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Collins et al.

[11] **3,906,272**

[45] **Sept. 16, 1975**

[54] **LOW WATTAGE HIGH PRESSURE SODIUM VAPOR LAMPS**

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[73] Assignee: **General Electric Company**, Schenectady, N.Y.

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[21] Appl. No.: **456,622**

[52] **U.S. Cl.** **313/214**; 313/220
[51] **Int. Cl.**[2] **H01J 17/04**
[58] **Field of Search** 313/214, 220, 184

[56] **References Cited**

UNITED STATES PATENTS

3,054,922	9/1962	Louden et al.	313/184
3,219,869	11/1965	Schmidt	313/184
3,243,635	3/1966	Louden et al.	313/220 X
3,248,590	4/1966	Schmidt	313/184

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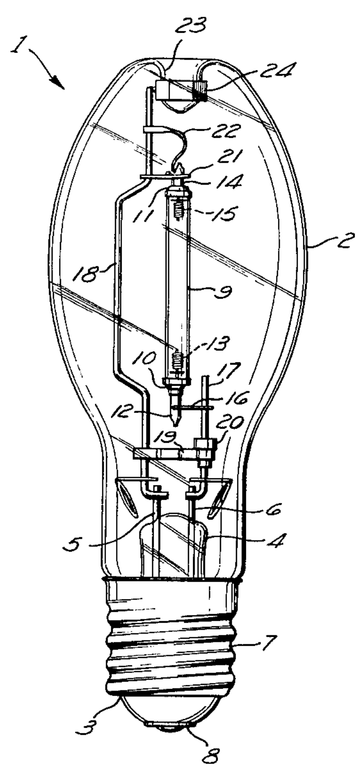
Attorney, Agent, or Firm—Ernest W. Legree; Lawrence R. Kempton; Frank L. Neuhauser

[57] **ABSTRACT**

A high pressure sodium vapor lamp arc tube comprising a tubular envelope of alumina ceramic having end closures supporting thermionic electrodes and containing a filling of sodium-mercury amalgam in excess of the quantity vaporized. In the smaller sizes of lamps from about 300 watts down to 50 watts, the arc tube bore has an important effect on efficacy, and a correlation exists between lamp voltage drop and optimum bore for a given power input. A bore of 5.5 millimeters is near optimum for a 150 watt lamp operating at a lamp voltage drop of 58 volts, and is also suitable for a 250 watt lamp operating at a lamp voltage drop of 98 volts.

