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(54) Arc tube for a metal halide lamp.

(57) An arc tube (6) for a metal halide discharge lamp (2) is formed of titanium oxide doped vitreous silica. In one embodiment of the invention the doped vitreous silica is fused quartz made from a melt doped with TiO_2. In a preferred embodiment, the concentration of titanium oxide in the vitreous silica is approximately 250 parts per million by weight. Metal halide discharge lamps utilizing arc tubes formed from the doped vitreous silica demonstrate improved lumen output and lumen maintenance. It is believed that arc tubes formed from the doped vitreous silica also suffer less sodium loss than arc tubes formed from conventional fused quartz.

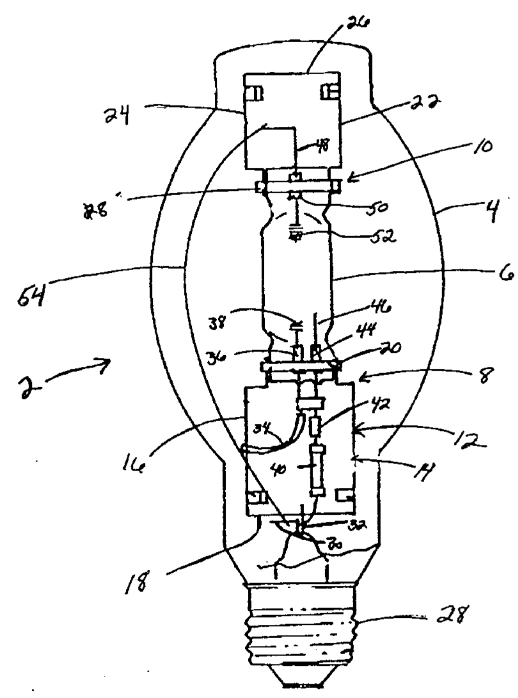

FIGURE 1

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This invention relates generally to an arc tube. In particular, this invention relates to an arc tube for a metal halide arc discharge lamp.

Metal halide arc discharge lamps are frequently employed in commercial usage because of their high luminous efficiency and long life. A typical metal halide arc discharge lamp includes a quartz or fused silica arc tube that is hermetically sealed within a borosilicate glass lamp envelope. The arc tube, itself hermetically sealed, has tungsten electrodes mounted therein and contains a fill material including mercury, metal halide additives and a rare gas to facilitate starting. In some cases, particularly in high wattage lamps, the lamp envelope is filled with nitrogen or another inert gas at less than atmospheric pressure. In other cases, particularly in low wattage lamps, the lamp envelope is evacuated.

Sodium is an important constituent in most high intensity metal halide arc discharge lamps, usually in the form of sodium iodide or sodium bromide. Sodium is used to improve the efficiency and colour rendering properties of the metal halide lamps. It has long been recognized that sodium loss during operation is a problem with metal halide discharge lamps having arc tubes that contain sodium halides. As sodium is lost through the arc tube wall, iodide is freed and combines with mercury to form mercury iodide. Mercury iodide leads to increased reignition voltages, thereby causing starting and lamp maintenance problems.

Sodium loss results from the movement or migration of sodium ions through the arc tube wall. There are two prevailing theories relating to the cause of this sodium movement. A first theory suggests that sodium loss is caused by the emission of ultraviolet (UV) photons from the arc tube. These UV photons cause electrons to be ejected from materials, such as metals, that are positioned within the outer jacket of the lamp. The electrons ejected from these materials collect on the outside surface of the arc tube and form a negatively charged layer. The build-up of negatively charged electrons along the outer surface of the arc tube attracts positively charged sodium ions from within the arc tube and enhances their migration through the quartz arc tube wall. Once the positively charged sodium ions reach the outer surface of the arc tube wall, they are neutralized by the electrons present on the surface of the arc tube, evaporate as atoms and travel to cold spots in the lamp where they condense.

A second theory suggests that the loss of sodium from the arc tube is not primarily caused by UV radiation emitted from the arc tube. Rather, this theory suggests that the loss of sodium is due to the thermal migration of sodium ions through the arc tube wall during the operation of the lamp.

