CESIUM LIGHT SOURCE

Filed Jan. 22, 1968 2 Sheets-Sheet 1

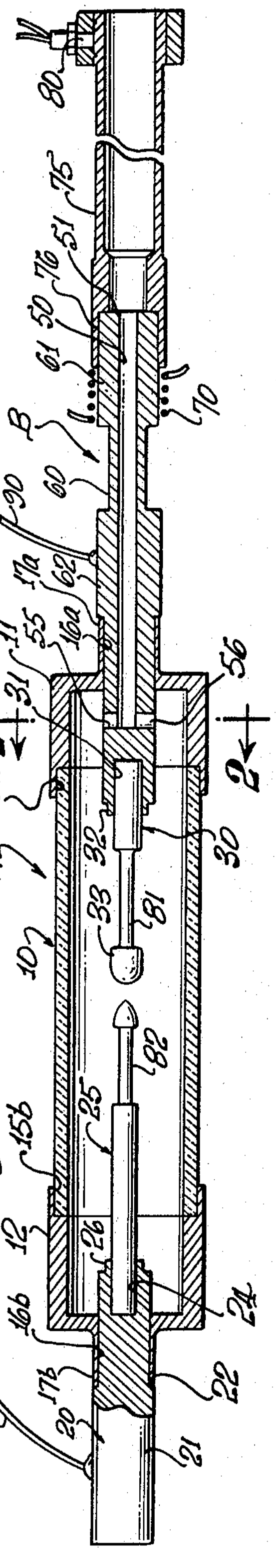

Fig. 1.

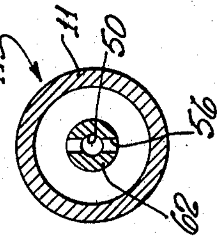

Fig. 2.

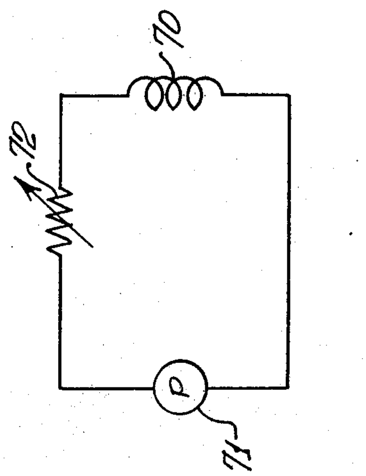

Fig. 3.