10 Claims, 3 Drawing Figures



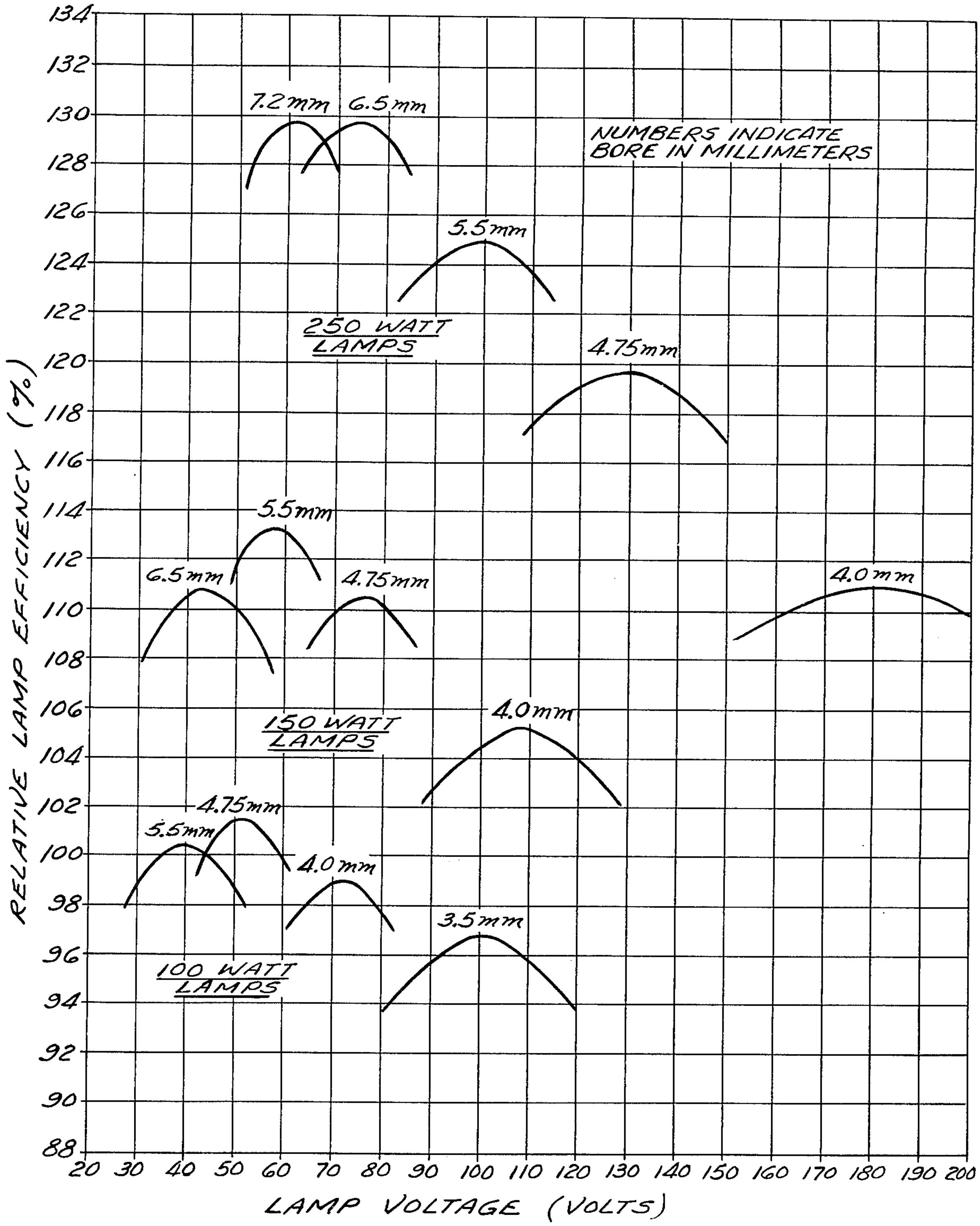

NUMBERS INDICATE BORE IN MILLIMETERS
7.2mm
6.5mm
5.5mm
250 WATT LAMPS
4.75mm
5.5mm
6.5mm
4.75mm
4.0mm
150 WATT LAMPS
4.0mm
4.75mm
5.5mm
4.0mm
3.5mm
100 WATT LAMPS
RELATIVE LAMP EFFICIENCY (%)
LAMP VOLTAGE (VOLTS)
134
132
130
128
126
124
122
120
118
116
114
112
110
108
106
104
102
100
98
96
94
92
90
88
20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200