Despite the uncertainty as to its causation, sodium loss from metal halide lamps having arc tubes that contain sodium halides has long been recognized as a problem. Consequently, a number of designs have been proposed for reducing sodium loss. In a so-called "frameless construction" disclosed in US-A-3,424,935, no frame members are located close to the arc tube. By eliminating heavy metallic support rods, by using a small diameter current return wire between the lamp base and the dome end of the arc tube, and by positioning the current return wire at a relatively large distance from the arc tube, the material from which electrons can be ejected by UV radiation is greatly reduced. However, this technique for reducing sodium loss is ineffective in small low-wattage lamps.

In US-A-3,988,628, a thick coating of TiO_2 is fused onto the outer surface of the fused quartz arc tube. The coating of TiO_2 is reported to reduce sodium ion conductivity through the arc tube and also reduce UV radiation from the arc tube to nearly zero at wavelengths less than approximately 240nm. However, this technique for reducing sodium loss increases the cost of producing metal halide arc tube lamps because of the added expense of materials, labor and facilities needed for coating the arc tube.

In US-A-4,866,328, a coating of ZrO_2 is provided over metal surfaces positioned within the lamp envelope external to the arc tube. The ZrO_2 coating prevents UV photons from reaching the metal surfaces, thereby preventing any electrons from being ejected therefrom. In addition to ZrO_2, ceramic tubes or other ceramic coatings have also been used to perform this function. This technique of shielding the metal surfaces within the lamp envelope suffers from disadvantages in that it increases the manufacturing costs of the metal halide lamps and may not be durable for extended burn life.

It is known to utilize titanium doped fused quartz to absorb UV radiation in reprographic lamps. The reduction of UV radiation in these lamps is beneficial because at some wavelengths, the UV radiation produces ozone and at other wavelengths, the UV radiation can damage human eyesight.

Viewed from one aspect the present invention provides an arc tube for a metal halide lamp comprising a sealed vitreous silica envelope and a fill material consisting substantially of mercury, metal halide additives and a rare gas, characterised in that said envelope is doped with titanium oxide.

The vitreous silica may be formed by doping quartz sand with a titanium compound, such as titanium oxide, prior to melting. The preferred concentration of the titanium oxide dopant is in the range of one hundred and fifty to three hundred and fifty parts per million by weight, with the most preferred concentration being approximately two hundred and fifty parts per million by weight. Preferred metal halide discharge lamps of the present invention utilizing arc tubes formed from the titanium oxide doped quartz can demonstrate increased lumen output and lumen maintenance.

Embodiments of the present invention will now be discussed by way of example only, and with reference to the accompanying drawings, in which:

Fig. 1 shows an example of a metal halide discharge lamp;

Figs. 2(a) - 2(d) show graphs illustrating results from a first test comparing the performance of standard production lamps with lamps having arc tubes made of quartz doped with TiO_2;

Figs. 3(a) - 3(d) show graphs illustrating the relative concentrations of various ion species as a function of time for the lamps taken over the course of the first test; and

Figs. 4(a) - 4(d) shows graphs illustrating results from a second test comparing the performance of standard production lamps with lamps having arc tubes made of quartz doped with TiO_2.

The present invention is directed to a metal halide lamp. Fig. 1 illustrates a typical metal halide arc discharge lamp in which embodiments of the present invention can be utilized. It should be understood that Fig. 1 is provided merely for illustrative purposes and that the preferred arc tubes of the present invention can be used with any type of metal halide arc tube lamp, including those having structures that differ from the example shown in Fig. 1. In Fig. 1, a lamp 2 includes a lamp envelope 4 and an arc tube 6 mounted within lamp envelope 4. The arc tube 6 is a metal halide arc discharge tube having characteristics that are described below.

The arc tube 6 is supported within the envelope 4 via a lower support means 8 and an upper support means 10. Lower support means 8 comprises a U-shaped support made up of vertical wires 14 and 16 extending from a base wire 18. The vertical wires 14 and 16 are welded to a strap 20 that supports the lower end of the arc tube 6. Upper support means 10 similarly comprises a U-shaped support made up of vertical wires 22 and 24 extending from a base wire 26. The vertical wires 22 and 24 are welded to a strap 28 that supports the upper end of the arc tube 6.

