United States Patent [19]

Silver et al.

[11] **3,771,009**

[45] **Nov. 6, 1973**

[54] **ELECTRODE DISCHARGE DEVICE WITH ELECTRODE-ACTIVATING FILL**

[75] Inventors: **H. Graham Silver**, Kings Port, N.Y.; **Adam Heller**, Sharon, Mass.; **Phillip J. Gardner**, Bayside, N.Y.; **Gary R. Argue**, Winchester, Mass.

[73] Assignee: **GTE Laboratories Incorporated**, Bayside, N.Y.

[22] Filed: **Dec. 27, 1971**

[21] Appl. No.: **212,458**

[52] **U.S. Cl.** **313/228**, 313/229

[51] **Int. Cl.** **H01j 61/18**

[58] **Field of Search** 313/225, 226, 227, 313/228, 229

[56] **References Cited**

UNITED STATES PATENTS

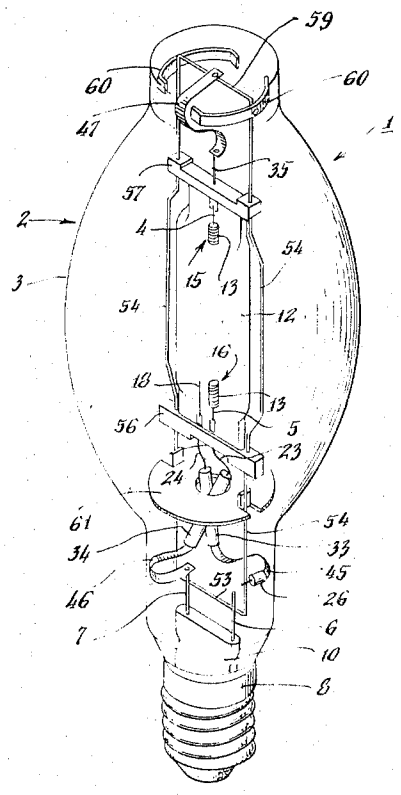
3,234,421	2/1966	Reiling	313/225
3,259,777	7/1966	Fridrich	313/229
3,319,119	5/1967	Rendina	313/225
3,445,719	5/1969	Thouret et al.	313/225
3,452,238	6/1969	Larson	313/228
3,536,947	10/1970	Higashi et al.	313/229
3,654,506	4/1972	Kuhl	313/225

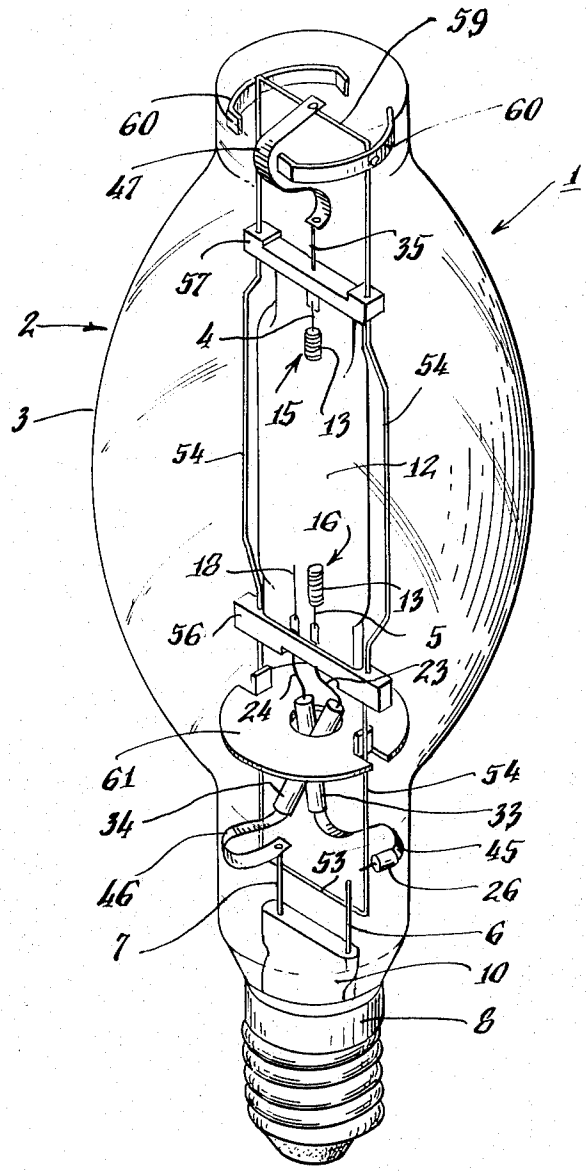
Primary Examiner—Roy Lake
Assistant Examiner—Siegfried H. Grimm
Attorney—Irving M. Kriegsman

[57] **ABSTRACT**

An electric discharge device comprising a sealed light-transmissive envelope having a pair of electrodes spaced therein, and a quantity of material within the envelope for facilitating an arc discharge between the electrodes, the quantity of material including, as the primary light-emitting material, at least one high melting, relatively non-volatile metallic iodide complexed with an iodide of a Group IIIA element to give a volatile complex having the general formula LnM_xI_{3x+3}, where Ln represents a lanthanide element or a Group IIIB element; M represents a Group IIIA element selected from the group consisting of boron, aluminum, indium and gallium, particularly aluminum; and $x = 3$ to 4. The use of this complex eliminates the need to use a heating element adjacent to but outside the sealed envelope to maintain sufficient amounts of the metallic iodide in the vaporous state, but, in addition and quite unexpectedly, it has been found that its use eliminates the need to pre-activate the spaced electrodes with an electron-emissive material, such as thorium.

25 Claims, 1 Drawing Figure




59
60
60
47
1
35
57
2
4
54
15
13
3
54
12
16
18
13
56
5
23
24
61
54
34
33
45
53
46
26
7
6
10
8

ELECTRODE DISCHARGE DEVICE WITH ELECTRODE-ACTIVATING FILL

BACKGROUND OF THE INVENTION

This invention relates to electric discharge devices, particularly of the type wherein the fill includes an iodide of a lanthanide element or a Group IIIB element complexed with a plurality of molecules of an iodide of a Group IIIA element selected from the group consisting of boron, aluminum, gallium and indium, particularly aluminum iodide.

In the prior art, high pressure electric discharge devices have been manufactured which contain a fill of mercury alone. When a potential is imposed across the spaced electrodes in such a device, a mercury is ionized and emits its characteristic spectral lines, principally in the ultraviolet and blue-green region of the spectrum. It has recently been discovered that these devices could be modified in their spectral emission by the inclusion of metals other than mercury, whereby the light produced is the combined emission of mercury and the included metals. Blending of emissions in this manner can produce wide variations in colors and, most importantly, an essentially white spectrum can be attained. Included metals which have been suggested have been the rare earth metals, added either in the form of the metal per se or as its halide.