Fig. 1

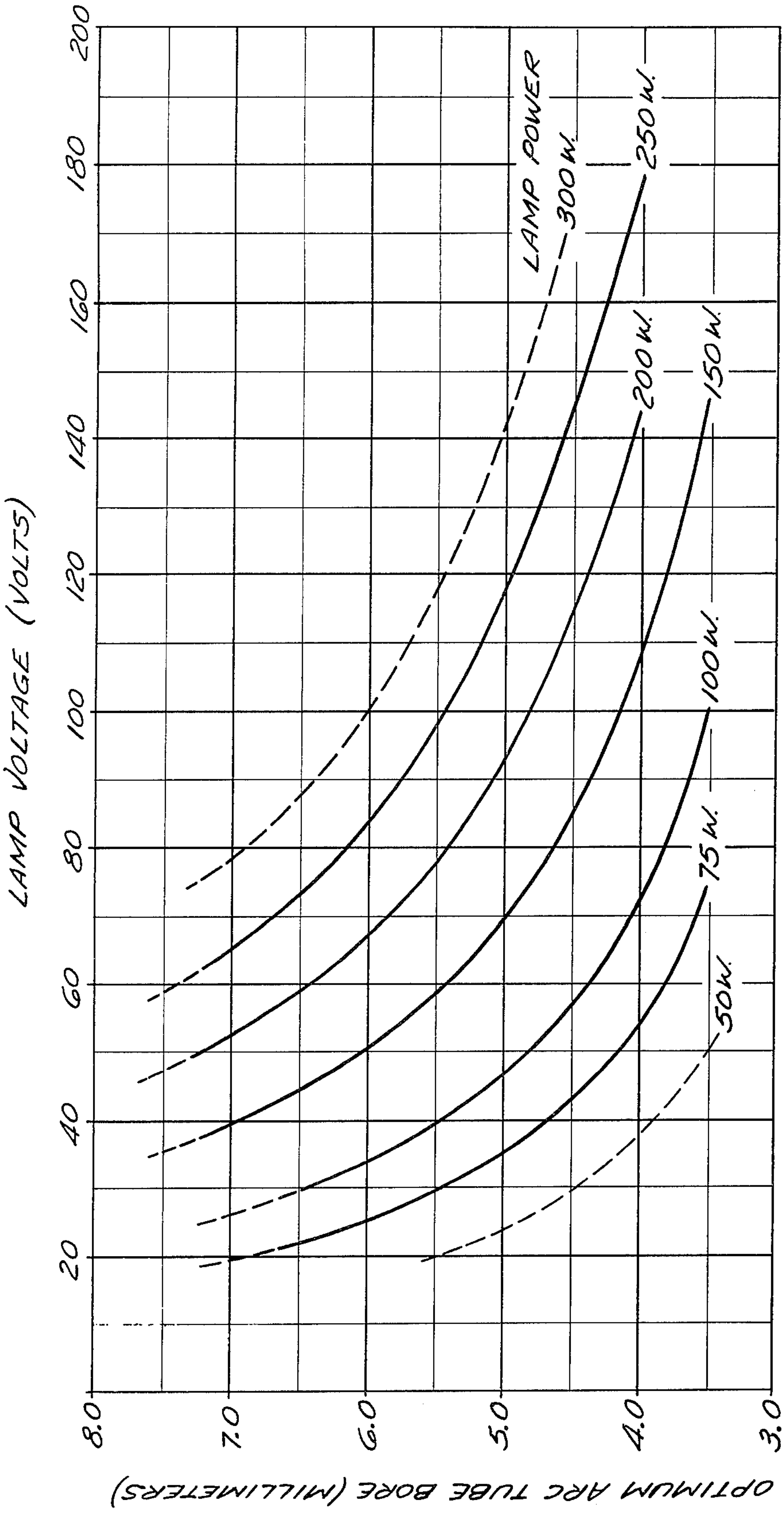

LAMP VOLTAGE (VOLTS)
OPTIMUM ARC TUBE BORE (MILLIMETERS)
LAMP POWER
300 W.
250 W.
200 W.
150 W.
100 W.
75 W.
50 W.
20
40
60
80
100
120
140
160
180
200
8.0
7.0
6.0
5.0
4.0
3.0