Electrical energy is coupled to the arc tube 6 through a base 28. A pair of stiff lead-in wires 30 and 32 are electrically connected to the base 28. Lead-in wire 32 is welded to base wire 18 of the lower support means 8. An additional lead-in wire 34 is electrically connected to vertical wire 16 of lower support means 8. Lead-in wire 34 is connected, via a molybdenum foil 36, to an electrode 38 within the arc tube 6. A resistor 40 is attached to lead-in wire 30 and to a connector 42. Connector 42 is connected, via a molybdenum foil 44, to a starting probe 46.

At the upper end of arc tube 6, a lead-in wire 48 is attached, via a molybdenum foil 50, to an electrode 52. Lead-in wire 48 is electrically connected to stiff lead-in wire 30 through a thin conducting lead 54. The molybdenum foils 36, 44 and 50 are located in press seals at opposite ends of arc tube 6.

As stated above, the present invention is directed to improving an arc tube for use in a metal halide lamp such as the one shown in Fig. 1. A preferred arc tube of the present invention is formed of a titanium oxide doped vitreous silica. In one embodiment of the invention, the vitreous silica is fused quartz that is made from a melt doped with TiO_2. This doped quartz is hereafter referred to as "ozone free quartz" because the titanium oxide dopant reduces the emission of UV radiation from the arc tube that would produce ozone. By utilizing ozone free quartz rather than conventional quartz in forming the arc tube, it is believed that sodium loss from the arc tube is reduced in two ways. First, the titanium oxide in the ozone free quartz may help to retard the movement of sodium ions through the arc tube wall. Second, the titanium oxide in the ozone free quartz absorbs UV radiation so that the amount of UV radiation emitted from the arc tube is reduced. As previously stated, one theory regarding the cause of sodium loss in metal halide lamps suggests that UV photons emitted from the arc tube cause electrons to be ejected from materials in the outer jacket, thereby generating a negatively charged layer that attracts positively charged sodium ions through the arc tube wall. Consequently, by reducing the amount of UV radiation emitted from the arc tube, it is believed that the use of ozone free quartz results in a reduction of sodium loss from the arc tube of the metal halide discharge lamp.

In order to verify the performance of the arc tubes made from ozone free quartz, a series of tests was run comparing four standard production GTE M175U Metalarc lamps (utilizing arc tubes made from quartz that did not contain a TiO_2 dopant), with four GTE M175U Metalarc lamps having arc tubes made of ozone free quartz. All the test lamps were made at the same time as part of a single production run. The ozone free quartz was made by doping the quartz sand normally utilized to form metal halide arc tubes with TiO_2 prior to melting. Thereafter, the mixture of quartz sand and TiO_2 was melted and formed into arc tubes in a conventional manner that is known to those skilled in the art.

The concentration of titanium oxide in the ozone free quartz utilized for the test run described above was 250 parts per million by weight. However, it is believed that the advantages of preferred embodiments of the present invention can be achieved with ozone free quartz having various other concentrations of titanium oxide within the range of 150 to 350 parts per million by weight. Additionally, although TiO_2 was used as the dopant in forming the ozone free quartz, other titanium compounds could also be utilized that form titanium oxide when heated. Examples of other titanium compounds that are believed to be suitable for use as a dopant are titanium nitrate and compounds from the family of titanium alkoxides, such as tetrabutyl titanate. Similarly, although the arc tubes utilized in the test lamps were formed from doped quartz, it should be appreciated that arc tubes embodying the present invention can also be formed from other types of vitreous silica such as synthetic silica produced from silane.

Prior to forming the ozone free quartz into tubes, it was vacuum baked to a low hydroxyl content indicated by a $Beta_{OH}$ of 0.0005 to 0.0007 nm^{-1}. Testing indicated that the amount of UV radiation emitted from the ozone free quartz was reduced to approximately zero at wavelengths below approximately 200 nm, with the 50% UV cut-off at approximately 240 nm. This test verifies that the use of ozone free quartz should successfully reduce the UV radiation emitted from the arc tube. As a result, the amount of photons available for ejecting electrons from materials in the outer jacket should be significantly reduced, thereby reducing sodium loss in comparison to metal halide lamps having arc tubes formed from conventional fused quartz.