Many of the rare earth metals, when dissociated from the halogen in the arc of a discharge lamp, emit a dense line spectrum predominantly in the visible region, thus producing a light source of good color. However, a sufficiently high vapor pressure of the rare earth additive must be attained in order to achieve such emission. It has been found that the temperature of the coolest part of the envelope must be maintained above about 900°C if such vapor pressures are to be attained.

Heretofore, the use of such rare earth additives in an arc discharge lamp, although known, was rarely considered because of the problem of maintaining the envelope at the high temperature required to generate sufficient additive vapor pressure. Such temperatures would most probably cause softening of the quartz envelope, particularly at the glass-to-metal seal, in high pressure mercury lamps. However, the use of such rare earth additives has been accomplished in certain, low-pressure cases by mounting the discharge envelope and a heating element within an outer glass envelope, the space between the inner and outer glass walls either being evacuated or filled with nitrogen or a noble gas to a pressure which meets the requirement of proper discharge envelope warmup. Such a lamp is shown, for example, in Thouret et al. U.S. Pat. No. 3,445,719. The need to maintain a high envelope and seal temperature increases, however, the chance for its earlier failure during operation.

High pressure discharge lamps, including both mercury and metal iodide lamps, require activation of the tungsten electrodes to increase the current and to lower the operating voltages. Many metals and metal oxides that have low work functions increase the electrode thermionic emission, reducing ballast requirements, and thus the cost of the lighting system. Of these, only one metal, thorium, has been used in the past in arc lamps, since it boils at a sufficiently high temperature (≈3900°C) to coat and remain on the tip of the hot tungsten electrode. However, due to electron impact, thorium atoms are knocked off the tip of the tungsten electrode and react near the wall with iodine to form volatile thorium iodide. The thorium iodide so formed decomposes at the tungsten electrode, depositing thorium metal on the hot tip and releasing iodine, thus providing a cycle that continuously reactivates the tungsten electrodes of those lamps containing iodine or iodides in the fill. Thorium was believed to be the only useful activator, since the other metals and compounds either did not have sufficiently high boiling points to remain on the electrodes or did not have iodides with appropriate vapor pressures and decomposition temperatures to continuously reactivate the electrodes.

As the need for such electrodes increases the cost of the discharge device, it would be desirable to provide a metal halide-type discharge device in which the active light-emitting component also activates the electrodes, allowing operation at a relatively low potential.

OBJECTS OF THE INVENTION

It is, therefore, an object of the present invention to provide a novel electric discharge device.

It is an object of the present invention to provide an electric discharge device of the metal halide type which allows operation at lower envelope and seal temperatures and eliminates the need for electron-emissive treated electrodes, such elimination being achieved by the use of the novel fill herein described.

It is a further object of the present invention to provide an electric discharge device of the metal halide type which eliminates the need for (a) an external heating element to maintain sufficent amounts of the light emitting material in the vaporous state and (b) electron-emissive material treated electrodes, such eliminations being achieved by the use of the novel fill herein described.

It is a further object of the present invention to provide an electric discharge device which, by providing a novel fill material, eliminates the need to provide, as part of the initial discharge device configuration, electrodes which are treated, or incorporate, an electron-emissive material.

These and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed disclosure.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE of the drawing shows an electric discharge device embodying the present invention.

BRIEF SUMMARY OF THE INVENTION

These and still further objects of the present invention are achieved, in accordance therewith, by providing an electric discharge device having a sealed light-transmissive envelope, a pair of electrodes spaced within the envelope, and a fill within the envelope, the fill including, as the primary light-emitting material, a quantity of a high melting, relatively non-volatile metallic iodide complexed with an iodide of a Group IIIA element selected from the group consisting of boron, aluminum, gallium and indium, particularly aluminum iodide, to give a volatile iodide complex having the general formula LnM_xI_{3x+3} where Ln represents either a lanthanide element, such as cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium, or the Group IIIB element, such as scandium, yttrium, and lanthanum; M represents a

Group IIIA element selected from the group consisting of boron, aluminum, gallium and indium, particularly aluminum; and x equals 3 to 4. In order to enhance the color rendition of the arc discharge in any portion of the visible spectrum, mixtures of some or all of the metallic iodide complexes discussed above can be used in varying proportions to produce white light or light of a variety of desired hues.

For brevity, the elements represented by Ln in the general formula above may hereafter sometimes be referred to as the "metallic elements".

The iodides of the suitable Group IIIA elements include boron iodide, aluminum iodide, gallium iodide and indium iodide. Where the term "Group IIIA element iodide" is used below in this specification, it should be understood to identify only those iodides listed in this paragraph. Aluminum iodide is presently preferred. Boron iodide attacks quartz envelopes. Accordingly, when boron iodide is used, an inert envelope, such as boron oxide should be used. Additionally, other components of the device, such as the seals, etc., should be selected, to the extent possible, from materials which offer greater resistance to attack by boron iodide and its dissociation products.

The metallic iodide complexes containing aluminum iodide are the presently preferred materials since they generally have higher vapor pressures at any particular temperature than the other halide complexes. Additionally, the iodide complexes are preferred because the use thereof precludes electrode transport problems such as might be encountered in tungsten electrode discharge lamps.

Since the complexes are solid materials, they can be added to the envelope in solid form. It has been determined that the advantages of the present invention are attained if sufficient complex is added to give, at cold fill, about 0.03–0.25 mg of the lanthanide element or Group IIIB element per cubic centimeter of envelope volume, though about 0.06 mg/cc of such element is generally used. The complex can be added per se, or materials can be added which will decompose, react, etc. during operation to give the required complex. For example, the complex can be generated during operation by the addition of a mixture of (a) a lanthanide element iodide and a suitable Group IIIA element iodide; (b) a lanthanide element, iodine, and a suitable Group IIIA element iodide; (c) a lanthanide element, a suitable Group IIIA element, and iodine; (d) a lanthanide element, a suitable Group IIIA element, and mercuric iodide; etc.; including the corresponding situations where the Group IIIB elements are substitued for the lanthanide element or iodide. The last exemplary selection of materials [i.e. (d)], is presently preferred because the materials can be attained in rigorously anhydrous form — this is desirable because fewer contaminants will be added to the envelope which might adversely affect the operation and lifetime of the discharge device. Of course, the mixture of materials must be in the proper proportions to give the required complex, or a mixture of complexes, either of the same or different metallic elements. As an exemplary way to achieve the desired concentration, 30 mg of the individual elements required to form the volatile complex are added to an envelope having a volume of about 14cc – 18 cc.