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CESIUM LIGHT SOURCE

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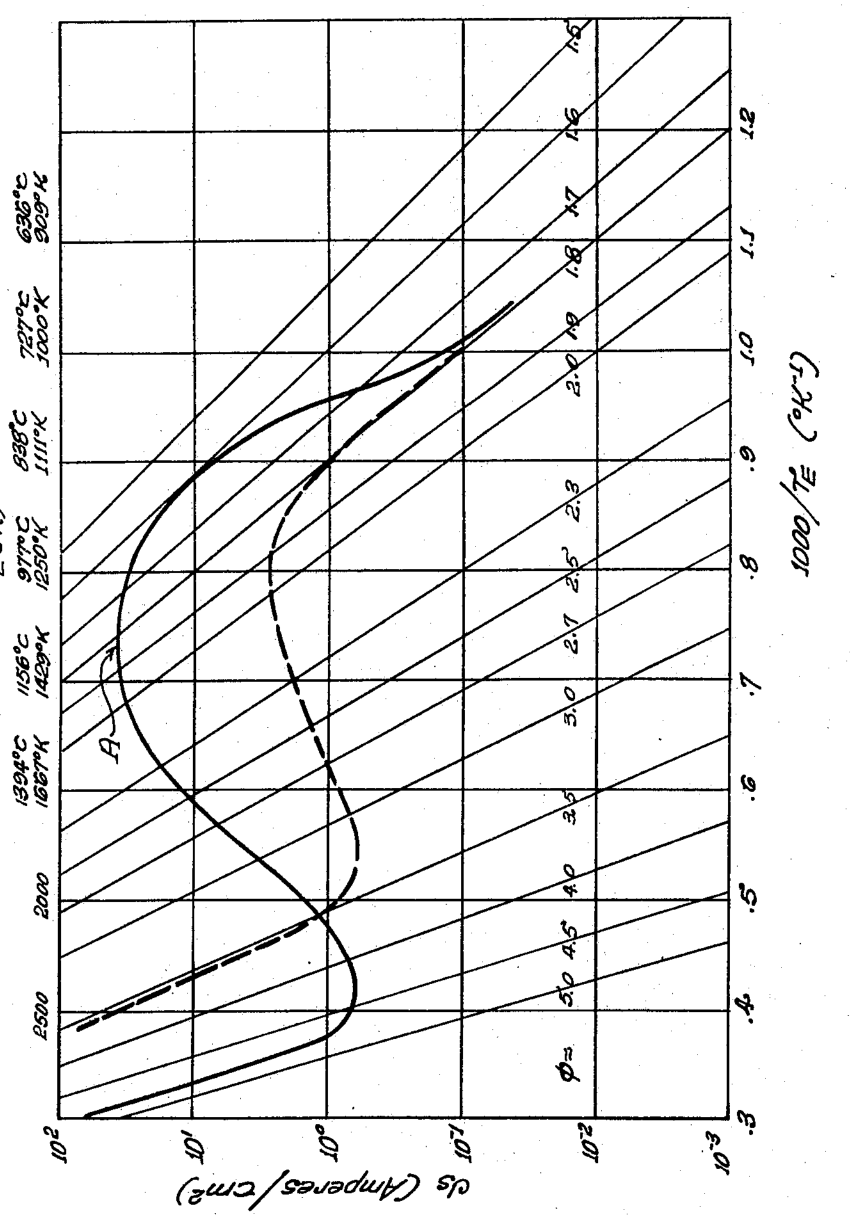

Fig. 4

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3,487,252
CESIUM LIGHT SOURCE

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Continuation-in-part of application Ser. No. 501,613, Oct. 22, 1965. This application Jan. 22, 1968, Ser. No. 706,211
Int. Cl. H01j 19/68, 61/24
U.S. Cl. 313—180 11 Claims

ABSTRACT OF THE DISCLOSURE

A vapor electric discharge tube having an electrode made of a pure refractory metal and having a temperature controlled reservoir of the vaporizable metal. Heat insulation is provided between the reservoir and operating region of the device so that the temperature of the reservoir may be independent of the temperature of the operating region.

CROSS REFERENCES TO RELATED APPLICATIONS

This is a continuation-in-part of my copending application Ser. No. 501,613, filed Oct. 22, 1965, now abandoned.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to an electric discharge tube which serves as a gas plasma arc discharge device.

Description of the prior art

Vapor discharge lamps utilizing a vaporizable metal typically utilize an alkali metal to provide a gas plasma for the arc discharge. Examples of such lamps in the prior art achieve the power output by ordinary methods such as increasing the temperature of the cathode until sufficient current is produced to provide an arc of the desired radiated output. To describe this in another way the vapor pressure within the unit may be varied with the corresponding change in the temperature to produce the desired radiated output. For high radiated outputs, typically the temperatures of the electrodes are so high that rapid degradation of the cathode material occurs with reduced light output and a result in short life of the device.

The present invention is directed to a vaporizable metal discharge device which can operate at high outputs with relatively low operating temperatures and thus high efficiency.

SUMMARY OF THE INVENTION

The present invention provides a novel electric discharge device construction which permits adjustment of the vapor pressure and has a pure refractory metal electrode. The vapor pressure is adjustable by including in the device a temperature controlled reservoir of the vaporizable metal which metal is utilized in the discharge arc. The reservoir is separated from the main arc region by a mechanical heat choke section so that the reservoir is always at the coolest temperature of the device. A heating coil surrounds the reservoir and by adjusting the current in the coil the temperature of the reservoir can be varied as desired thus controlling the vapor pressure. One of the electrodes in the present invention comprises a pure refractory metal such as tungsten, for example.

