is another object of the invention to provide a metal halide HID lamp having a color rendering index greater than 75; an efficacy greater than 90 LPW and a CCT of between 3500 and 4040°K.

These objects are accomplished, in one aspect of the invention, by the provision of a metal halide HID lamp which comprises an outer glass envelope having a pair of electrical conductors extending into the interior thereof. A quartz discharge tube is disposed within the outer envelope and includes a pair of spaced electrodes which are electrically connected to the electrical conductors for creating an electrical discharge during operation of the lamp. The discharge tube has an arc chamber with the configuration of a prolate spheroid having a major cross-sectional diameter and a given arc distance as measured by the linear distance between the interior terminations of the electrodes, the ratio of the major diameter to the arc distance being less than 1 and greater than 0.9. An arc generating and sustaining medium is contained within the arc chamber and includes the halides of sodium, scandium, lithium, thulium and thallium, a fill gas selected from argon and xenon, and a given quantity of mercury to achieve a desired lamp voltage. The lamp is operated with a wall loading greater than 17 W/cm^2.

Lamps produced as above have fulfilled these design requirements and additionally have shown better lamp-to-lamp uniformity, improved color consistency, long life, reduced near UV emission, elimination of the troublesome end paint, reduced arc mantle color separation and manufacturing cost savings by reducing the amount of chemical fill necessary for the lamp dose.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of a lamp in accordance with an aspect of the invention;

Fig. 2 is a graph of CRI vs. Life of lamps employing the chemistry of the invention and prior art lamps;

Fig. 3 is a graph of CCT vs. Life of lamps employing the chemistry of the invention and prior art lamps;

Fig. 4 is a graph of the lumen maintenance of lamps employing the chemistry of the invention and prior art lamps;

Fig. 5 is a cross-sectional view of an embodiment of an arc tube in accordance with an aspect of the invention; and

Fig. 6 is a graph of core temperatures at peak current for various prior art chemistries and the chemistry of the invention.

BEST MODE FOR CARRYING OUT THE INVENTION

For a better understanding of the present invention, together with other and further objects, advantages and capabilities thereof, reference is made to the following disclosure and appended claims taken in conjunction with the above-described drawings.

Referring now to the drawings with greater particularity, there is shown in Fig. 1 a metal halide arc discharge lamp 10 including a lamp envelope 12 and an arc tube 14 mounted within the envelope by mounting frame 16. The arc tube may be positioned within a shroud 20 which can also be supported by the mounting frame 16. Electrical energy is coupled to the arc tube 14 through a base 22, a lamp stem 24 and electrical leads 26 and 28. The arc tube contains a chemical fill or dose of materials to provide light when an arc is initiated therein, as will be explained hereinafter. The shroud 20 comprises a cylindrical tube of light transmissive, heat resistant material such as quartz.

As noted, in this particular instance, the mounting frame 16 supports both the arc tube and the shroud within the lamp envelope 12. The mounting frame 16 includes a metal support rod 30 attached to lamp stem 24 by a strap 31. The support rod engages an inward projection 32 in the upper end of the lamp envelope 12. The support rod 30 in its central portion is parallel to a central axis of the arc tube 14 and shroud 20. The mounting means 16 further includes an upper clip 40 and a lower clip 42 which secure both arc tube 14 and shroud 20 to support rod 30. The clips 40 and 42 are attached to the support rod 30, preferably by welding.

It has been discovered that when a metal halide chemical composition comprised of the iodides of thulium, scandium, sodium and lithium is incorporated within an arc tube 14, and that arc tube is operated at power loadings heretofore found to be excessive for prior art chemistries, unexpected advantages ensue. For example, it has been found that when such a chemistry, in which the mole fractions of the iodides of Tm, Sc, Na and Li are 0.316, 0.020, 0.474 and 0.190, respectively, is dosed into a low wattage (i.e., 75 W) cylindrical arc tube which is then operated at 100 W, so that the actual wall loading is 100/75 x 15.5 = 20.67 W/cm^2, the performance is unexpectedly improved while no deleterious effects owing to the elevated loading, which would have been present with prior art chemistries, are found. The CRI performance of such a lamp is shown in Fig. 2 wherein plot A is a lamp in accordance with the aspect of the invention described above, showing an initial value of 87 while maintaining a value of 84 at 10,000 hours. Plots B, C, D and E depict prior art lamps. Similarly, the CCT is remarkably stable, as shown by plot A of Fig. 3, holding the initial value of 4600°K $\pm$ 100°K over the 10,000 hours. Plots B, C, D and E, again depict prior art lamps. The lumen maintenance, (Fig. 4) likewise, is remarkably constant following an initial drop which is believed to be caused by tungsten evaporation from the electrodes caused by operating the lamps above their rated wattage. Again, in Fig.4, plot A represents a lamp in accordance with an aspect of the invention and plots B, C, D and E represent prior art lamps. Plots C and D illustrate lamps operated at a conventional average low wattage power loading of 15.5 W/cm^2, while plot E represents a prior art lamp with a conventional fill operated at 33% over the design power loading. Although this latter lamp has a life of over 10,000 hours, its maintenance is not as good as lamps prepared with the improved chemistry and, thus, it is not a viable alternative absent the improved chemical fill of this invention.