The spectral output of the lamps of this invention is characterized by a whiter light than that obtained from mercury discharge lamps; however, depending upon the exact selection of the materials added to the envelope for generation of the fill during operation, the spectral output can be varied to give a variety of different colors. Furthermore, since these devices operate at temperatures that can be maintained by the heat generated by the device itself, external means to heat the device are not needed. As indicated above, this eliminates the need to provide an external heater between the sealed envelope and an outer bulb, for example, as shown by Thouret et al. U.S. Pat. No. 3,445,719. Additionally, the devices of this invention can be operated, with some loss in efficiency, without an outer bulb.

The envelope is generally made of quartz, although other types of glass may be used, such as Vycor, the latter being a glass containing a high proportion of silica. It is essential, of course, that the material utilized for the envelope and the materials utilized in the fill should not adversely react with one another, or with reactive products that might be produced during discharge device operation.

The spaced electrodes can be of any desired configurations, and generally are prepared from a suitable metal, such as tungsten. As indicated above, the electrodes need not be activated, as with thorium, to increase their electron emissivity. It was unexpectedly found that, during the operation of the discharge devices herein described, ordinary tungsten electrodes were activated due to the composition of the fill employed, whereby the devices could be operated at a lower operating potential than that required by such a device with thorium activated electrodes. In many cases, the operating potential can be lowered by as much as 50 percent below the operating potential required for devices with thorium activated electrodes.

The envelope contains, in addition to the complex herein described, a small quantity of a noble gas, such as argon, and a small quantity of mercury which, during operation gives a pressure up to about eight to 10 atmospheres, generally about two to three atmospheres. During operation, the pressure within the envelope is principally generated by the volatization of the mercury with only a small contribution to the total pressure being made by the volatile complex. In addition, other well known additives can be added to the fill for their known purposes. For example, color additives, such as sodium iodide or thallium iodide, can be added to the fill to adjust the spectral output of the discharge device, as desired.

The sealed envelope is desirably held within an outer jacket or bulb, such a device being shown in elevational form in the FIGURE. Referring to the FIGURE, discharge device **1** comprises an outer vitreous bulb or jacket **2** of generally tubular form having a central bulbous portion **3**. The jacket is provided at its end with a re-entrant stem having a press through which extend relatively stiff lead-in wires **6** and **7** connected at their outer ends to the electrical contacts of the usual screw-type base **8** and at their inner ends to envelope **12** and the harness. Sealed in the envelope **12** at the opposite ends thereof are main discharge electrodes **15** and **16** which are supported on lead-in wires **4** and **5** respectively. Each main electrode **15** and **16** comprises a core portion which may be a prolongation of the lead-in wires **4** and **5** and may be prepared of a suitable metal such as, for example, molybdenum or tungsten. The prolongations of these lead-in wires **4** and **5** are sur-

rounded by molybdenum or tungsten wire helixes **13.**

An auxiliary starting electrode **18,** generally prepared of tantalum or tungsten, is provided at the base end of the envelope **12** adjacent main electrode **16** and comprises an inwardly projecting end of another lead-in wire.

Each of the current lead-in wires described have their ends welded to intermediate foil sections of molybdenum which are hermetically sealed within the pinched sealed portions of the envelope. The foil sections are very thin, for example, approximately 0.0008 inch thick and go into tension without rupturing or scaling off when the heated envelope cools. Relatively short molybdenum wires **23, 24** and **35** are welded to the outer ends of the foils and serve to convey current to the various electrodes inside envelope **12.**

Metal strips **45** and **46** are welded to the lead-in wires **23** and **24,** respectively. A resistor **26** is welded to foil strip **45** which, in turn, is welded to the envelope harness. The resistor, which may have, for example, a value of 40,000 ohms, serves to limit current to auxiliary electrode **18** during normal starting of the lamp. Metal foil strip **46** is welded directly to stiff lead-in wire **7.** Lead-in wire **35** is welded at one end to a piece of molybdenum foil sealed in envelope **12.** The foil, in turn, is welded to main electrode **15** via lead-in wire **4.** Metal foil strip **47** is welded to the other end of lead-in wire **35** and at the other end to the harness. The pinched or flattened end portions of envelope **12** form a seal which can be of any desirable width and can be made by flattening or compressing the ends of envelope **12** while they are being heated.

The U-shaped internal wire assembly or envelope harness serves to maintain the position of the envelope **12** substantially coaxial within jacket **2.** To support envelope **12** within the jacket, stiff lead-in wire **6** is welded to base **53** of the harness. Because stiff lead-in wires **6** and **7** are connected to opposite sides of a power line, they, and all members associated with each of them, must be electrically insulated from each other. Clamps **56** and **57,** fixedly attached to legs **54** of the harness, hold envelope **12** at the end portions thereof. Rod **59** bridges the free ends of the U-shaped support wire **54** and is fixedly attached thereto for imparting stability to the structure. The free ends of the U-shaped wire **54** are also provided with a pair of metal leaf springs **60,** frictionally engaging the upper tubular portion of jacket **2.** Optionally, a heat shield **61** can be disposed beneath envelope **12** and above resistor **26** so as to protect the resistor from excessive heat generated during lamp operation.

The present invention is considered distinct and separate from the method developed by Oye and Gruen [J.Amer.Chem. Soc. 91 (1969)] for increasing the vapor pressure of neodymium chloride by complexing that metal halide with aluminum chloride. Although the authors of the aforementioned article teach that the vapor pressure of neodymium chloride can be significantly increased by the complexing thereof with aluminum chloride, they do not relate their activities to electric discharge devices, do not suggest the use of the iodide complexes as herein proposed for use in electric discharge devices and, most importantly, because such materials were not used in electric discharge devices, they do not teach the highly unexpected results herein described as to the elimination of electron-emissive material activated electrodes in such discharge devices.

Subsequent to the realization that, by using the metallic iodide-Group IIIA element iodide complexes of the present invention as the primary component of the fill, the electron-emissive material treated electrodes could be eliminated, it has been postulated that the volatile complex breaks down at the hot electrode tips to generate either a non-volatile metallic compound or the metal itself. This decomposition material is either sputtered off or boiled off of the hot electrodes and is transported to the cold inner wall of the sealed envelope where it reacts with iodine and the Group IIIA iodide present to regenerate the initial complex. Since the complex is a volatile material, the non-volatile metallic compound or metal is continuously removed from the system as it is generated by decomposition of the complex at the hot electrode tips. The volatile complex is transported to the hot electrodes where it decomposes as described above. In this manner, it is believed that at all times during operation of the discharge device, the electrode materials are uniformly coated with a thin layer of a metallic compound or the metal itself. It is further believed that this uniform layer functions as an electron-emissive activator which enables non-activated electrodes to be utilized in the electric discharge devices herein described.

DESCRIPTION OF SPECIFIC EMBODIMENTS

The following Examples are given to enable those skilled in the art to more fully understand and practice the present invention. They should not be considered as a limitation upon the scope of the invention but merely as being illustrative and representative thereof.