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BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a cross sectional view of device embodying this invention;

FIGURE 2 is a sectional view taken along line 2—2 of FIGURE 1;

FIGURE 3 is a schematic view of the heating coil circuit and the temperature sensing means of the invention; and

FIGURE 4 is a graphical representation of current density as a function of temperature.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Although a number of vaporizable metals such as, for example, rubidium, mercury, lithium, and francium are capable of utilization in a vapor discharge arc device the metal cesium is readily available and has particularly desirable characteristics for this use and, accordingly, the invention herein, although not so limited, will be described with respect to cesium.

The construction of a successful cesium vapor-electric discharge device has long been a desired goal since cesium has a number of advantages not held by mercury or other vaporizable metals. For example, cesium possesses one of the lowest ionizable potentials of the available metals and, therefore, a cesium vapor discharge device operates at a lower arc drop for a particular current than devices using other vaporizable metals. It has been discovered in the invention herein that cesium in a discharge device coats the electrodes during operation of the arc and provides extremely efficient electron emission from the coated electrodes. This cesiation of the electrodes provides higher efficiency of operation and, thus, lower operating temperatures which reduces tube blackening and increases the life of arc-discharge devices.

The employment of cesium as an ionizable medium in an electric discharge device presents many problems. Minimum operating voltage for efficient arc operation is dependent upon and inversely proportional to the vapor pressure of the vaporizable metal used in the discharge arc. Therefore, to achieve low operation voltage and high efficiency, the vapor pressure must be maintained at a relatively high value. Further, high vapor pressures allow the arc-discharge device to operate at a lower current for a particular radiated output. This results from the great concentration of cesium ions in the arc region at high vapor pressures so that less current is required to produce the desired radiated output. That is, a higher arc voltage can be maintained and, thus, a lower current so that less heating loss through the electrodes results. If current is increased in the arc-discharge device, a point will be reached when more cesium atoms leave the electrodes than arrive so that the electrodes may no longer have even a monoatomic layer of cesium thereon. Thus, the current decreases and the electrodes cool. This may cause the operation point of the device to oscillate. To avoid such problems, it is necessary to increase vapor pressure when current is increased to maintain proper cesiation of the electrodes and to have a cathode construction which is conducive to good cesiation.

Referring to the drawing, a preferred embodiment of the invention is shown. The device shown is a metal vapor discharge-arc device embodying the invention. The device comprises generally two sections or portions, a tubular housing A and a tubular control section B.

Housing A comprises a tube **10** which is closed at the ends by electrode holders, namely anode mount **11** and cathode mount **12**.

Tube **10** is cylindrical and in the preferred embodiment of the invention is made of fused alumina. Although other tube materials can be utilized, fused alumina was chosen because of its high capability to withstand heat which capability is higher than that of quartz and because of its capability of being easily brazed to metals. Thus, fused alumina is an economical and practical tube material for use in an arc-discharge device that operates at high temperatures. Furthermore, fused alumina is substantially transparent in the infrared and near-infrared regions.

Provided at the ends of tube **10** are mounts **11** and **12** which are made of nickel or other high temperature metal. The mounts **11** and **12** are generally cylindrical and have recessed sections **15*a*** and **15*b*** which have inside diameters substantially equal to the outside diameter of tube **10**. The recesses **15*a*** and **15*b*** are cooperatively press fitted to tube **10** at the ends thereof and are brazed into sealing engagement therewith. The braze material may be copper or any other high temperature braze material such as, for example, an active alloy braze, that is, any braze that can satisfactorily withstand temperatures of 1000° C. or over.

Mounts **15*a*** and **15*b*** defined therein circular openings **16*a*** and **16*b*** which are extended by circular flanges **17*a*** and **17*b***. Cathode holder **20** is press fitted through flange **17*b***. The cathode holder **20** has a larger diameter rear portion **21** which defines a shoulder **22**. Shoulder **22** abuts against the end of flange **17*b*** and the assembly is brazed together for sealing. Cathode holder **20** in its forward portion contains a cylindrical recess **24** which is sized to receive the generally cylindrical cathode **25** in a press fit. Cathode **25** is welded to holder **20**. A reduced diameter portion **26** is provided in holder **20** for ease of welding; that is, the thinner portion of metal becomes somewhat fluid during the welding process and flows into contact with the cathode **25** thus making a secure and reliable weld. It is not necessary to have portion **26**, but it provides for more reliable welding and, therefore, is convenient for ease of manufacture. The cathode **25** is made of tungsten which is substantially pure for reasons which will be discussed hereinafter.

Cathode holder **20** is made of stainless steel, but can be fabricated of any suitable high temperature metal.

Control section B has a recess **31** and a reduced diameter portion **32** is provided to hold anode **33** in the same manner as is cathode **25** as described hereinabove. Control section B is brazed to mount **11** at flange **17*a*** in the same manner, described hereinabove, as is holder **20** to flange **17*b***. Extending coaxially through control section B is cylindrical bore **50** which is open at end **51** of section B. A cylindrical bore **56** is provided near plane **55** and oriented transversely to the axis of bore **50**. Bore **56** is located within housing section A. Thus, as is easily observed in the drawing, bore **56** provides communication between housing section A and bore **50**.

Section B is cylindrical and made of stainless steel or other metals capable of withstanding the temperatures of 1000° C. or over which are encountered in operation of the device. A necked down portion **60** is provided in section *b* to create a heat choke. That is, since the heat flux created by the arc is constant, the reduced cross-sectional area of the necked down portion **60** will cause the temperature change per unit length to be greater for the necked down portion **60** and, thus, a significantly greater temperature differential will exist across portion **60** than would exist if no reduced diameter section was included. Because of the large differential of temperature across portion **60**, the temperature of portion **61** of the control section B will be substantially cooler than section **62** and, thus, substantially cooler than temperatures in the vicinity of the arc in housing section A. All cesium that condenses in the device will condense at the coolest point and, thus, will condense the bore in portion **61**. Thus, portion **61** provides in substance a chamber or reservoir in which all condensed cesium of the device is contained.

Disposed about portion **61** is an electrical heating coil **70** shown schematically in FIGURE 1. The heating coil **70** is connected to a power source **71** and the current through coil **70** is adjusted or controlled by means of rheostat **72**.

Any heating means, as for example a gas burner, may be utilized; however, a heating coil is relatively inexpensive and easy to control and, thus, was chosen for the preferred embodiment of the invention.

Connected to portion **61** is a cap section **75** which is welded at flange **76**. The cap section **75** is used for initial charging and sealing of the device and can be of any convenient shape or size. A thermocouple **80** is installed in the wall of cap section **75** for measuring the temperature within section **75**. This measured temperature is close to the temperature within portion **61** because of proximity of the areas. Necked down portions **81** and **82** are provided in the electrodes for providing electrode heat isolators, that is, to keep the posts of the device which are not close to the arc relatively cool. The shapes of the electrodes as shown in FIGURE 1 were designed for efficient arc operation.

Nickel wires **90** and **91** are welded to the electrode holders and are adapted for connection to a power source for operating the arc.

A predetermined quantity of cesium or other vaporizable alkali metal such as any of the metals from Group I of the Periodic Table or material is sealed with the device.

It is a very important feature of this invention that the cathode be made of pure refractory metal. It is not necessary to have the cathode made of a single refractory metal, it may be made of a combination of such metals. However, it is to be noted expressly that if desired the cathode may be made of a single refractory metal. In an embodiment of the invention which has been lab tested, the electrode was made of tungsten and was approximately 99.99% pure elemental tungsten. Other metals have been utilized such as, for example, the refractory metals of molybdenum, rhenium, zirconium, niobium and tantalum. Tests and other data indicate that a cathode made of any combination of this group of metals, which include tungsten, will be satisfactory for the invention provided that there is no greater than .1% other matter in the composition of the cathode. Accordingly, it is believed that for the purposes of this invention that the cathode is substantially pure refractory metal if its composition is 99.9% or more refractory metals.

For a clearer understanding, an explanation of the operation of the invention is desirable. In operation, wires **90** and **91** are connected to a power source. The voltage of the power source is raised until an arc is struck between electrodes **25** and **33**. The arc generates heat which ionizes the cesium in the system, which makes the arc self-sustaining, this is, the voltage across the arc equalizes at a level sufficient to sustain the arc which level is substantially lower than the breakdown voltage required to strike the arc. Cesium will condense at the coolest point of the system which is, as discussed hereinabove, in reservoir or chamber **61**. Thus, the temperature of chamber **61** will determine the vapor pressure and the operating point of the device. To change this operating point, it is merely necessary to change the temperature of portion **61** by varying the current through heating coil **70** by rheostat **72**. The vapor pressure can be measured by interrelating it to the temperature of portion **61** which can be sensed by an temperature sensor such as, for example, thermocouple **80**.

An experimental model made in accordance with this invention has an overall length of approximately five inches, an outside diameter of approximately 0.5 inch and is comptued to be capable of operating at input powers of 1000 watts or more. Spectrometer analyses of the model show that the device can produce an output in which 80% or more of the radiated energy occurs at wavelengths of greater than one micron; thus, the device provides an extremely efficient infrared source.

Referring to FIGURE 4 of the drawing, the graph therein shown has plotted in the abscissa 1000 times the reciprocal of the emitter temperature, i.e., cathode in degrees Kelvin, the ordinate of the graph is in terms of the current density in amperes per centimeters squares or the current flux as it is sometimes named. The diagonal lines designated by the Greek letter ϕ are ideal plots of work function, that is iso work function curves which assume materials which would retain the same work function as the temperature of the material increases. Tungsten and other refractory metals conform closely with these curves. The solid line curve is a plot of characteristics of the present invention during operation. Actually, a family of such curves would result, one for each vapor pressure, however, for clarity only one of such curves is shown. The dotted line indicates the characteristics of a typical prior art lamp under the same conditions. It is clear that there is a substantial improvement in performance utilizing the present invention. It is believed that the curves of FIGURE 4 can be explained as follows. Referring specifically to the solid line curve which represents performance of the present invention, at the extreme right of the plotted curve electron emission is somewhat low. It is believed that under the conditions represented that the cathode of the device is completely cesiumated, that is, that a thick layer of cesium coats the cathode and that all the electrons emitted for purposes of the arc-discharge are emitted from the cesium layer and that under these conditions the underlying base material or cathode material is not significant. Emission characteristics, of course, are excellent since cesium has such a low work function. However, under these conditions output is not great since the operating temperature of the electrode is low. As the temperature is increased more electrons are emitted from the cesium layer and emission increases until a maxim is reached at point A. It is believed that the conditions at point A represent a condition where the emission of free electrons for the discharge arc are still coming almost entirely from the cesium layer but because of the increase in temperature substantial evaporation of cesium from the cathode has occurred, however, a monoatomic layer of cesium remains on the cathode. Accordingly, if the temperature is increased further more cesium evaporates from the cathode leaving less than a monoatomic layer of cesium thereon and so the current density drops although the temperature of the cathode increases. This drop continues over a substantial differential of temperature as shown by the graph until finally current density starts rising rapidly and asymptotically to the iso work function curve for the cathode meal which in the preferred embodiment of the invention is tungsten having a work function of between 4.5 and 5.0. Of course, at this high output point the temperature is so high that the cathode of tungsten would rapidly deterioriate and be impractical for a lamp. It is significant to note, however, that prior art lamps to achieve the high outputs necessary for modern applications do indeed operate at the high temperatures which rapidly degrade cathode performance. Since, as stated hereinabove, operating temperatures to achieve such outputs in prior art lamps are so high that electrode deterioration is rapid, prior efforts have sought methods of lowering the work function of the cathode material. A well-known example is the adding of an impurity to the cathode material such as in a thoriated cathode having an oxide impurity added to the cathode material. The dotted line of the graph indicates the curve obtained from the operation of such a typical prior art lamp which includes a cathode material such as tungsten which has impurities added thereto. It is believed that the degradation of performance by use of typical prior art lamps is explained as follows. It is believed that the work function of a cathode coated by cesium is reduced due to the dipole atomic forces existing between the adsorbed cesium atoms on the metal surface of the cathode and the surface atoms themselves. When impurities such as oxides are added to the cathode material such as in thoriated tungsten cathode, it is believed that there is a disturbance or distortion of the crystal structure of the cathode material such that dipole forces are not as effective in lowering the work function of the cesiumated cathode. Furthermore, as is well known cesium is a highly active material which combines readily with many other substances. Therefore, it is believed that cesium will react with the oxide normally added to lower work function in the typical prior art lamp, thus, effectively reducing the advantages thought to be obtained by adding such impurities as in a thoriated cathode. In fact, it is believed that as the cesium combines with the oxides, the work function of the cathode is raised to a point which is higher than a totally untreated cathode base material.