Fig. 2

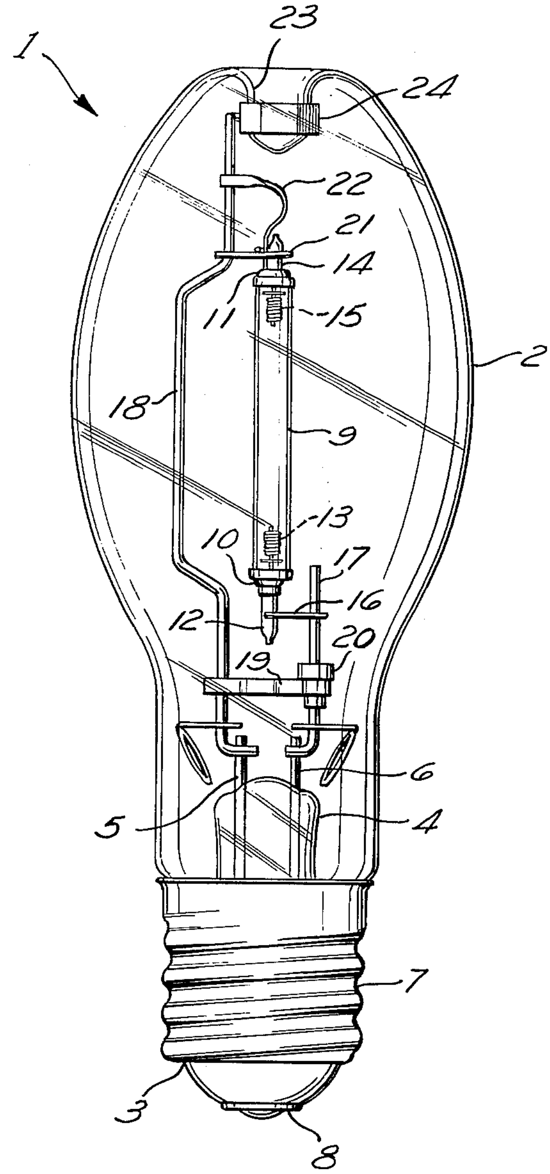


Fig. 3

LOW WATTAGE HIGH PRESSURE SODIUM VAPOR LAMPS

BACKGROUND OF THE INVENTION

The invention relates to high pressure sodium vapor lamps comprising a sealed ceramic envelope, suitably of alumina, in which an electric discharge takes place in sodium vapor, and is more particularly concerned with the optimum bore of the ceramic envelope in smaller sizes of lamps.

High intensity sodium vapor lamps of the present kind are described in U.S. Pat. No. 3,248,590 — Schmidt, entitled "High Pressure Sodium Vapor Lamp". These lamps utilize a slender, tubular envelope of light-transmissive refractory oxide material resistant to sodium at high temperatures, suitably high density polycrystalline alumina or synthetic sapphire. The filling comprises sodium along with rare gas such as xenon to facilitate starting, and mercury for improved efficiency. The ends of the alumina tube are sealed by suitable closure members affording connection to thermionic electrodes which may comprise a refractory metal structure activated by electron emissive material. The ceramic arc tube is generally supported within an outer vitreous envelope or jacket provided at one end with the usual screw base. The electrodes of the arc tube are connected to the terminals of the base, that is to shell and center contact, and the interenvelope space is usually evacuated in order to conserve heat.

The high pressure sodium vapor lamps which have been manufactured commercially up to the present time, have generally utilized a ceramic arc tube having an inside diameter or bore of 7.2 millimeters or larger. This bore was used for a 400 watt lamp operating at a current of about 4.7 amperes and a lamp voltage drop of about 100 volts. Larger sizes of lamps such as the 1000 watt lamp utilized a longer arc tube of the same bore. For smaller sizes of lamps, for instance a 250 watt lamp, the same bore was again used in a shorter arc operating at a voltage drop of 100 volts and at a current reduced to about 3 amperes. These smaller sizes of high pressure sodium vapor lamps were appreciably less efficient.

SUMMARY OF THE INVENTION

We have made a study of the parameters of lamp design for the smaller sizes of high pressure sodium vapor lamps ranging from 50 to 300 watts. The factors which were particularly analyzed were arc efficiency, arc gap, arc tube bore, voltage gradient, end losses and loading of the ceramic.

We have found that in the smaller sizes of lamps starting at about 300 watts and down to 50 watts, the arc tube bore has an important effect on efficacy and a correlation exists between lamp voltage drop and optimum bore for a given power input. In general a higher lamp voltage and a lower power input both call for decreases in bore. We have determined the optimum bores for all lamp sizes in the range from 50 to 300 watts having lamp voltage drops in the range from 20 to 180 volts. These results have been plotted as a series of curves at spaced wattage levels from which the optimum arc tube bore for a lamp required to operate at a given lamp voltage drop is readily determined.

One design of particular interest and a preferred embodiment of the invention is a 150 watt lamp which utilizes an alumina arc tube having a bore of 5.5 millimeters. This bore is about optimum in conjunction with a lamp voltage drop of 58 volts, a figure which permits economical operation of the lamp and effective regulation by means of a low cost series reactor on a nominal 120 volt a.c. line. The same bore of arc tube is also near optimum for a 250 watt lamp for operation at a lamp voltage drop of 98 volts, a figure suitable for operation and regulation of the lamp by means of a simple series reactor on a nominal 220 volt a.c. line.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a graph containing a series of curves showing the relationship of lamp efficiency to lamp voltage drop at various bores for several families of lamps at different input powers or wattages.

FIG. 2 is a graph showing the optimum bore for lamps in the wattage range from 50 to 300 watts at lamp voltages from 20 to 180 volts.

FIG. 3 is a side view of a high pressure sodium vapor discharge lamp embodying the invention in preferred form.