Figs. 2(a) - 2(d) show a comparison of the results of a first test comparing the performance of the four lamps having ozone free quartz arc tubes (indicated by plots 30, 32, 34 and 36) with the four standard production lamps (indicated by plots 31, 33, 35 and 37). Figs. 2(a)-2(d) are graphs of arc tube voltage, lumen output, colour temperature and colour rendering index, respectively, as a function of time. As can be seen from Fig. 2(b), the lamps having arc tubes made from ozone free quartz (indicated by plot 32) displayed roughly a 20% improvement in both lumen output and lumen maintenance at 6,000 hours from the standard production lamps (indicated by plot 33). The improvement in lumen output and lumen maintenance indicates that lamps utilizing ozone free quartz arc tubes have a significant performance advantage over lamps with arc tubes made from conventional fused quartz.

The improvement in both lumen output and lumen maintenance was unexpected prior to conducting the above-described test. The reason for the improved lumen output and lumen maintenance exhibited by the arc tubes made from ozone free quartz is not precisely known. It is possible that the increased sodium retention resulting from the use of the titanium oxide dopant enables the arc tubes made from ozone free quartz to have greater lumen output over a longer period of time than conventional arc tubes. It is also possible that the titanium oxide dopant changes the conductivity of the arc tube, thereby altering the energy balance in a manner that results in the generation of an increased amount of visible radiation. Additionally, the energy balance may also be altered by the conversion of UV radiation into thermal or visible radiation since the titanium oxide dopant inhibits UV radiation from escaping the arc tube.

An analysis of Figs. 2(a) - 2(d) demonstrates that the lamps having arc tubes made from ozone free quartz not only demonstrated improved lumen output and lumen maintenance, but also did not demonstrate any significant deficiencies with regard to other lamp characteristics. Although the lamps made with arc tubes of ozone free quartz had a higher voltage rating, their voltage reached a plateau at approximately 3,000 hours and thereafter remained steady while the voltage of the standard production lamps continued to rise in an undesirable fashion. The colour rendering index (CRI) remained lower for the lamps utilizing the ozone free quartz arc tubes for the majority of the test. The voltage plateau and lower colour rendering index for the lamps having ozone free quartz arc tubes is believed to be the result of a reduction in sodium loss from those arc tubes.

Figs. 3(a) - 3(d) are graphs showing the relative concentrations of various ion species as a function of time for the lamps having arc tubes made from ozone free quartz (indicated by plots 38, 40, 42 and 44) and the standard production lamps (indicated by plots 39, 41, 43 and 45). These graphs show no major differences in the arc species contents between the groups, although the iodine content of the ozone free group (indicated by plot 44) hit a plateau early while that of the control group (indicated by plot 45) gradually dropped. The similarity of values for scandium and sodium in the two groups of lamps suggests that the higher lumen production in the group of lamps with the ozone free quartz arc tubes did not result from heating of those arc tubes.

Figs. 4(a) - 4(d) illustrate the results of a second lamp test which utilized double ended lamps of a non-standard design. The control group (indicated by plots 47, 49, 51 and 53) utilized standard 175W production arc tubes while the test group (indicated by plots 46, 48, 50 and 52) utilized lamps that were made at the same time and were identical except for the use of arc tubes formed from ozone free quartz. Many of the lamps in both groups failed early in the test as a result of oxidation at the inleads of the outer jacket. However, those that survived showed that the lamps with the ozone free arc tubes again had higher lumen output and lumen maintenance than the lamps with the conventional quartz arc tubes. These results are consistent with the results of the first test shown in Figs. 2(a) - 2(d). Each of these tests indicates that lamps having arc tubes made from ozone free quartz perform significantly better in terms of both lumen output and lumen maintenance than lamps utilizing conventional arc tubes.

Embodiments of the present invention may provide an arc discharge lamp wherein sodium loss from the arc tube is relatively low; and further may provide a metal halide discharge lamp having increased light output.

Claims

1. An arc tube for a metal halide lamp comprising a sealed vitreous silica envelope (6) and a fill material consisting substantially of mercury, metal halide additives and a rare gas, characterised in that said envelope (6) is doped with titanium oxide.

2. An arc tube as claimed in claim 1, characterised in that the concentration of titanium oxide in the vitreous silica is within the range of about 150 to 350 parts per million by weight.

3. An arc tube as claimed in claim 2, characterised in that the concentration of titanium oxide in the vitreous silica is about 250 parts per million by weight.