The present invention allows operation at a substantially lower temperature as in prior art devices and yet achieves a high radiated output.

In a plasma arc, the high cathode temperatures found in prior art devices are obtained by the formation of a high voltage sheath at the metal surface of the cathode which accelerates ions generated in the plasma on to the metal surface creating the required temperature. Usually this sheath takes the form of a glowing ball at the tip of the cathode. The glowing ball often wanders about the cathode surface creating an unstable situation particularly where the lamp is used for imaging purposes such as in photographic or calibration applications. The lamp of the present invention since it operates at substantially lower temperatures, because of the pure refractory metal in the cathode, than prior art devices does not have this problem and, therefore, can be used for accurate imaging and calibration purposes.

There has thus been described a new and improved vaporizable material discharge-arc device. It is to be expressly understood that various modifications can be made without departing from the spirit of the invention.

I claim:

1. A discharge-arc device comprising:

a sealed housing having first and second portions, said portions being in communication;

a cathode and an anode disposed within said first portion of said housing and spaced apart to form an arc gap,

said cathode and said anode being adapted for connection to a power source for providing a potential drop across said arc gap;

said second portion having heat choke means as an integral part thereof for maintaining the temperature of the end of said second portion remote from said first portion lower during operation than the temperature of said first portion of said arc device; and

a predetermined quantity of vaporizable material within said arc device, whereby when said arc device is energized the arc is created at a particular vapor pressure with excess material being condensed in said second portion of said housing, said pressure being adjustable by controlling the temperature of said second portion of said housing.

2. The discharge-arc device of claim **1** wherein said cathode is constructed of substantially pure refractory material.

3. A discharge-arc device as claimed in claim **2**, wherein said refractory material is selected from the group of molybdenum, tungsten, tantalum, rhenium, zirconium and niobium and mixtures thereof.

4. A discharge-arc device as claimed in claim **3**, wherein said vaporizable material is an alkali metal.

5. A discharge-arc device as claimed in claim **4**, wherein said alkali metal is cesium.

6. A discharge-arc device as claimed in claim **1**, wherein said first portion of said housing is tubular and said electrodes are disposed coaxially within said first portion.

7. The discharge-arc device of claim **1** wherein said second portion comprises a metallic member having an axial bore therein for connecting said first portion of said housing about said cathode and said anode with a zone in said second portion which is temperature adjustable, said heat choke means comprising a necked down portion of said metallic member disposed between said first portion of said housing and said temperature adjustable zone.

8. The discharge-arc device of claim **7** further including means disposed about said zone in said second portion of said housing for adjustably controlling the temperature thereof .

9. A discharge-arc device comprising;

a sealed housing having first and second portions, said portions being in communication;

a cathode and an anode disposed within said first portion of said housing spaced apart to form an arc gap, said cathode and said anode being adapted for connection to a power source for providing a potential drop across said arc gap;

said second portion having means as an integral part thereof for maintaining a temperature gradient between said first portion of said housing and the end of said second portion remote from said first portion whereby the temperature of said remote end of second portion is independent of the temperature of said first portion; and,

a predetermined quantity of vaporizable material within said arc device, whereby when said arc device is energized an arc is created at a particular vapor pressure with excess material being condensed in said second portion of said housing adjacent said remote end, said pressure being adjustable by controlling the temperature of said second portion of said housing.

10. The discharge-arc device of claim **9** wherein said second portion comprises an elongated member having an axial bore therein for connecting said first portion of said housing with a zone in said second portion which is temperature adjustable, temperature gradient maintaining means comprising a necked down portion of said elongated member disposed between said first portion of said housing and said temperature adjustable zone.

11. The discharge-arc device of claim **10** wherein said elongated member is metallic.

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313—34, 218, 227; 315—108