DETAILED DESCRIPTION

Our invention resulted from a study of the design parameters in high pressure sodium vapor lamps ranging from 50 to 300 watts. The factors particularly considered for their effect on lamp efficiency were lumen output, arc gap, arc tube bore, lamp voltage drop, end losses and loading of the ceramic. Lamps were made having bores ranging from 3.5 to 6.5 millimeters in addition to comparison lamps at the conventional bore of 7.2 millimeters. For the lamp envelopes or arc tubes, tubes or both polycrystalline as well as single crystal alumina or synthetic sapphire having wall thickness of 0.5 and 0.75 millimeters were used.

The various lamps of different bore were uniformly dosed with a charge of 20 torr xenon and 10 milligrams of amalgam consisting of 25 weight percent sodium and 75 weight percent mercury. The lamps were tested at a loading of 18 watts per centimeter square of envelope surface which is a safe upper limit assuring long life with the polycrystalline alumina ceramic commonly used for high pressure sodium vapor lamps.

The end loss in a lamp of given bore can be determined by making two lamps having the same bore but different arc gaps. Both lamps are operated at the same voltage gradient and current. The spectrum of the lamp is directly related to the voltage gradient and similarity of spectra can be used as a measure of equal voltage gradient. In a lamp of conventional construction, the lamp voltage drop and the voltage gradient cannot be adjusted independently of the current. However this difficulty was readily resolved by providing a resistance heater coiled around the lower metal exhaust tube of the lamp in which the excess amalgam condenses. The outer jacket of the lamp is provided with a three-lead stem whereby heating current to the heater can be supplied and regulated independently of lamp current. By varying the temperature of the exhaust tube reservoir, the metal vapor pressure and therefore the voltage gradient could be varied over a wide range. This made for more accurate results and greatly reduced the number of lamps needed to be built in order to conduct the study.

The lumen output of the lamps was measured as a function of the lamp voltage drop while maintaining the input power or wattage constant. The lamps were tested at loadings of 18 watts per square centimeter and also at loadings 15% above and below this value. In addition several conventionally constructed lamps without heaters were made at each design point and the lumen output plotted against lamp voltage as a check upon the accuracy of the heater lamp data.

The results are shown in FIG. **1** for three families of lamps having input wattages of 250 watts, 150 watts, and 100 watts. In the various families, each separate humped curve represents the relationship of relative lamp efficiency (as measured in lumens per watt) to lamp voltage for the lamp of the indicated bore as the voltage drop across it, that is the voltage gradient, is varied by control of the amalgam reservoir temperature through heater current regulation. It will be observed that for each bore and wattage there is a peak in efficacy at one lamp voltage drop. If lamps were constructed having bores intermediate between those whose results have been plotted, they would peak in efficacy at intermediate points between the peaks of the plotted curves. In addition there is a general arching of the series in each wattage family, with the efficiency falling off on each side of the maximum. In the 250 watt family, the available data shows the series extending primarily on the right side of the maximum. We believe that the arching phenomenon is explainable as follows. If there were no end losses, lamp efficiency would increase with bore. Thus there is a fall-off in efficiency on the right side of the maximum in each family due to the reduction in bore. The fall-off on the left side of the maximum results from the end losses which become proportionately greater as lamp voltage is reduced.

For a given size of lamp, the optimum bore will change with the lamp voltage drop to which the lamp is designed. However a lamp bore occurring near the peak in a family of curves, and which accepts a lamp voltage for which a ballast or current regulator can be conveniently and economically made to operate on a commonly available a.c. voltage, is particularly advantageous. In the 150 watt family, it will be observed that the 5.5 millimeter bore is a serendipitous one bacause it occurs near the top of the arch at a lamp voltage of 58 volts which is readily provided by a simple series reactor on a common 120 volt a.c. line.

In FIG. **2**, the results of lamp measurements such as are indicated in FIG. **1** are replotted to show the optimum bore as a function of lamp voltage drop for various input powers or wattages in the range from 50 to 300 watts. The dotted portions of the curves in the chart were obtained by extrapolation. The curves are based on use of an amalgam of 25 weight percent sodium and 75 weight percent mercury. However departures from the indicated bores of up to ± 20% may be made in order to accommodate the range from 10 to 40 weight percent sodium in the amalgam and surface loadings ranging from 14 to 24 watts per cm^2.