In the following Examples, three different envelope configurations have been utilized. These are a 175 watt envelope, a 400 watt envelope, and a 400 watt "shallow-press" (S.P.) envelope. The 175 watt envelope has a volume of about 3.4 cc., a diameter of about 1.5 cm, a length of about 3.8 cm and a length between the adjacent tips of the spaced electrodes of about 3.0 cm. The envelope is made of quartz.

The 400 watt and the 400 watt S.P. envelopes are each made of quartz, have dimeters of about 2.3 cm, lengths of about 6.0 cm, and lengths between electrode tips of about 5.3 cm. Because of slightly different shapes of the ends of each envelope about the electrodes, the volume of the 400 watt envelope is about 14.0 cc. whereas the volume of the 400 watt S.P. envelope is about 17.8 cc.

In all of the Examples, tungsten electrodes are utilized. They are connected to molybdenum foils which, in turn, are connected to tantalum lead-in wires. Where the peak operating potentials of the discharge devices of the present invention are contrasted with those potentials obtained from devices having activated electrodes, the activated electrodes are made of tungsten activated with about 2 percent thorium.

When given in the following Examples, "strike potential" is defined as the peak AC voltage (with reference to zero potential) required for lamp ignition, and "peak potential" is defined as the peak AC voltage (with reference to zero potential) after lamp stabilization when operated at its rated power.

The lamps of these Examples have been "aged" by running for 1 hour at their full rated power. In Examples I-XXVIII and XLVIII-L, the lamps were cooled at ambient conditions (sometimes for 24 hours or so) and then reignited, and the electrical and physical charac-

terics measured during ignition and lamp stabilization. In Examples XXIX–XLVII and LVII the identified characteristics were measured without a cooling period.

EXAMPLE I

A 20 mg sample of $NdAl_3I_{12}$ complex was placed in a 175 watt envelope together with about 2 mg HgI_2 and 23 mm. Ar, the latter two additives being introduced to facilitate ignition of the lamp. An AC power source was used for the operation of the lamp at 2 amps, 85 volts. After an initial warm-up period of a few seconds, the discharge of the lamp assumed an intense white color with a tinge of green. The temperature of the quartz envelope walls was measured by thermocouple to be about 600°C, a temperature apparently quite adequate to generate a considerable vapor pressure of the $NdAl_3I_{12}$ complex. An atomic line spectrum taken of the lamp emission revealed numerous Nd lines throughout the range of 2000A to 8500A. As a reference, another 175 watt envelope was filled with 20 mg NdI_3, 2 mg HgI_2, and 23 mm Ar, and operated under exactly the same conditions as the lamp containing the $NdAl_3I_{12}$ complex. No Nd lines were observable in this reference spectrum. This confirms that a volatile neodymium iodide-aluminum iodine complex was operative in the former case.

EXAMPLE II

A 400 watt envelope is filled with the individual elements which will yield 30 mg $TmAl_3I_{12}$ during lamp operation, and 50 mg Hg. When operated at 410 watts and 2.55 amps, the lamp had a strike potential of 1600 volts, a peak potential of 378 volts, a color temperature of 10[60]°K, and an efficiency of 54 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with a slight tinge of blue. A similar envelope, but with thorium activated electrodes, when charged with components yielding the same fill and operated at 400 watts and 1.86 amps, had a strike potential of 1700 volts, a peak potential of 900 volts and an efficiency of 66.4 lm/w. The discharge was white with a slight blue-green tint. Thus, the lamp without the thorium activated electrodes could be operated at an operating potential of about 45 percent of that required for the lamp with the thorium activated tungsten electrodes.

EXAMPLE III

A 400 watt envelope is filled with the individual elements which will yield 30 mg $TmAl_3I_{12}$ during lamp operation; 5 mg $NaAlI_4$; and 50 mg Hg. When operated at 418 watts and 3.13 amps, the lamp had a strike potential of 1200 volts, a peak potential of 330 volts, a color temperature of about 3900°K, and an efficiency of 62.7 lm/w. After an initial warm-up period of a few seconds, the discharge assumed an exceptionally fine intense white color offering good flesh tones. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 427 watts and 2.45 amps, the lamp had a strike potential of 1300 volts and a peak potential of 550 volts. Thus, the lamp without the thorium activated electrodes could be operated at an operating potential of about 40 percent of that required for the lamp with thorium activated tungsten electrodes.

EXAMPLE IV

A 400 watt envelope was filled with the individual elements which will yield 30 mg $TmAl_3I_{12}$ during lamp operation; 5 mg $NaAlI_4$; 5 mg TlI; and 50 mg Hg. When operated at about 410 watts and about 2.8 amps, the lamp had a strike potential of 1500 volts, a peak potential of 375 volts, a color temperature of about 4900°K, and an efficiency of 77.8 lm/w. After an initial warm-up period of a few seconds, the discharge assumed an intense white color with only slightly yellow flesh tones. By comparison, when a similar envelope having an identical charge and thorium activated electrodes was operated at 409 watts and 2.5 amps, the lamp had a strike potential of 1000 volts, and a peak potential of 420 volts. A similar spectral output was obtained. Thus, the lamp without the thorium activated electrodes could be operated at an operating potential of about 90 percent of that required for the lamp with the thorium activated tungsten electrodes.

EXAMPLE V

A 400 watt S.P. envelope is filled with the individual elements which will yield 40 mg $CeAl_3I_{12}$ during lamp operation; 5 mg TlI; 5 mg $NaAlI_4$; and 60 mg Hg. When operated at 395 watts and 3.5 volts, the lamp had a strike potential of 1000 volts, a peak potential of 260 volts, a color temperature of about 8000°K, and an efficiency of 51.2 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a blue-white color with slightly green flesh tones.

EXAMPLE VI

A 400 watt S.P. envelope is filled with the individual elements which will yield 40 mg $PrAl_3I_{12}$ during lamp operation; 5 mg TlI; 5 mg $NaAlI_4$ and 60 mg Hg. When operated at 400 watts and 3.6 amps, a lamp had a strike potential of 1400 volts, a peak potential of 240 volts, a color temperature of about 6500°K, and an efficiency of 56.9 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a blue-white color with slightly green flesh tones.

EXAMPLE VII

A 400 watt S.P. envelope is filled with the individual elements which will yield 30 mg $SmAl_3I_{12}$ during lamp operation; 5 mg TlI; 5 mg $NaAlI_4$; and 50 mg Hg. When operated at 404 watts and 3.5 amps, the lamp had a strike potential of 1400 volts, a peak potential of 260 volts, a color temperature of about 5200°K, and an efficiency of 60.3 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with slightly yellow-orange flesh tones.