All of the above to the contrary notwithstanding, it has been discovered that even further performance gains can be made with an optimized chemical dose and by increasing the power loading to even higher levels by departing from the cylindrical shape of the prior art arc tubes and shaping the arc tube to conform more closely with the configuration of the arc discharge. The arc discharge is known to take a more or less ellipsoidal shape and variations of such shapes have been previously proposed for arc tubes. See, for example, U.S. Patent No. 4,020,377, which discusses isothermal arc tubes of elliptical configuration. However, the specific configuration of arc tube 14 shown in Fig. 5 provides a definite advance in the art and is preferred. This shape is a prolate spheroid generated by rotating an ellipse with semi-axes "a" and "b", where a>b, about the major axis, "a". If "a" and "b" are internal dimensions, then the internal surface area is given as

$$A = 2\pi\left(b^2 + ab\frac{ARCSIN\ e}{e}\right)$$

where

$$e = \frac{(a^2 - b^2)^{1/2}}{a}$$

so that the average power loading is P/A, where P is the input power.

The arc tube 14 is made from quartz or other suitable translucent, high temperature material and has a cavity 44 with tungsten electrodes 46 sealed therein by means of the usual molybdenum foils 48 in a press seal 50. The arc tube cavity 44 has a major cross-sectional diameter Z and an arc distance Y, as measured by the linear distance between the interior terminations of the electrodes 46, and the ratio Z/Y is less than 1 and greater than 0.9. In a preferred form of the invention, Z equals 0.440 "(1.1176 cm); Y equals 0.472 "(1.1988 cm); and Z/Y equals 0.932. Electrode penetration is 3 mm and the electrode tips are not at the foci of the prolate spheroid arc tube 14. This arc tube has a volume of 1.167 cm^3 and an interanl surface area of 5.55 cm^2.

The permissible average power loading for this shape is higher than for conventional shapes for the prior art sodium-scandium-lithium chemistry, owing to the more uniform heat load upon the conformably tailored shape. Moreover, the permissible wall loading is unexpectedly higher for the thulium-scandium-sodium-lithium-iodides- thallium/mercury chemical dose. For example, while low wattage (i.e., 75 W) conventional cylindrical shapes containing sodium-scandium-lithium iodides are limited to 15.5 W/cm^2 for long life operation, and ellipsoidal shapes containing this chemistry have been successfully operated at 17.8 W/cm^2, ellipsoidal shapes containing thulium-scandium-sodium-lithium-iodides with thallium/mercury have shown good photometric results at wall loadings as high as 26.7 W/cm^2. This result occurs because of the lowering of core temperature for the latter chemistry, as shown in Fig.6. Therein, it will be seen that the core temperature for the chemistry including thallium/thulium is some 850°K cooler than that with thulium alone, and some 900°K cooler than the previous standard without either the thallium or thulium.

In Table I, lamps designated K and L represent prior art lamps having the designated fills, and M and N represent lamps having the fills of the instant invention. From the table, it will be apparent that merely increasing the wall loading of the prior art lamps will not achieve the benefits of the instant invention. Additional increases in LPW were shown between lamp M and lamp N when the fill gas of 100 Torr argon was replaced with 100 Torr xenon. The preferred mercury dose is that quantity which provides the desired lamp voltage. For example, to achieve a lamp voltage of 95 volts in the arc tube described above, a mercury dose of 15 mg is required with 0.3 mg of thallium. The preferred method of dosing the thallium is as an amalgam with about 0.5 to 2 wgt. percent of the mercury; however, dosing may also be accomplished as thallium iodide.

The scandium is preferably added in the form of the iodide and as a 0.13 mg metallic chip to getter residual oxygen impurities and scavenge any excess iodine released by the metal iodide salts.

TABLE I

		Wall Loading - 17.8 W/cm^2 $T_h \cong 925°C$ $T_c \cong 790°C$			Wall Loading - 26.7 W/cm^2 $T_h \cong 990°C$ $T_c \cong 880°C$		
	Chemistry	LPW	CRI	CCT	LPW	CRI	CCT
K	Na/Sc/Li/Tm (no paint) 24:1:10:16 MR Hg & 100 Torr Ar	83	83	4350	79	92	3800
L	24:1:10:16 MR 2% Tl/Hg & 100 Torr Ar	91	81	4210	88	91	3610
M	48:1:10:16 MR 2% Tl/Hg & 100 Torr Ar	92	78	3900	94	88	3560
N	48:1:10:16 MR 2% Tl/Hg & 100 Torr Xe	98	75	4040	102	85	3670

The chemical dose described herein is more tolerant of elevated power loadings heretofore found to be detrimental to long lamp life and provides for good life expectancy, LPW greater than 90; and a CCT of between 3500 and 4040 °K.

While there have been shown and described what are at present considered the preferred embodiments of the invention, it will be apparent to those skilled in the art that various changes and modifications can be made herein with-

out departing from the scope of the invention as defined by the appended claims.

Claims

1. A highly efficient discharge lamp having a color rendering index greater than 75, a lumens per watt rating greater than 90, a correlated color temperature of between 3500 and 4040°K, and a wall loading greater than 17 W/cm^2, comprising:

   an outer glass envelope and a pair of electrical conductors extending into the interior of the glass envelope;
   a quartz discharge tube disposed within the outer envelope and including a pair of spaced electrodes which are electrically connected to the electrical conductors for creating an electrical discharge during operation of the lamp, the discharge tube having an arc chamber with the configuration of a prolate spheroid having a major diameter and a given arc distance as measured by the linear distance between the interior terminations of the electrodes, the ratio of the major diameter to the arc distance being less than 1 and greater than 0.9; and
   an arc generating and sustaining medium within the arc chamber comprising the halides of sodium, scandium, lithium, thulium and thallium, a fill gas selected from argon and xenon, and a given quantity of mercury to achieve a desired lamp voltage.

2. The lamp of Claim 1 wherein the halides are iodides.

3. The lamp of Claim 2 wherein the sodium, scandium, lithium, thulium are present in the ratio of 48:1:10:16.

4. The lamp of Claim 3 wherein the thallium is dosed as an amalgam.

5. The lamp of Claim 4 wherein the arc chamber has a volume of about 1.2 cm^3; an arc length of about 1.0 cm; and said fill contains 15 mg of mercury and .3 mg of thallium.

6. The lamp of Claim 5 wherein said fill gas is xenon at a cold fill pressure of about 100 Torr.

7. The lamp of Claim 6 wherein said lumens per watt is about 98, said correlated color temperature is about 4040°K, said color rendering index is about 75, and said wall loading is about 17.8 W/cm^2.

8. The lamp of Claim 5 wherein said lumens per watt is about 102, said correlated color temperature is about 3670°K, said color rendering index is about 85, and said wall loading is about 26.7 W/cm^2.

9. The lamp of Claim 5 wherein said fill gas is argon at a cold fill pressure of about 100 Torr.

10. The lamp of Claim 9 wherein said lumens per watt is about 92, said correlated color temperature is about 3900°K, said color rendering index is about 78, and said wall loading is about 17.8 W/cm^2.

11. The lamp of Claim 9 wherein said lumens per watt is about 94, said correlated color temperature is about 3560°k, said color rendering index is about 88, and said wall loading is about 26.7 W/cm^2.