To illustrate the utilization of the chart of FIG. **2**, assume a 150 watt lamp is desired to be regulated by a simple series reactor on a 120 volt line. A rule of thumb for good regulation is to provide across the lamp a voltage drop not more than half the line voltage, say 55 to 60 volts in this instance. Referring to FIG. **2**, the 150 watt curve intersects the **58** volt line at a bore of 5.5 millimeters which is near optimum for those conditions. It will also be noted that the 250 watt curve intersects the 5.5 millimeter bore line at a voltage drop of 98 volts. This is a suitable voltage for good regulation of a lamp by means of a simple series reactor on a nominal 220 volt line. Thus a 5.5 millimeter bore arc tube is near-optimum for a 150 watt lamp intended for regulation by a simple series reactor on a 120 volt line, and is also suitable for a 250 watt lamp intended for regulation by a series reactor on a 220 volt line.

A high pressure sodium vapor lamp of 150 watt rating and embodying the invention in preferred form is illustrated in FIG. **3**. The lamp **1** comprises an outer envelope **2** of glass to the neck of which is attached a standard mogul screw base **3**. The outer envelope comprises a re-entrant stem press **4** through which extend, in conventional manner, a pair of relatively heavy lead-in conductors **5,6** whose outer ends are connected to the screw shell **7** and eyelet **8** of the base.

The arc tube **9** centrally located within the outer envelope comprises a length of polycrystalline alumina tubing which, for ease of illustration, is shown as being clear whereas in fact it is translucent The tube has its ends closed by end closures hermetically sealed to the alumina by means of a glassy sealing composition. Preferred end closures are metal caps **10,11** suitably of niobium which matches the expansion coefficient of alumina ceramic. The lower end cap **10** has a metal tube **12** sealed through it which serves as an exhaust and fill tubulation during manufacture of the lamp. The exhaust tube is sealed off at its outer end and serves as a reservoir in which excess sodium-mercury amalgam condenses during operation of the lamp. The lower electrode **13** within the lamp is attached to the inward projection of exhaust tube **12**. A dummy exhaust tube **14** extending through upper metal end cap **11** supports upper electrode **15**. The electrodes are double layer windings of tungsten wire on a tungsten shank and are activated with Ba_2CaWO_6 contained in the interstices between turns. The dummy exhaust tube does not open into the interior of the arc tube and for this reason need not be hermetically sealed off at its outer end. The filling in the lamp comprises xenon at a pressure of about 30 torr and a charge of 25 milligrams of amalgam of 25 weight percent sodium and 75 weight percent mercury.

A relatively short wire connector **16** is welded to exhaust tube **12** and to rigid support rod **17** which in turn is welded to inlead conductor **6**. Support rod **17** is braced to single side rod **18** and lead-in conductor **6** by means of a strap **19** attached to it and wrapping around an insulator **20** threaded over support rod **17**. Thus the lower end of the arc tube is quite rigidly fixed in place. Provision for thermal expansion of the upper end is made by extending dummy exhaust tube **14** through a ring support **21** attached to the upper end of side rod **18**. A flexible metal strap **22** is spot welded to the dummy exhaust tube and to the single side rod **18** to assure electrical connection to the upper electrode irrespective of contact between ring support **21** and dummy exhaust tube **14**. The upper end of side rod **18** is braced to inverted nipple **23** in the dome end of envelope **2** by a clip **24** which engages it. The illustrated lamp is intended for base down operation. In a similar lamp for base up operation, the arc tube and its immediate connectors are inverted relative to the outer envelope, short wire connector **16** then being attached to side rod **18** about in the position of ring support **21** in FIG. **3**, and the latter being attached to support **17**.

In accordance with our invention, the illustrated lamp utilizes an arc tube bore of 5.5 millimeters and an arc gap of approximately 3.7 centimeters measured between the tips of the electrodes **13,15.** The voltage gradient, that is the voltage drop per centimeter of arc gap, depends upon the temperature of the cold spot, that is the sealed off exhaust tube or appendix **12** where the excess amalgam collects. The appendix temperature depends upon the heat balance and can be raised by reducing the heat losses from the appendix as by shortening it, or lowered by increasing the thermal radiation as by roughening the appendix or painting it with a material of higher radiant emissivity. The temperature can also be regulated by varying the cross-section and length of the wire connector **16.** In the illustrated lamp, the heat losses result in an appendix or cold spot temperature of about 680°C., and a lamp voltage drop of about 58 volts. Under these conditions, the lamp operates at maximum efficiency with a light output of 16,000 lumens corresponding to an efficacy of 107 lumens per watt. This lamp has the unexpected advantage of peaking in efficiency at a voltage which is very conveniently supplied by a simple series reactor from a 120 volt a.c. line.

Another 150 watt lamp intended for operation from a 220 volt a.c. line has a bore of 4.2 millimeters and an arc gap of about 5.6 centimeters. The lamp is proportioned in respect of heat losses to operate at a voltage drop of about 100 volts as specified by the 150 watt curve in FIG. **2.**

A lamp of 100 watt rating for operation on a 120 volt a.c. line has a bore of 4.8 millimeters and an arc gap of approximately 2.9 centimeters. This lamp operates at a voltage drop of about 51 volts as specified by the 100 watt curve in FIG. **2.**

A lamp of 250 watt rating for operation on a 120 volt a.c. line has a bore of 7.5 millimeters and an arc gap of approximately 4.7 centimeters. This lamp operates at a voltage drop of about 58 volts as specified by the 250 watt curve in FIG. **2.**

A lamp of 250 watt rating for operation on a **220** volt a.c. line has a bore of 5.5 millimeters and an arc gap of approximately 7.0 centimeters. This lamp operates at a voltage drop of about 98 volts as specified by the 250 watt curve in FIG. **2,** and has an output of 30,000 lumens corresponding to an efficacy of 120 lumens per watt. It will be observed that this lamp utilizes the same bore as the lamp illustrated in FIG. **3,** but in a longer arc tube and is coupled with a greater lamp voltage drop.

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

1. A high pressure sodium vapor lamp for operation at a given power input in the range of 50 to 300 watts and at a given lamp voltage drop in the range of 20 to 180 volts comprising:

a tubular light-transmitting alumina ceramic envelope having thermionic electrodes sealed into its ends and containing inert starting gas and a charge of sodium-mercury-amalgam in excess of the quantity vaporized in normal operation;

the proportion of sodium in said charge being from 10 to 40% by weight;

said envelope being substantially uniform in bore in the space between the electrodes and being dimensioned in respect of bore and effective length for a loading in the range of 14 to 24 watts per square centimeter of envelope surface;

said envelope having a bore in the range of 3.0 to 7.5 millimeters, said bore being determined within ± 20% by the intersection of the given power input curve with the given lamp voltage line by utilizing the curves of FIG. **2** and interpolations therebetween;

said lamp being proportioned in respect of heat losses to the outside to have a temperature at the cold spot where the excess amalgam collects which results in a metal vapor pressure producing said given lamp voltage drop at which said bore is optimum for lamp efficacy.

2. A lamp as in claim **1** for operation at a power input of approximately 150 watts and a lamp voltage drop of approximately 58 volts wherein the envelope has a bore of approximately 5.5 millimeters and an arc gap between electrodes of approximately 3.7 centimeters.

3. A lamp as in claim **1** for operation of the power input of approximately 150 watts and a lamp voltage drop of approximately 100 volts wherein the envelope has a bore of approximately 4.2 millimeters and an arc gap of about 5.6 centimeters.

4. A lamp as in claim **1** for operation at a power input of approximately 100 watts and a lamp voltage drop of approximately 51 volts, wherein the envelope has a bore of approximately 4.8 millimeters and an arc gap between electrodes of approximately 2.9 centimeters.

5. A lamp as in claim **1** for operation at a power input of approximately 250 watts and a lamp voltage drop of approximately 58 volts, wherein the envelope has a bore of approximately 7.5 millimeters and an arc gap between electrodes of about 4.7 centimeters.

6. A lamp as in claim **1** for operation at a power input of approximately 250 watts and a lamp voltage drop of approximately 98 volts, wherein the envelope has a bore of approximately 5.5 millimeters and an arc gap of approximately 7 centimeters.

7. A lamp as in claim **1** wherein the amalgam contains about 25 weight percent sodium.

8. A lamp as in claim **2** wherein the amalgam contains about 25 weight percent sodium.

9. A lamp as in claim **3** wherein the amalgam contains about 25 weight percent sodium.

10. A lamp as in claim **6** wherein the amalgam contains about 25 weight percent sodium.

* * * * *