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[54] **ALUMINUM CHLORIDE DISCHARGE LAMP**
5 Claims, 2 Drawing Figs.

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313/174, 313/184, 313/223
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[50] **Field of Search** 313/184,
223, 225, 227, 228, 229

[56] **References Cited**

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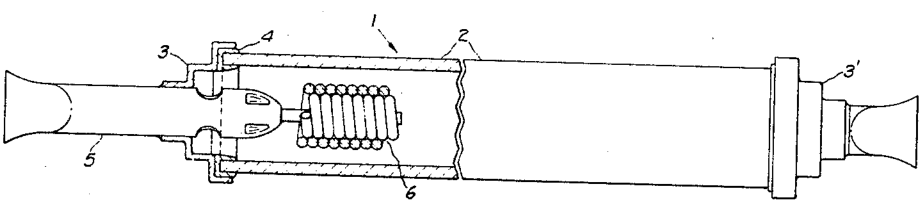
ABSTRACT: A metal halide high intensity lamp containing $AlCl_3$ and providing a continuous spectrum. Excess aluminum in the filling gives thermodynamic stability against attack of the tungsten electrodes and other lamp metals by chlorine, and an alumina envelope is used which does not react with $AlCl_3$. The filling also preferably contains aluminum tri-iodide, mercury for a buffer gas, and an inert gas to facilitate starting.



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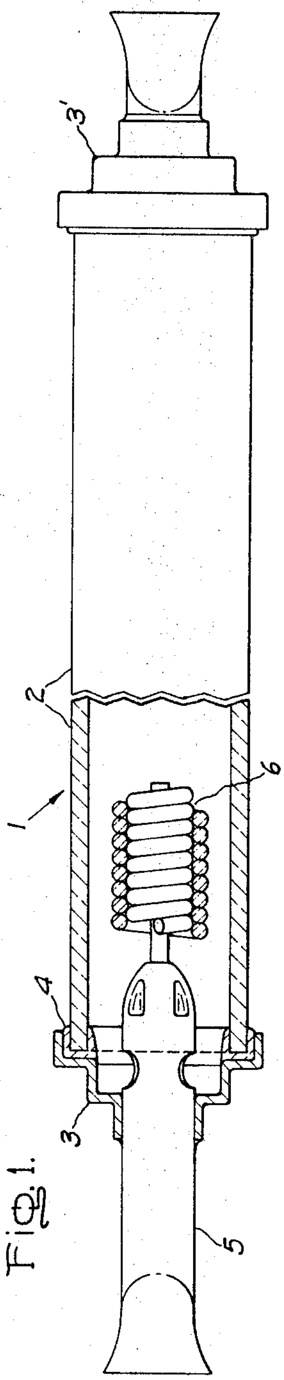

Fig. 1.

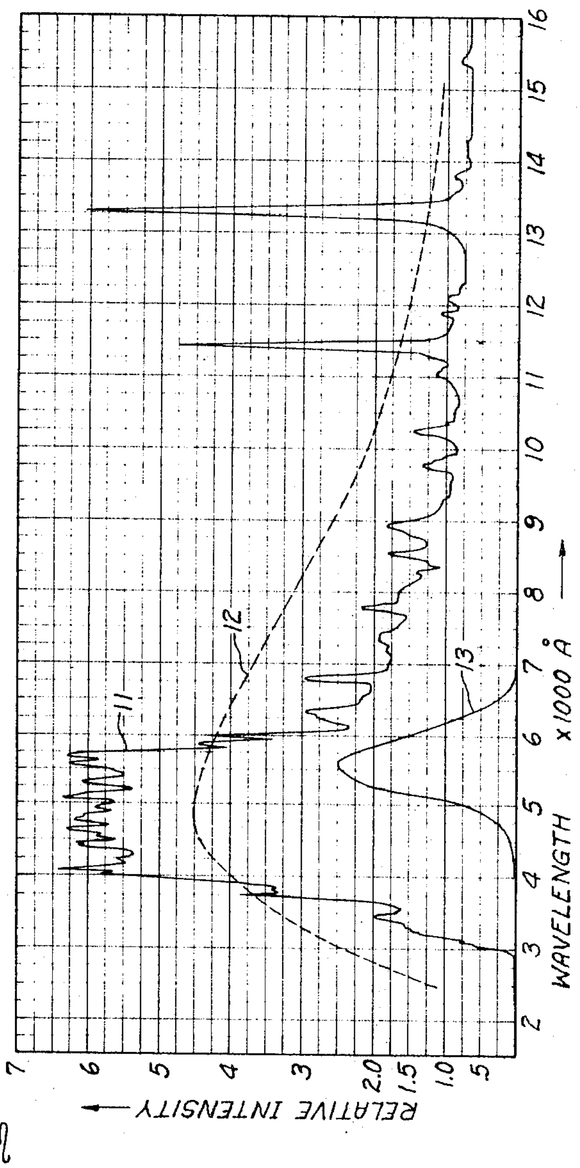

Fig. 2.

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ALUMINUM CHLORIDE DISCHARGE LAMP

CROSS-REFERENCES TO RELATED APPLICATIONS

Application Ser. No. 825,722 concurrently filed by D. M. Speros, W. E. Smyser and R. M. Caldwell, entitled "Metal Halide Discharge Lamp" and similarly assigned.

BACKGROUND OF THE INVENTION

The invention relates to a high intensity discharge lamp containing a filling of aluminum trichloride.

The high pressure mercury vapor lamp has in recent years been improved in color rendition and light output by the addition of certain metal iodides to the basic filling of mercury and a rare gas. The addition of, for instance, NaI, TlI and InI has been the most favored and the most widely used. The presence of NaI assures a very substantial increase in efficiency and the combination of metals, by their resonance lines, complete the mercury radiation in the blue, green and yellow range of the spectrum. Notwithstanding, the color rendition, consisting essentially of lines superimposed on a weak continuum, though much improved is not equivalent to natural daylight.

A discharge through aluminum trichloride vapor results in emission consisting almost entirely of a continuum closely matching solar radiation. However when it is attempted to make a lamp in the usual fashion utilizing a quartz or vitreous silica envelope, tungsten electrodes and a filling of argon, mercury and $AlCl_3$, it is found that the silica envelope reacts and devitrifies rapidly and the tungsten electrodes are destroyed in as little as 10 minutes. Even during its operative period, the lamp is unstable due to the rapidly changing electrode configuration as tungsten is transported from cooler to hotter regions of the electrode. The instability is aggravated by the introduction of impurities such as $SiCl_4$ resulting from the reaction between $AlCl_3$ and SiO_2 into the arc, changes in light transmission due to early devitrification of the silica envelope, and changes in vapor pressure of components due to alteration of the thermal configuration within the lamp.

The object of the invention is to provide an improved aluminum chloride lamp which is long lived, stable in character, and which overcomes the above-described shortcomings.

SUMMARY OF THE INVENTION

Our invention is predicated on a thermodynamic analysis which shows that in an aluminum chloride discharge the attack upon the metals such as the tungsten electrodes contained in the lamp envelope can be reduced by a large factor if the following condition is made to prevail in the lamp:

$$[M]>[Cl] \qquad I$$

where M is the total concentration of the metal and Cl is the total concentration of chlorine. In order to realize this condition, excess metal, suitably aluminum, may be placed in the lamp. In addition, some iodide of the metal, namely AlI_3 may be added to the lamp filling and this further reduces the attack upon the electrodes.

Our thermodynamic analysis has also indicated that aluminum trichloride is incompatible with a fused quartz arc chamber due to the possibility of reaction between $AlCl_3$ and SiO_2. It is therefore necessary to provide an envelope material which is not attacked by $AlCl_3$ and we have found that high density alumina ceramic is such a material and that $AlCl_3$ will not react with Al_2O_3. Alternatively, if it is desired to use a fused silica envelope, the silica must be protected by an internal coating of Al_2O_3.

DESCRIPTION OF DRAWING

FIG. 1 illustrates an aluminum chloride lamp in an alumina ceramic arc tube embodying the invention.

FIG. 2 shows the spectral output of an aluminum chloride arc.

DETAILED DESCRIPTION

A measure of the severity of the attack by the chlorides on tungsten is the equilibrium pressure of gaseous tungsten species that will form in the lamp. The results of thermodynamic analysis based upon data obtained from JANAF tables and their supplements are given in Table 1 below. The JANAF Thermochemical Tables are a compendium of thermochemical data made under joint Army-Navy-Air Force sponsorship and is a U.S. Department of Commerce publication distributed by Clearing House for Federal Scientific and Technical Information.