4. An arc tube as claimed in any of claims 1, 2 or 3, characterised in that the fill material includes a sodium halide.

5. An arc tube as claimed in any preceding claim, characterised in that the vitreous silica comprises fused quartz.

6. A metal halide lamp characterised in that it has an arc tube as claimed in any preceding claim.

7. A metal halide lamp as claimed in claim 6, characterised in that said lamp further comprises an arc tube support assembly (8,10) and means (28,30,32 etc.) for coupling electrical energy to said arc tube.

8. A method for producing an envelope (6) for an arc tube as claimed in any of the preceding claims, characterised in that a titanium compound is added to the raw materials at a melt stage such that vitreous silica doped with titanium oxide is produced for forming said envelope.

9. A method as claimed in claim 8, characterised in that the titanium compound is titanium oxide.

10. A method as claimed in claim 8, characterised in that the titanium compound forms titanium oxide when heated.

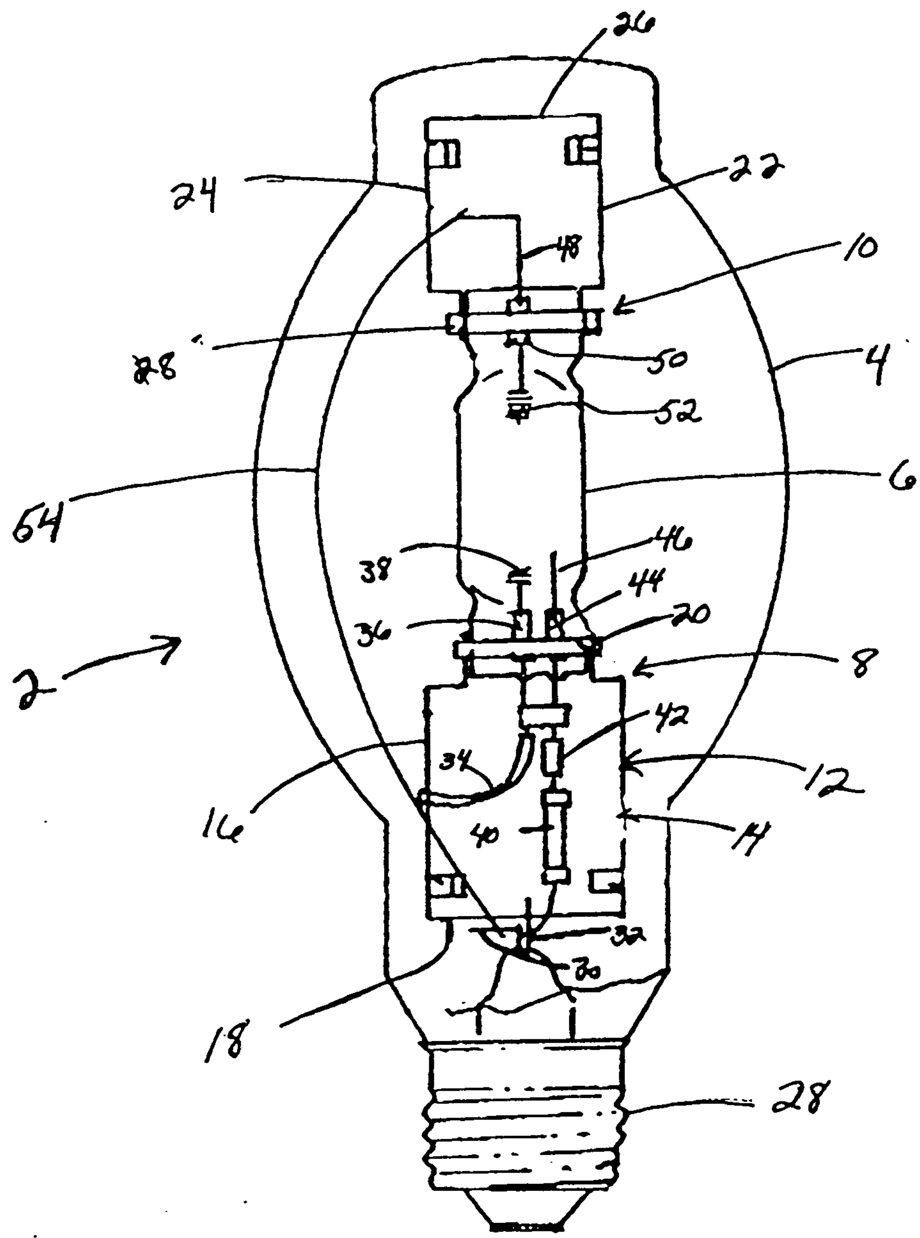
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FIGURE 1