EXAMPLE VIII

A 400 watt S.P. envelope is filled with the individual elements which will yield 45 mg $EuAl_3I_{12}$ during lamp operation; 5 mg TlI; 5 mg $NaAlI_4$; and 60 mg Hg. When operated at 402 watts and 3.47 amps, the lamp had a strike potential of 1300 volts, a peak potential of 260 volts, a color temperature of about 5700°K, and an efficiency of 48 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color.

EXAMPLE IX

A 400 watt envelope is filled with the individual elements which will yield 30 mg $GdAl_3I_{12}$ during lamp op-

eration; 5 mg TlI; 5 mg $NaAlI_4$ and 50 mg Hg. When operated at 405 watts and 2.93 amps, the lamp had a strike potential of 1200 volts, a peak potential of 315 volts, a color temperature of 8500°K, and an efficiency of 58.1 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with a slight blue-white tinge.

EXAMPLE X

A 400 watt envelope is filled with the individual elements which will yield 30 mg $TbAl_3I_{12}$ during lamp operation; 5 mg TlI; 5 mg $NaAlI_4$; and 50 mg Hg. When operated at 404 watts and 2.7 amps, the lamp had a strike potential of 1300 volts, a peak potential of 350 volts, a color temperature of about 7750°K, and an efficiency of 60.7 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with a slight blue-white tinge.

EXAMPLE XI

A 400 watt envelope is filled with the individual elements which will yield 30 mg $DyAl_3I_{12}$ during lamp operation; 5 mg TlI; 5 mg $NaAlI_4$; and 50 mg Hg. When operated at 406 watts and 2.75 amps, the lamp had a strike potential of 1600 volts, a peak potential of 360 volts, a color temperature of about 5000°K, and an efficiency of 55.3 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with slightly orange flesh tones.

EXAMPLE XII

A 400 watt envelope is filled with the individual elements which will yield 30 mg $HoAl_3I_{12}$ during lamp operation; 5 mg TlI; 5 mg $NaAlI_4$; and 50 mg Hg. When operated at 408 watts and 2.5 amps, the lamp had a strike potential of 1200 volts, a peak potential of 410 volts, a color temperature of about 5100°K and an efficiency of 65.1 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with slightly yellow-orange flesh tones.

EXAMPLE XIII

A 400 watt envelope is filled with the individual elements which will yield 30 mg $ErAl_3I_{12}$ during lamp operation; 5 mg TlI; 5 mg $NaAlI_4$; and 50 mg Hg. When operated at 396 watts and 2.7 amps, the lamp had a strike potential of 1300 volts, a peak potential of 365 volts, a color temperature of about 5600°K and an efficiency of 59.8 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with slightly organge flesh tones.

EXAMPLE XIV

A 400 watt envelope is filled with the individual elements which will yield 30 mg $YbAl_3I_{12}$ during lamp operation; 5 mg TlI; 5 mg $NaAlI_4$; and 50 mg Hg. When operated at 403 watts and 2.8 amps, the lamp had a strike potential of 1300 volts, a peak potential of 310 volts, a color temperature of 5500°K, and an efficiency of 67.7 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with slightly green flesh tones.

EXAMPLE XV

A 400 watt S.P. envelope is filled with the individual elements which will yield 30 mg $LuAl_3I_{12}$ during lamp operation; 5 mg TlI; 5 mg $NaAlI_4$; and 50 mg Hg. When operated at 395 watts and 3.7 amps, the lamp had a strike potential of 1200 volts, a peak potential of 210 volts, a color temperature of about 6750°K and an efficiency of 62.2 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with slightly yellow-green flesh tones.

EXAMPLE XVI

A 400 watt S.P. envelope is filled with 6 mg Tb, 26 mg AlI_3, 7 mg NaI, 10 mg HgI_2, and 75 mg Hg. When operated at 408 watts and 2.39 amps, the lamp had a strike potential of 1600 volts, a peak potential of 350 volts, a color temperature of 50,000°K, and an efficiency of 31 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a blue-white color with a slight tinge of purple.

EXAMPLE XVII

Example XVI is repeated except 6 mg Nd is substituted for the 6 mg Tb. When operated at 404 watts and 2.66 amps, the lamp had a strike potential of 1600 volts, a peak potential of 270 volts, a color temperature of about 10,500°K and an efficiency of 43.9 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a blue-white color with slightly yellow flesh tones.

EXAMPLE XVIII

Example XVI is repeated except 6 mg Tm is substituted for the 6 mg Tb. When operated at 408 watts and 2.5 amps, the lamp had a strike potential of 1300 volts, a peak potential of 285 volts, a color temperature of 9000°K, and an efficiency of 61.2 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with slightly yellow flesh tones.

EXAMPLE XIX

A 400 watt envelope is filled with 6 mg Dy, 26 mg AlI_3, 7 mg NaI, 10 mg HgI_2 and 25 mg Hg. When operated at 398 watts and 3.5 amps, the lamp had a strike potential of 1200 volts, a peak potential of 200 volts, and an efficiency of 31.8 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a blue-white color.

EXAMPLE XX

A 400 watt envelope is filled with 25 mg of a mixture of Dy, NaI, and HgI_2; 30 mg GaI_3; and 25 mg Hg. When operated at 394 watts and 3.34 amps, the lamp had a strike potential of 1500 volts, a peak potential of 275 volts and an efficiency of 35.3 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a blue-white color with a slight tinge of purple.

EXAMPLE XXI

Example XX is repeated except 35 mg InI_3 is substituted for the 30 mg GaI_3 of Example XX. When operated at 406 watts and 3.33 amps, the lamp had a strike potential of 1600 volts, a peak potential of 295 volts, a color temperature of about 5750°K and an efficiency of 31.1 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with a purple tint.

EXAMPLE XXII

A 400 watt envelope is filled with 6 mg Dy, 7 mg NaI, 10 mg HgI_2, 20 mg TlI and 25 mg Hg. When operated

at 400 watts and 3.38 amps, the lamp had a strike potential of 1300 volts, a peak potential of 180 volts, a color temperature of about 7000°K, and an efficiency of 50.4 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a green-white color.

EXAMPLE XXIII

A 400 watt envelope is filled with 6 mg Yb, 26 mg AlI_3, 7 mg NaI, 10 mg HgI_2 and 75 mg Hg. When operated at 405 watts and 2.4 amps, the lamp had a strike potential of 1350 volts, a peak potential of 265 volts, a color temperature of about 5900°K, and an efficiency of 64.4 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with a slight tinge of purple.

EXAMPLE XXIV

A 175 watt envelope is filled with 4 mg Dy, 1 mg Sc, 3 mg NaI, 15 mg TlI, 3 mg HgI_2, and 25 mg Hg. When operated at 172 watts and 1.55 amps, the lamp had a strike potential of 1000 volts, a peak potential of 195 volts, a color temperature of about 6750°K, and an efficiency of 36.7 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with a slightly yellow-green tint.