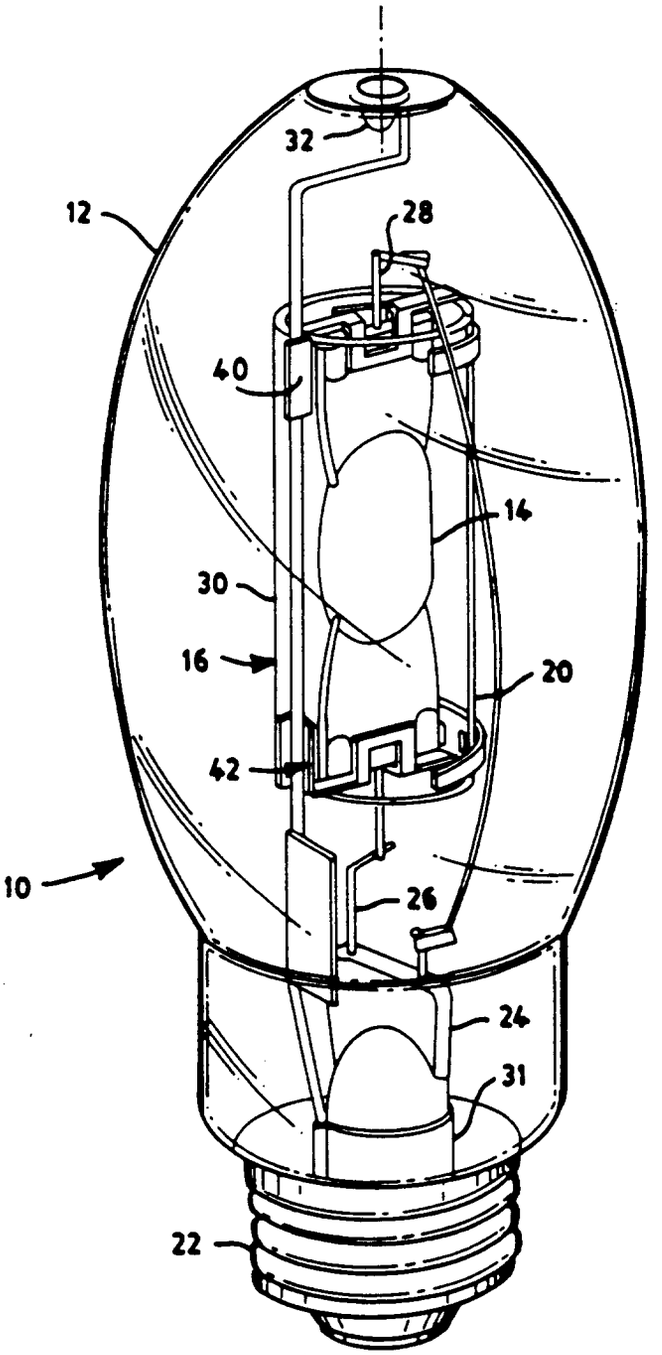
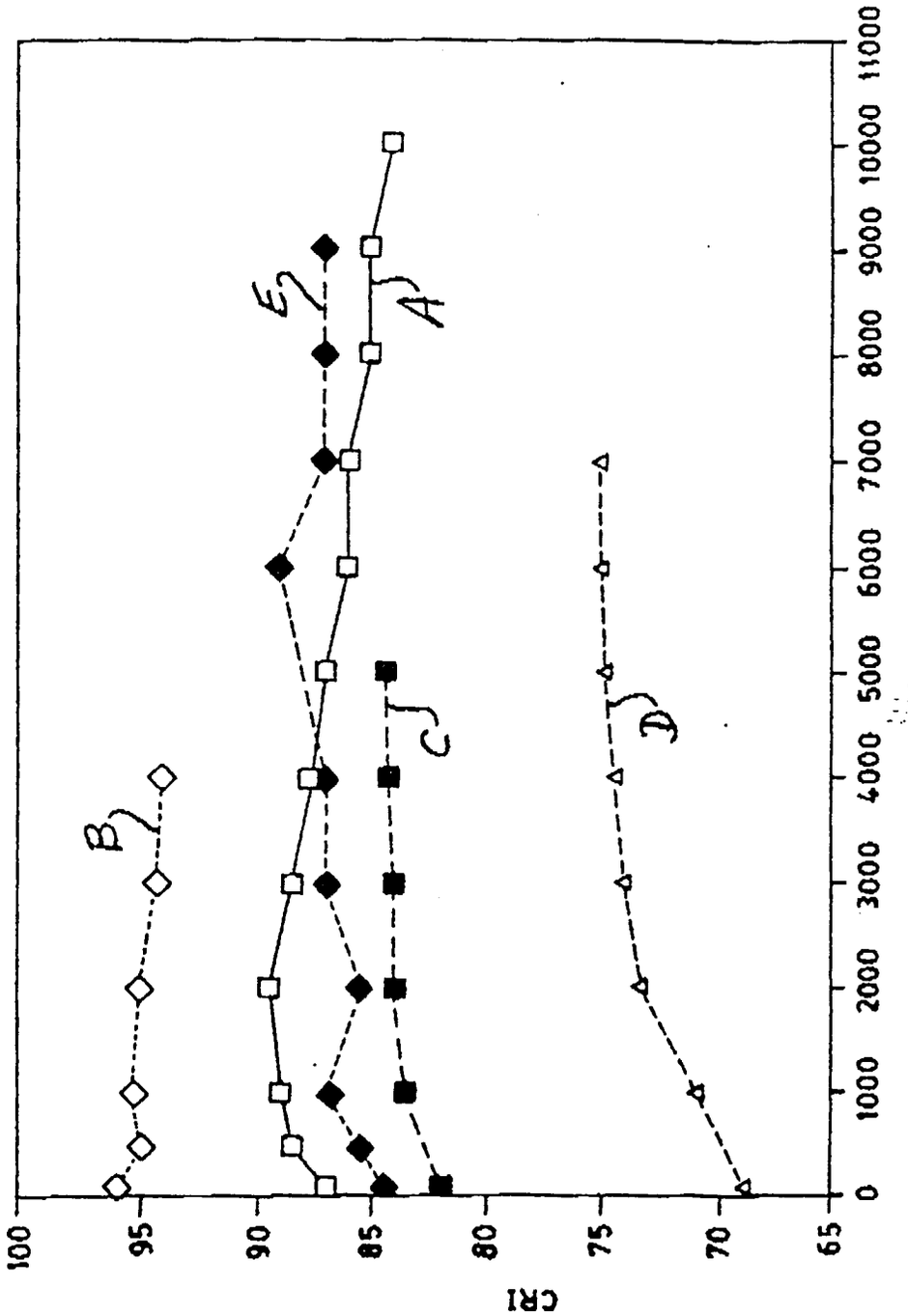


FIG. 1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90
85
80
75
70
65
0
1000
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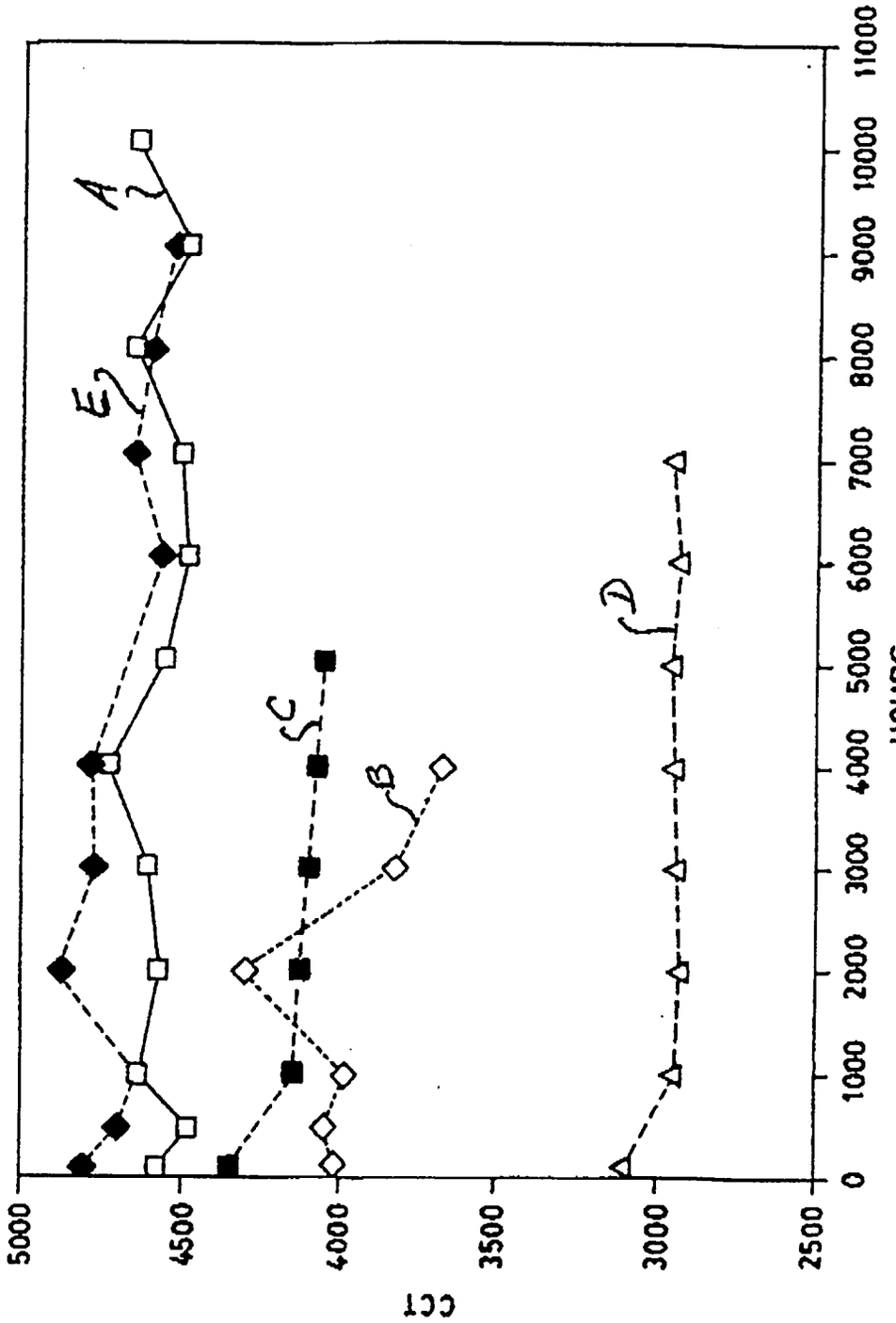
4000
5000
6000
7000
8000
9000
10000
11000
HOURS
A
B
C
D
E