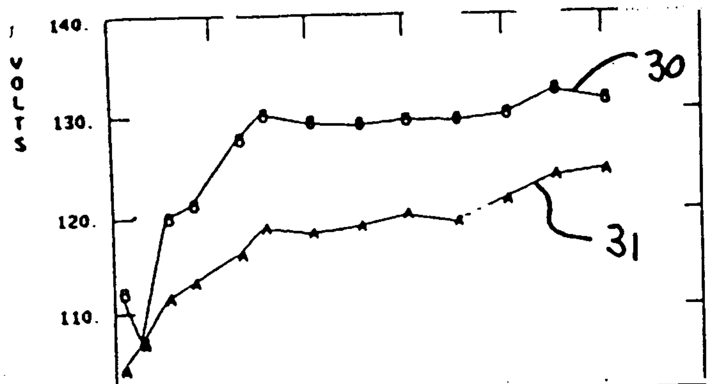

Fig 2(a)

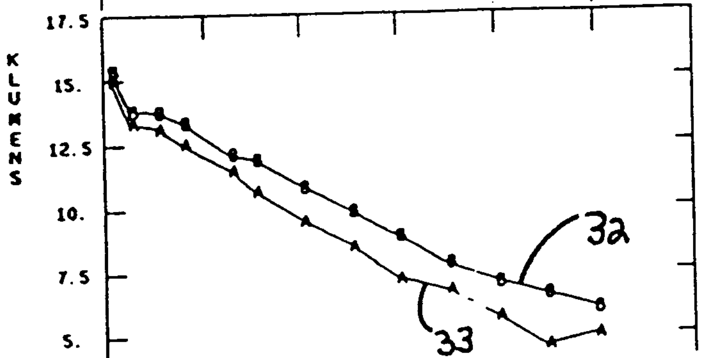

Fig 2(b)

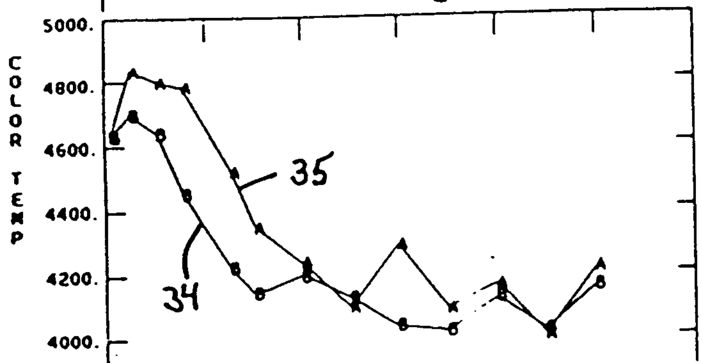

Fig 2 (c)

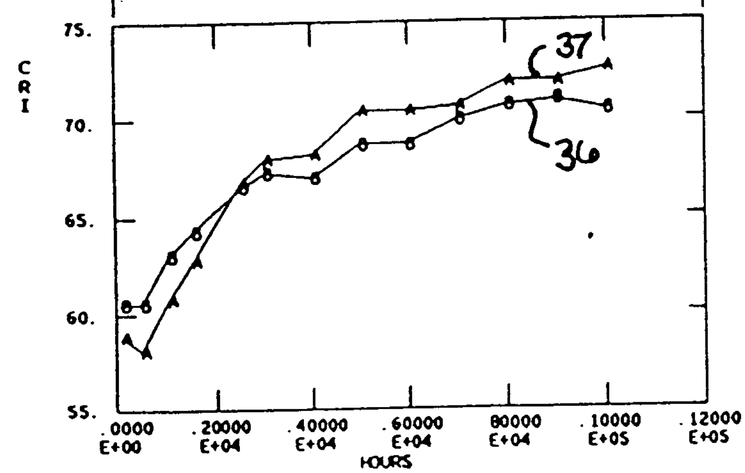

Fig 2(d)

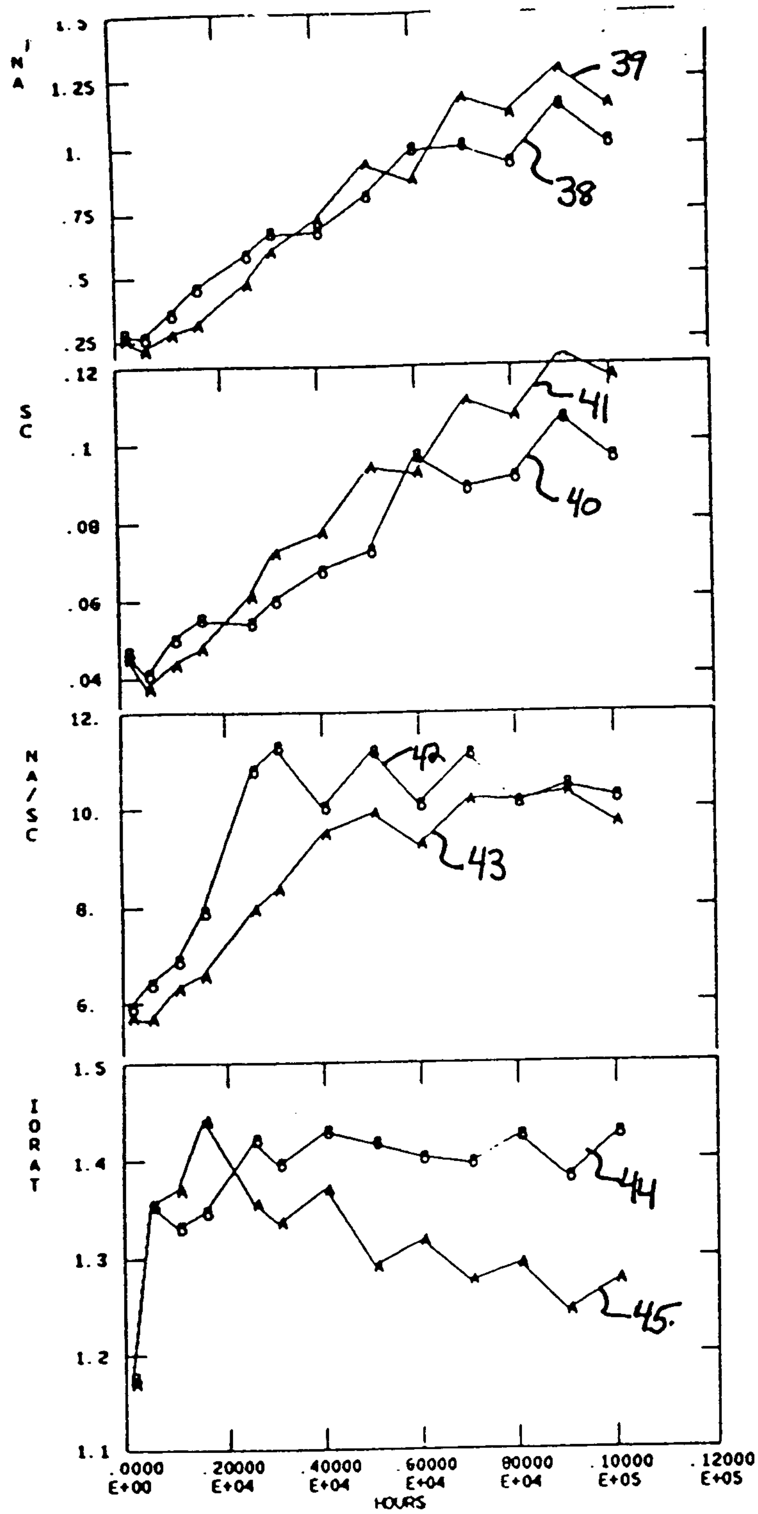

Fig 3(a)

Fig 3(b)

Fig 3(c)

Fig 3(d)