EXAMPLE XXV

A 175 watt envelope is filled with 0.6 mg Sc, 3.0 mg AlI_3, 0.9 mg NaI, 1.1 mg HgI_2, and 25 mg Hg. When operated at 176 watts and 1.2 amps, a lamp had a strike potential of 1100 volts, a peak potential of 330 volts, and an efficiency of 57.5 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a blue-white color with a slight pink tint.

EXAMPLE XXVI

A 175 watt envelope is filled with 4.6 mg $NaAlI_4$, 0.5 mg Sc, 2.5 mg HgI_2, and 25 mg Hg. When operated at 178 watts and 1.7 amps, the lamp had a peak potential of 190 volts, and an an efficiency of 58.8 lm/w. After an initial warm-up period of a few seconds the discharge assumed a white color with a slight green tint to flesh tones.

EXAMPLE XXVII

A 175 watt envelope is filled with 0.5 mg Sc, 9.1 mg $NaAlI_4$, 2.5 mg HgI_2, and 25.0 mg Hg. When operated at 184 watts and 1.5 amps, the lamp had a strike potential of 2400 volts, a peak potential of 305 volts, a color temperature of about 8250°K and an efficiency of 67.2 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a blue-white color with good flesh tones.

EXAMPLE XXVIII

A 400 watt S.P. envelope is filled with the individual elements which will yield 30 mg $TmAl_3I_2$ during lamp operation and 50 mg Hg. When operated at 399 watts and 3.52 amps, the lamp had a strike potential of 1500 volts, a peak potential of 240 volts, a color temperature of about 9500°K, and an efficiency of 39.6 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a blue-white color with a slight purple tint.

EXAMPLE XXIX

A 400 watt envelope is filled with 4 mg Ce, 1.4 mg Al, 48 mg HgI_2, 30 mg Hg, and 23 mm Ar. When operated at 400 watts and 3.00 amps, the lamp had a peak potential of 278 volts and an efficiency of 58 lm/w. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 400 watts and 1.63 amps, the lamp had a peak potential of 1050 volts and an efficiency of 72 lm/w. The discharge in both cases was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 73 percent was attained.

EXAMPLE XXX

Example XXIX is repeated except 4 mg Pr is substituted for the 4 mg Ce of Example XXIX. When operated at 400 watts and 2.93 amps, the lamp had a peak potential of 317 volts and an efficiency of 48 lm/w. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 408 watts and 1.8 amps, the lamp had a peak potential of 760 volts and an efficiency of 65 lm/w. Both lamps had a white discharge with a slight tint of blue. Without the thorium activated electrodes, a decrease in the peak operating potential of about 58 percent was attained.

EXAMPLE XXXI

Example XXIX is repeated except 4 mg Nd is substituted for the 4 mg Ce. When operated at 400 watts and 3.19 amps, the lamp had a peak potential of 272 volts and an efficiency of 45 lm/w. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 400 watts and 1.74 amps, the lamp had a peak potential of 900 volts and an efficiency of 77 lm/w. In both cases, the discharge was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 70 percent was attained.

EXAMPLE XXXII

Example XXIX is repeated except 4 mg Sm is substituted for the 4 mg Ce of Example XXIX. When operated at 401 watts and 2.95 amps, the lamp had a peak potential of 292 volts and an efficiency of 47 lm/w. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 402 watts and 2.38 amps, the lamp had a peak potential of 504 volts and an efficiency of 62 lm/w. In both cases, the discharge was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 41 percent was attained.

EXAMPLE XXXIII

Example XXIX is repeated except 4 mg Eu is substituted for the 4 mg Ce of Example XXIX. When operated at 400 watts and 3.39 amps, the lamp had a peak potential of 245 volts and an efficiency of 44 lm/w. The discharge was white with a pink-purple tint. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 397 watts and 2.05 amps, the lamp had a peak potential of 730 volts and an efficiency of 70 lm/w. The dis-

charge was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 67 percent was attained.

EXAMPLE XXXIV

Example XXIX is repeated except 4 mg Gd is substituted for the 4 mg Ce of Example XXIX. When operated at 400 watts and 3.00 amps, the lamp had a peak potential of 269 volts and an efficiency of 45 lm/w. The discharge was white with a pink-purple tint. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 400 watts and 1.93 amps, the lamp had a peak potential of 680 volts and an efficiency of 70 lm/w. The discharge was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 60 percent was attained.

EXAMPLE XXXV

Example XXIX is repeated except 4 mg Tb is substituted for the 4 mg Ce of Example XXIX. When operated at 403 watts and 3.11 amps, the lamp had a peak potential of 279 volts and an efficiency of 46 lm/w. The discharge was white with a pink-purple tint. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 399 watts and 1.82 amps, the lamp had a peak potential of 740 volts and an efficiency of 59 lm/w. The discharge was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 62 percent was attained.

EXAMPLE XXXVI

Example XXIX is repeated except 4 mg Dy is substituted for the 4 mg Ce of Example XXIX. When operated at 400 watts and 3.19 amps, the lamp had a peak potential of 254 volts and an efficiency of 60 lm/w. The discharge was white with a pink-purple tint. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 397 watts and 1.76 amps, the lamp had a peak potential of 760 volts and an efficiency of 69 lm/w. The discharge was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 67 percent was attained.

EXAMPLE XXXVII

Example XXIX is repeated except 4 mg Ho is substituted for the 4 mg Ce of Example XXIX. When operated at 400 watts and 3.13 amps, the lamp had a peak potential of 262 volts and an efficiency of 47 lm/w. The discharge was white with a pink-purple tint. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 402 watts and 1.97 amps, the lamp had a peak potential of 660 volts and an efficiency of 65 lm/w. The discharge was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 60 percent was attained.

EXAMPLE XXXVIII

Example XXIX is repeated except 4 mg Er is substituted for the 4 mg Ce of Example XXIX. When operated at 400 watts and 2.96 amps, the lamp had a peak potential of 286 volts and an efficiency of 42 lm/w. The discharge was white with a blue-purple tint. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated, at 400 watts and 1.88 amps, the lamp had a peak potential of 780 volts and an efficiency of 64 lm/w. The discharge was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 63 percent was attained.

EXAMPLE XXXIX

Example XXIX is repeated except 4 mg Tm is substituted for the 4 mg Ce of Example XXIX. When operated at 400 watts and 3.16 amps, the lamp had a peak potential of 258 volts and an efficiency of 52 lm/w. The discharge was blue-white. When a similar envelope, having the same charge of materials but thorium activated electrodes in place of the non-activated of the non-activated tungsten electrodes, was operated at 400 watts and 2.08 amps, the lamp had a peak potential of 680 volts and an efficiency of 76 lm/w. The discharge was also blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 60 percent was attained.