FIG. 2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3500
3000
2500
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5000
6000
7000
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10000
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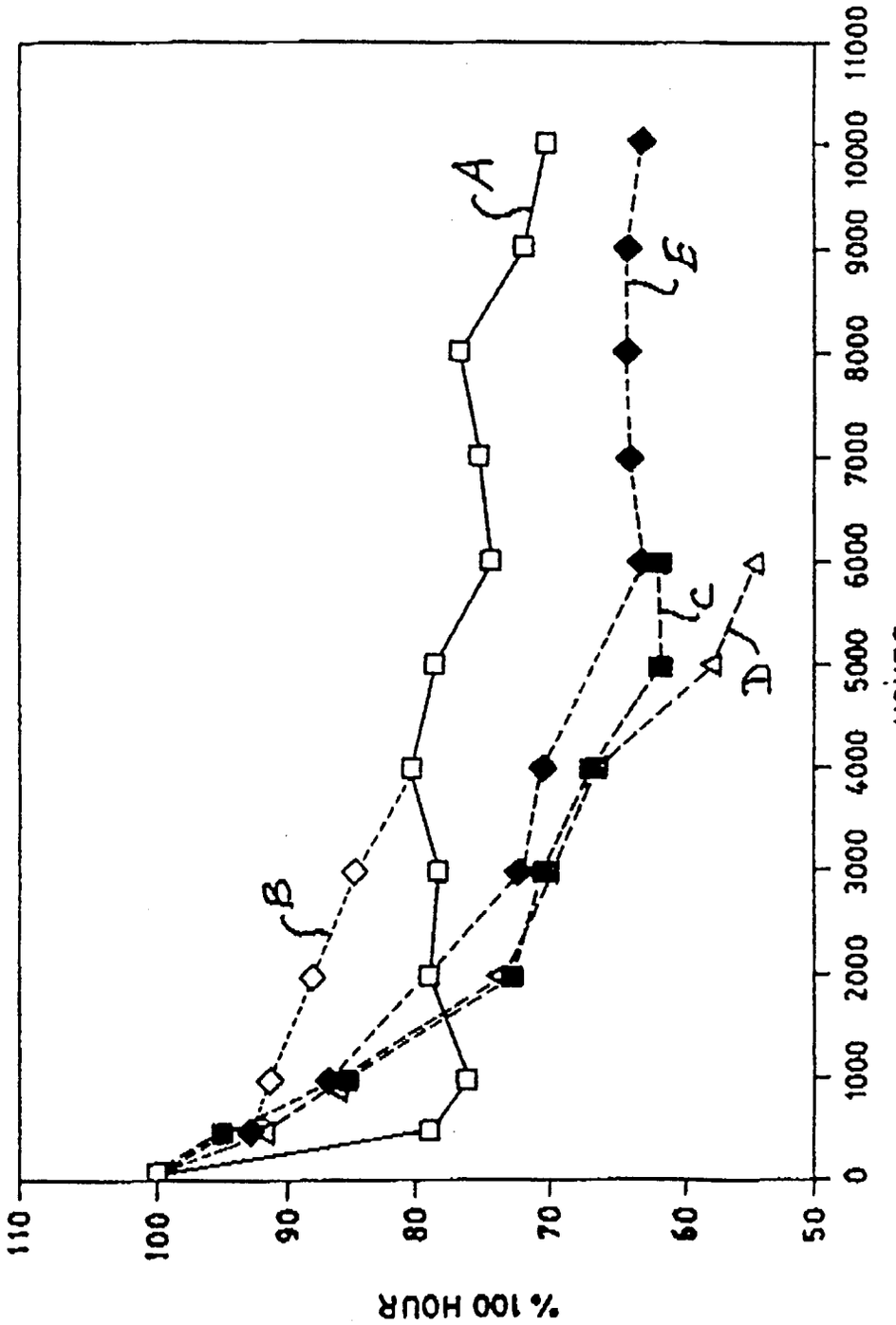
HOURS
A
E
C
B
D

FIG. 3


% 100 HOUR
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60
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HOURS
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FIG.4

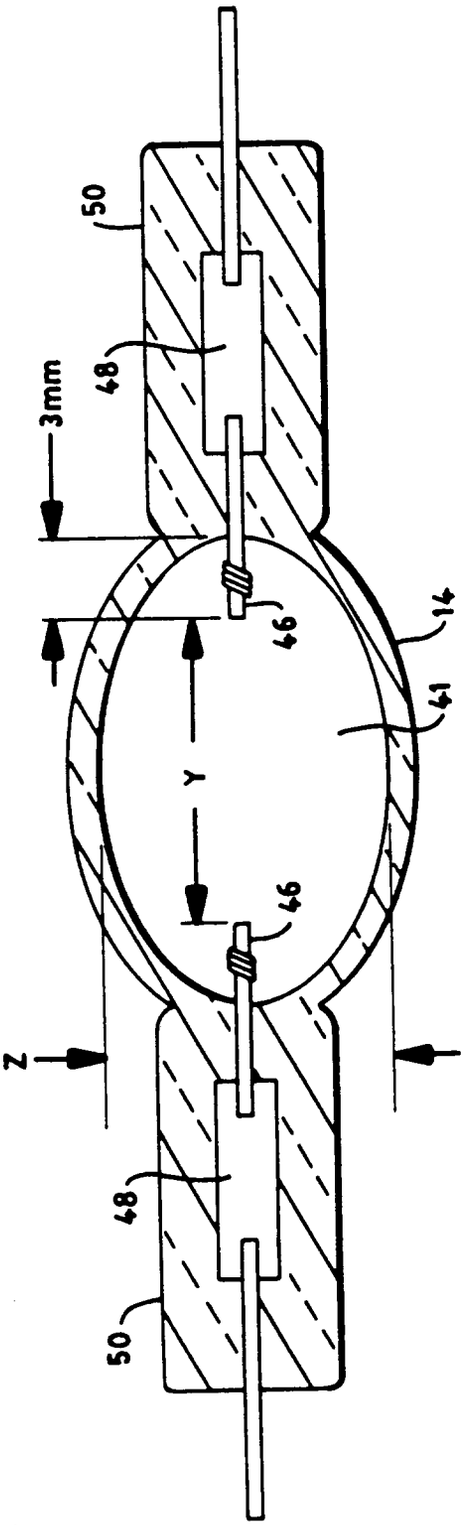
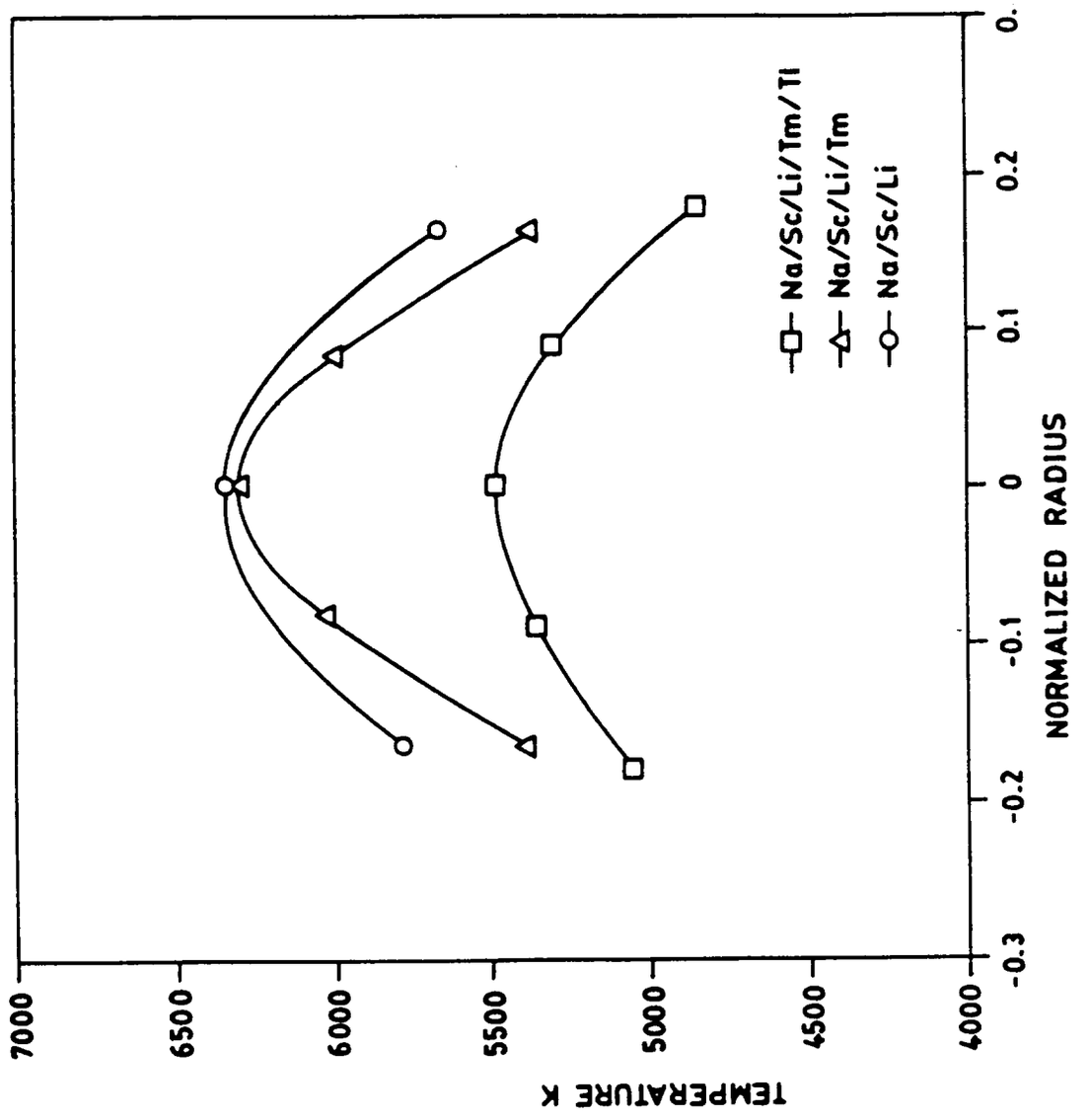


FIG. 5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6000
5500
5000
4500
4000
-0.3
-0.2
-0.1
0
0.1
0.2
0.
NORMALIZED RADIUS
Na/Sc/Li/Tm/Tl
Na/Sc/Li/Tm
Na/Sc/Li

FIG. 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 12 0431

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US 3 654 506 A (KÜHL BERNARD ET AL) 4 April 1972 * the whole document *	1-11	H01J61/82 H01J61/30
A	GB 2 000 637 A (GEN ELECTRIC) 10 January 1979 * claims 1-7; figures 2,4,5 *	1,5-11	
D,A	FR 2 309 974 A (PATRA PATENT TREUHAND) 26 November 1976 * claims 1-3,8; figure 1 *	1-11	
A	US 4 968 916 A (DAVENPORT JOHN M ET AL) 6 November 1990 * claim 1; figure 2 *	1-11	
A	EP 0 382 516 A (TOSHIBA LIGHTING & TECHNOLOGY) 16 August 1990 * claims 1-8; figure 1 *	1-11	
D,A	EP 0 359 200 A (GTE PROD CORP) 21 March 1990 * claims 1-18; figure 1 *	1-11	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 April 1997	Deroubaix, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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