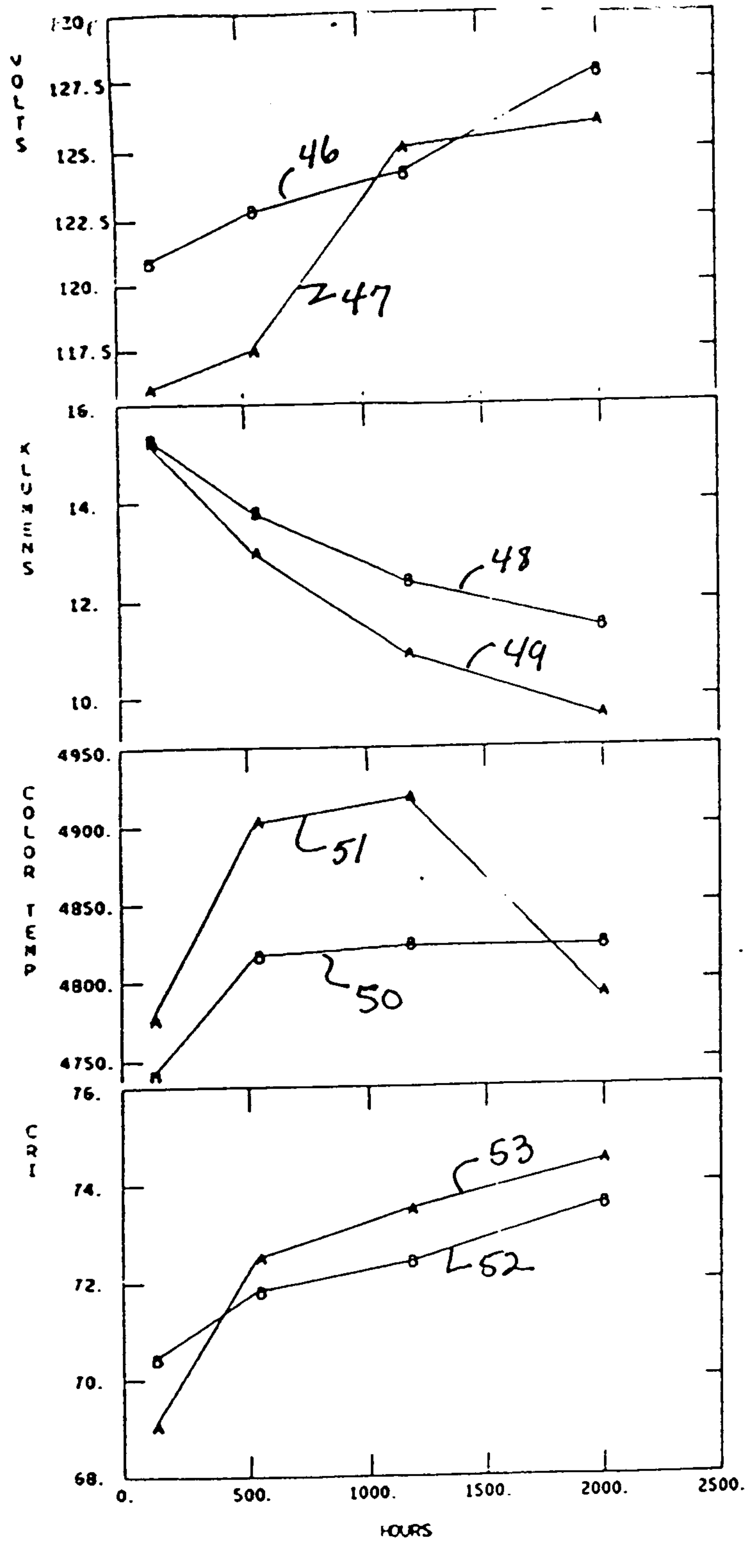

Fig 4(a)

Fig 4(b)

Fig 4(c)

Fig 4(d)

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EUROPEAN SEARCH REPORT

Application Number
EP 93 31 0407

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.5)
D,A	US-A-3 988 628 (CLAUSEN) * column 1, line 36 - line 50; claims *	1,4-7	H01J61/30
A	FR-A-2 599 890 (USHIO DENKI K.K.) * claim *	1,4-7	
A	US-A-3 148 300 (GRAFF) * column 3, line 25 - column 4, line 57; figure 2 *	1,8,9	
P,X	US-A-5 196 759 (PARHAM ET AL.) * column 2, line 26 - column 3, line 13; figure 3B *	1,5	

TECHNICAL FIELDS SEARCHED (Int.Cl.5)
H01J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 February 1994	Schaub, G

CATEGORY OF CITED DOCUMENTS

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