EXAMPLE XL

Example XXIX is repeated except 4 mg Yb is substituted for the 4 mg Ce of Example XXIX. When operated at 403 watts and 2.97 amps, the lamp had a peak potential of 300 volts and an efficiency of 52 lm/w. The discharge was blue-white. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 401 watts and 2.31 amps, the lamp had a peak potential of 605 volts and 73 lm/w. The discharge was also blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 50 percent was attained.

EXAMPLE XLI

Example XXIX is repeated except 4 mg Lu is substituted for the 4 mg Ce of Example XXIX. When operated at 400 watts and 3.38 amps, the lamp had a peak potential of 239 volts and an efficiency of 43 lm/w. The discharge was white with a blue-purple tint. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 402 watts and 2.04 amps, the lamp had a peak potential of 710 volts and an efficiency of 71 lm/w. The discharge was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 66 percent was attained.

EXAMPLE XLII

Example XLI is repeated except 3.7 mg Ga is substituted for the 1.4 mg Al of Example XXIX. When operated at 400 watts and 2.68 amps, the lamp had a peak potential of 370 volts and an efficiency of 59 lm/w. The discharge was white with a blue-purple tint.

EXAMPLE XLIII

Example XXIX is repeated except 6.1 mg In is substituted for the 1.4 mg Al of Example XXIX. When oper-

ated at 400 watts and 2.79 amps, the lamp had a peak potential of 347 volts and an efficiency of 55 lm/w. The discharge was blue-white.

EXAMPLE XLIV

Example XXIX was repeated except 2 mg Dy and 2 mg Lu are substituted for the 4 mg Ce of Example XXIX. When operated at 400 watts and 2.97 amps, the lamp had a peak potential of 290 volts and an efficiency of 54 lm/w. The discharge was white with a slight purple tint.

EXAMPLE XLV

Example XLIV is repeated except 2 mg Gd is substituted for the 2 mg Lu of Example XLIV. When operated at 400 watts and 3.21 amps, the lamp had a peak potential of 248 volts and an efficiency of 44 lm/w. The discharge was white with a purple tint, but with good flesh tones.

EXAMPLE XLVI

Example XLIV is repeated except a 400 watt S.P. envelope is used, 2 mg Tm is substituted for the 2 mg Lu of Example XLIV, and 5 mg NaI and 2 mg TlI are additionally added. When operated at 401 watts and 3.87 amps, the lamp had a strike potential of 1700 volts, a peak potential of 210 volts, and an efficiency of 66 lm/w. The discharge was white with a red-purple tint.

EXAMPLE XLVII

Example XLVI is repeated except 2 mg Pr is substituted for the 2 mg Tm of Example XLVI. When operated at 398 watts and 3.66 amps, the lamp had a strike potential of 1600 volts, a peak potential of 220 volts, and an efficiency of 63 lm/w. The discharge was white with a pink tint.

EXAMPLE XLVIII

A 400 watt S.P. envelope is filled with 8 mg Tm, 1.4 mg Al, 5 mg NaI, 48 mg HgI_2, 30 mg Hg, and 23 torr Ar. When operated at 404 watts and 3.8 amps, the lamp had a strike potential of 1650 volts, a peak potential of 208 volts, a color temperature of about 4400°K, and an efficiency of 80.3 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with a slight pink-purple tint.

EXAMPLE IL

A 400 watt S.P. envelope is filled with 6 mg Tm, 1.1 mg Al, 31 mg HgI_2, 5 mg NaI, 3 mg Ce, and 1 mg TlI, 36 mg Hg and 23 torr Ar. When operated at 403 watts and 3.62 amps, the lamp had a strike potential of 1300 volts, a peak potential of 192 volts, a color temperature of 6250°K, and an efficiency of 95.2 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a greenish-white color.

EXAMPLE L

A 400 S.P. envelope is filled with 8 mg Tm, 1.4 mg Al, 48 mg HgI_2, 5 mg NaI, 2 mg TlI, 14 mg Hg, and 23 torr Ar. When operated at 400 watts and 3.25 amps, the lamp had a strike potential of 1700 volts, a peak potential of 225 volts, a color temperature of about 5800°K, and an efficiency of 103.5 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with a slight green tint.

EXAMPLE LI

A 400 watt envelope is filled with 0.75 mg Sc, 0.60 mg Al, 20 mg HgI_2, 48 mg Hg and 23 mm Ar. When operated at 400 watts and 2.93 amps, the lamp had a strike potential of 1200 volts, a peak potential of 280 volts, and an efficiency of 63 lm/w. The discharge was white with a blue-green tint. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 400 watts and 1.83 amps, the lamp had a strike potential of 2000 volts, a peak potential of 720 volts, and an efficiency of 62 lm/w. The discharge was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 50 percent was attained.

EXAMPLE LII

Example LI is repeated except 1.5 mg Y is substituted for the 0.75 mg Sc of Example LI. When operated at 401 watts and 3.4 amps, the lamp had a strike potential of 1650 volts, a peak potential of 194 volts, and an efficiency of 42 lm/w. The discharge was white with a blue-purple tint. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 400 watts and 2.43 amps, the lamp had a strike potential of 1300 volts, a peak potential of 400 volts and an efficiency of 56 lm/w. The discharge was white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 50 percent was attained.

EXAMPLE LIII

Example LI is repeated except 2.4 mg La is substituted for the 0.75 mg Sc of Example LI. When operated at 400 watts and 3.41 amps, the lamp had a strike potential of 1700 volts, a peak potential of 190 volts, and an efficiency of 41 lm/w. When a similar envelope, having the same charge of materials but thorium activated tungsten electrodes in place of the non-activated tungsten electrodes, was operated at 400 watts and 2.91 amps, the lamp had a strike potential of 1200 volts, a peak potential of 450 volts, and an efficiency of 61 lm/w. In both cases the discharge was blue-white. Without the thorium activated electrodes, a decrease in the peak operating potential of about 60 percent was attained.

In the following Examples, the molar ratios of the lanthanide element, the Group IIIA element, and iodine are 1 to 4 to 15, respectively.

EXAMPLE LIV

A 400 watt envelope is filled with 4 mg Ce, 1.9 mg Al, 60.4 mg HgI_2, 25 mg Hg, and 23 torr Ar. When operated at 402 watts and 2.77 amps, the lamp had a strike potential of 1650 volts, a peak potential of 318 volts, and an efficiency of 44 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with a slight blue-green tint.

EXAMPLE LV

Example LIV is repeated except 4 mg Gd is substituted for the 4 mg Ce of Example LIV. When operated at 402 watts and 2.87 amps, the lamp had a strike potential of 1650 volts, a peak potential of 320 volts, and an efficiency of 42 lm/w. After an initial warm-up pe-

riod of a few seconds, the discharge assumed a white color with a slight blue-purple tint.