TABLE I

Lamp condition	P_{WCl_4} at 1000° K	P_{WCl_2} at 2000° K	P_{WCl_2} at 3000° K
Trace free Cl_2: $P_{Cl_2} = 10^{-3}$ torr	5.4 atm	4×10^{-9} atm	4×10^{-12} atm
Only $AlCl_3$, $P_{AlCl_3} = 1$ atm	10^{-10}	4×10^{-2} atm	0.3 atm
$AlCl_3+Al$, $P_{AlCl_3}=1$ atm, $P_{AlCl}=1$ atm	10^{-26} atm	10^{-4} atm	1.2×10^{-2} atm
$AlCl_3+Al+AlI_3$ $P_{AlCl_3}=1$ atm P_{AlI_3}, $P_{AlI}=1$ atm		2.5×10^{-7} atm	2×10^{-4} atm

The first line in the table gives the equilibrium pressure of tungsten chlorides that will form in the presence of 10^{13} torr or 1 micron of Cl_2 in the absence of Al or other getter metal. The reaction considered in this case is:

$$W(s)+Cl(g)—W_xCl_y(g) \qquad I$$

The second line of the table gives the results for the case in which only $AlCl_3$ exists in the lamp. The reaction then will take the form:

$$AlCl_3(g)+W(s)—W_xCl_y(g)+AlCl(g) \qquad II$$

The third line of the table gives the results for the case in which both $AlCl_3$ and Al exist in the lamp. The reaction then will be:

$$2AlCl(g)+W(s)—W_xCl_y(g)+2Al(g) \qquad III$$

Finally the last line of the table gives the results for the case in which, in addition to $AlCl_3$ and Al, AlI_3 also exists in the lamp. The reaction then is the same as in III above but with the partial pressure of Al(g) being equal to that from the dissociation:

$$AlI(g)—Al(g)+I(g) \qquad IV$$

The table shows dramatically the suppression of the attack by the utilization of excess metal and excess metal plus iodide.

Because of uncertainties in the data, the results of table I should be taken in a qualitative rather than an absolute sense, and as indicative of the strong effect of the additions of metal and metal iodides in accordance with our invention.

The thermodynamic considerations given here are applicable not only to aluminum chloride but are of general applicability to other halide systems, such as the $SnCl_2$ system of the copending application.

The desirability of excess metal, namely aluminum in the lamp comes from two reasons:

1. Oxygen-containing trace impurities in the lamp could liberate free chlorine from the aluminum trichloride through the following reaction:

$$AlCl_3+[O]—Al_2O_3+3/2Cl_2 \qquad V$$

The trace of free chlorine would then enter a transport cycle involving the lamp metals and causing a rapid attack on the electrodes. However by having excess aluminum present, either the oxygen impurity or the trace of free chlorine is gettered and the transport cycle is prevented.

2. At high temperatures, aluminum trichloride may dissociate directly and release chlorine according to the following reaction:

$$AlCl_3—AlCl+2Cl \qquad VI$$

The aluminum being present in excess tends to combine with any chlorine so released and thus reduces the extent of attack on the tungsten electrodes. When the lamp is turned off and cooled, the reverse of reaction III above occurs and the excess aluminum metal may often be seen depositing in dendritic crystals or dark film.

The beneficial effect of the addition of aluminum tri-iodide to the lamp filling in further reducing attack of electrodes is probably accounted for by the following three factors:

1. Chlorine liberated from $AlCl_3$ by oxygen containing trace impurities (reaction II) may attack the tungsten electrodes before it can diffuse to the excess aluminum and be gettered by it. However if there is aluminum tri-iodide in the lamp filling, the following reaction may take place:

$$3/2Cl_2+AlI_3AlCl_3+I_2 \quad \text{VII}$$

Even though there may be some iodine temporarily present in the lamp filling as the lamp warms up, the rate of attack of iodine on tungsten is much less than that of chlorine. Of course, the iodine eventually diffuses to the excess pool of aluminum to regenerate the aluminum tri-iodide. Thus the composition of the lamp atmosphere should remain constant with only some of the excess aluminum being consumed in gettering oxygen containing trace impurities.

2. The presence of aluminum tri-iodide in the lamp atmosphere further increases the concentration of aluminum thereby decreasing the chlorine concentration and this further reduces the attack on the lamp electrodes. Thus the iodine may be said to "volatilize" the excess metal and thereby reduce the rate of attack of chlorine on electrodes.
3. The presence of the iodide may enhance such "regenerative" transport cycles as may occur and thereby help to keep the lamp walls clean of tungsten deposits.

A lamp arc tube **1** embodying the invention is shown in FIG. **1** of the drawing and comprises an envelope **2** of ceramic tubing consisting of sintered high density polycrystalline alumina. This material tends to be translucent rather than clear like quartz but has exceedingly high light transmittance so that it is quite adaptable to lamp purposes. A central portion of the tube has been cut out to shorten the figure, and the internal construction can be seen in the sectioned portion. By way of example, in a 400 watt size of lamp, the arc tube is about 65 millimeters long and 7 millimeters in internal diameter, the gap between electrodes being about 40 millimeters. The ends of the tube are closed by thimblelike niobium closures or end caps **3,3'** hermetically sealed to the ceramic by an alumina-calcia sealing composition shown at **4**. A niobium tube **5** penetrates into the thimble and is used as an exhaust tube during manufacture after which it is closed off. A thermionic electrode **6** is mounted in each end of the arc tube and is supported through the niobium tube **5** from the end cap **3**. As illustrated, the electrode **6** comprises an inner tungsten wire coil wound around a rodlike tungsten shank and an outer tungsten coil wound around the inner coil, the tungsten shank being seized in the niobium tube **5**.

The filling of the arc tube consists of $AlCl_3$, aluminum, mercury, argon and optionally AlI_3. In the illustrated lamp, quantities are 1 mg. $AlCl_3$, 0.5 to 1 mg. Al, 5 mg. Hg., and argon at 20 torr. The arc tube operates with its ends at a temperature of better than 600° C. and this means that protection of the metal end caps from oxidation must be provided. In a practical lamp, the arc tube is not operated in air but is mounted within an evacuated outer jacket (not shown). The illustrated lamp operated at 200 volts with a current of 1.6 amperes on alternating current and a reignition peak of about 600 volts was observed. To further reduce attack on the electrodes, 0.1 mg. of AlI_3 may be added to the filling; the amount of mercury may be reduced to offset the increase in arc drop from the addition of AlI_3.

The aluminum chloride lamp may also be made using a fused silica or quartz arc tube provided with an internal protective coating of Al_2O_3 to protect the silica against attack by the $AlCl_3$. One way of coating the silica with Al_2O_3 is to expose the hot tube to a mixture of $AlCl_3$ vapor and an oxidizing gas mixture, suitably CO_2 diluted with argon. The following reaction then takes place:

$$AlCl_3 + [O]\,(g) \xrightarrow{\text{hot quartz}} Al_2O_3 + [Cl]\,(g)$$

By way of example, aluminum chloride lamps made from alumina-coated fused silica envelopes having volumes ranging from 0.2 to 1 cc. contained 2.2 mg. Al, 3.9 mg. $HgCl_2$, and Ar at 40 torr. The arc gap was about 4 mm. At a loading of 600 watts, current 5.1 amperes and voltage 148 volts, the efficiency was 75 lumens per watt.

In the case of an alumina envelope, the niobium end caps may be sealed directly to the tubing by machining them to a close fit and fitting them to the ends of the tubing in a vacuum at a very high temperature. Where the alternative method previously described of sealing a niobium end cap by a sealing composition or glass consisting primarily of alumina and calcia is used, the seal areas may be coated with Al_2O_3 in order to protect the calcia from attack by $AlCl_3$.

In FIG. **2** of the drawing, the spectral output of the aluminum chloride lamp is represented by curve **11**. Dotted line curve **12** shows the solar spectrum for purposes of comparison, and curve **13** is the eye sensitivity curve. It will be observed that the spectrum is a strong continuum with a great number of relatively weak lines or bands superposed. The amplitude is high in the region of the eye sensitivity curve so that a high luminous efficiency may be expected from the discharge. Measurements have confirmed efficiencies of 70 lumens per watt and up.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A high-intensity arc lamp comprising a light-transmissive envelope of a material nonreactive with aluminum trichloride at an elevated temperature, tungsten electrodes sealed into the ends thereof, and a filling within said envelope comprising aluminum trichloride, aluminum, and an inert gas to facilitate starting.

2. A lamp as in claim **1** wherein the filling also includes aluminum tri-iodide.

3. A lamp as in claim **1** wherein the filling includes aluminum tri-iodide. and mercury.

4. A lamp as in claim **1** wherein the envelope is high density polycrystalline alumina.

5. A lamp as in claim **1** wherein the envelope is fused silica coated internally with a protective layer of aluminum oxide.