EXAMPLE LVI

Example LIV is repeated except 4 mg Tm is substituted for the 4 mg Ce of Example LIV. When operated at 400 watts and 2.98 amps, the lamp had a strike potential of 1500 volts, a peak potential of 297 volts, and an efficiency of 52 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with a slight purple tint.

EXAMPLE LVII

Example LIV is repeated except 4 mg Lu is substituted for the 4 mg Ce of Example LIV. When operated at 400 watts and 2.83 amps, the lamp had a strike potential of 1050 volts, a peak potential of 315 volts, and an efficiency of 45 lm/w. After an initial warm-up period of a few seconds, the discharge assumed a white color with a slight pink-purple tint.

Unless otherwise indicated, the data given in these Examples are individual run test data, and not averages of a number of test runs. The individual run test data is considered, however, to be representative of the results which can be obtained when following the teachings of this invention.

In preparing the lamps of these Examples, conventional procedures, well known to those skilled in this field, have been employed. It should be understood that the Examples given in this specification do not represent optimizations and, therefore, additional advantages, such as increased efficiencies, are expected to accrue when such optimizations are performed.

When NaI is added to the envelope (for example to decrease the operating potential and/or to adjust the spectral output), it can be added as the complex thereof with the iodide of the Group IIIA metal (eg. AlI_3), that is, it can be added as $NaAlI_4$. During lamp operation, an equilibrium exists between the volatile complex herein described and its dissociation components, i.e., the metallic iodide (eg. TmI_3) and the iodide of the Group IIIA element (eg. AlI_3). When NaI is added as NaI, it forms a complex with AlI_3 and alters the equilibrium that would otherwise be established in the operation of the device. This results in a decrease in the concentration of the volatile complex availale for volatilization. When NaI is added as $NaI{\cdot}AlI_3$ (i.e., $NaAlI_4$), however, the equilibrium which would normally be established is not disrupted since the $NaAlI_4$ does not tie up AlI_3 dissociated from the volatile complex.

While the present invention has been described with reference to specific embodiments thereof, it will be understood by those skilled in this art that various changes may be made without departing from the true spirit and scope of the invention. In addition, many modifications may be made to adapt a particular situation, material, apparatus, process or then present objective to the spirit of this invention without departing from its essential teachings.

What is claimed is:

1. An electric discharge device comprising a sealed light-transmissive envelope; a pair of unactivated electrodes spaced within said envelope and capable of being connected, at those portions thereof extending outside of said envelope, to means for applying an electrical potential thereto; and a fill within said sealed envelope, said fill including at least one volatile complex having the formula LnM_xI_{3x+3}, where Ln is a lanthanide element, M represents a Group IIIA element selected from the group consisting of boron, aluminum, gallium and indium, and $x = 3$ to 4, said complex serving to activate said electrodes during operation of said discharge device whereby the need to provide electron-emissive material activated electrodes is eliminated; said volatile complex being present in sufficient quantity to constitute the primary light-emitting component of the fill.

2. The discharge device of claim **1** wherein Ln is selected from the group consisting of cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium.

3. The discharge device of claim **1** wherein Ln is thulium.

4. The discharge device of claim **1** wherein Ln is dysprosium.

5. The discharge device of claim **1** wherein Ln is cerium.

6. The discharge device of claim **1** wherein M is aluminum.

7. The discharge device of claim **1** wherein Ln is selected from the group consisting of thulium, dysprosium, and cerium.

8. The discharge device of claim **1** wherein Ln is thulium and M is aluminum.

9. The discharge device of claim **1** wherein M is selected from the group consisting of gallium and indium.

10. The discharge device of claim **1** wherein said complex is present in said envelope in a quantity sufficient to provide 0.03 – 0.25 mg of the metallic element represented by the symbol Ln per cc. of envelope volume.

11. The discharge device of claim **1** wherein said fill further includes a small quantity of a noble gas.

12. The discharge device of claim **11** wherein said noble gas is argon.

13. The discharge device of claim **1** wherein said fill further includes a small quantity of mercury.

14. The discharge device of claim **1** wherein said mercury generates, during operation of said device, a pressure up to about 10 atmospheres.

15. The discharge device of claim **1** wherein said fill includes a small quantity of $NaAlI_4$.

16. The discharge device of claim **1** wherein said sealed envelope is positioned within an outer transparent envelope, said complex being sufficiently volatile during operation of said device that the need to provide a heating element in the space between said sealed and outer envelopes is eliminated.

17. The discharge device of claim **1** wherein essentially stoichiometric amounts of complex-forming materials are added to said envelope, whereby during operation of said device said volatile complex is found in the absence of a substantial excess of a rare earth halide material.

18. An electric discharge device comprising a sealed light-transmissive envelope; a pair of unactivated electrodes spaced within said sealed envelope, said electrodes being initially free of electron emissive material which would function to lower the operating potential of the device during operation; and a fill within said envelope, said fill including at least one volatile complex having the general formula LnM_xI_{3x+3}, where Ln repre-

sents a lanthanide element, M represents a Group IIIA element selected from the group consisting of boron, aluminum, gallium, and indium, and x equals 3 to 4, said complex serving to activate said electrode during operation of said device whereby the need to initially provide electron-emissive material activated electrodes is eliminated, said volatile complex being present in sufficient quantity to constitute the primary light-emitting component of the fill.

19. The discharge device of claim **18** wherein M is aluminum.

20. The discharge device of claim **18** wherein M is selected from the group consisting of gallium and indium.

21. The discharge device of claim **18** wherein Ln is selected from the group consisting of thulium, dysprosium, and cerium.

22. The discharge device of claim **18** wherein Ln is thulium and M is aluminum.

23. The discharge device of claim **18** wherein said complex is present in said envelope in a quantity sufficient to provide 0.03 – 0.25 mg of said lanthanide element per cc. of envelope volume.

24. The discharge device of claim **18** wherein said sealed envelope is positioned within an outer transparent envelope, said complex being sufficiently volatile during operation of said device that the need to provide a heating element in the space between said sealed and outer envelopes is eliminated.

25. The discharge device of claim **18** wherein essentially stoichiometric amounts of complex-forming materials are added to said envelope, whereby during operation of said device said volatile complex is found in the absence of a substantial excess of a rare earth halide material.

* * * * *

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,771,009 Dated November 6, 1973

Inventor(s) H. Graham Silver, Adam Heller, Phillip J. Gardner and Gary R. Argue

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 15, "a mercury" should be --the mercury--.

Column 15, line 51, "Nal" should be --NaI--.

Column 18, line 43, "claim 1" should be --claim 13--.

Signed and sealed this 9th day of April 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents