

July 18, 1944.

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2,353,783

MANUFACTURE AND PROCESSING OF DISCHARGE DEVICES

Filed June 8, 1943

2 Sheets-Sheet 1

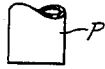


Fig. 1.

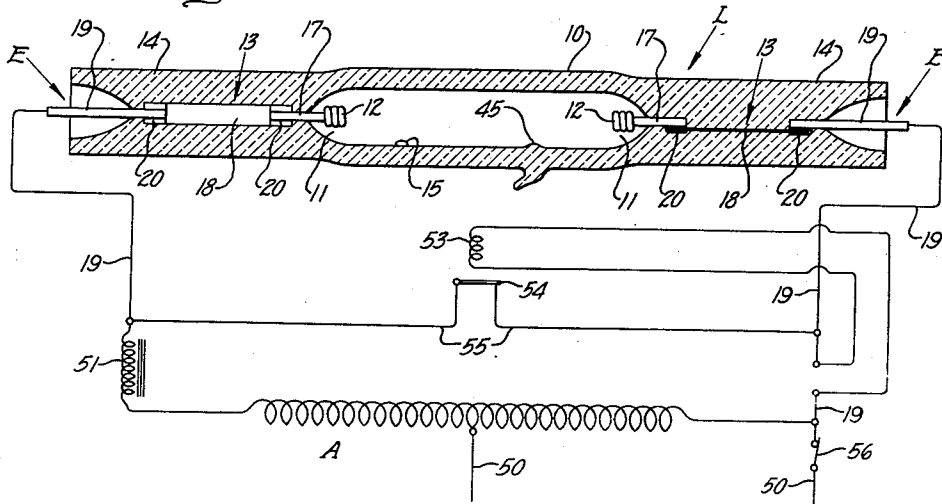


Fig. 2.

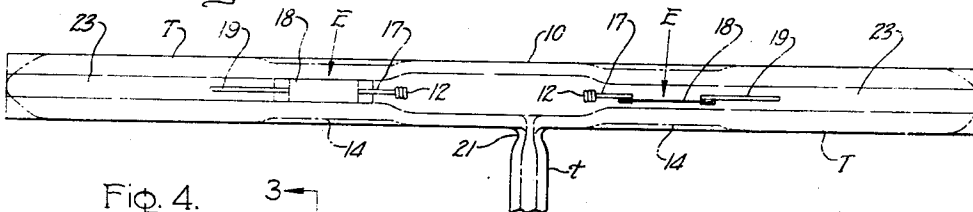
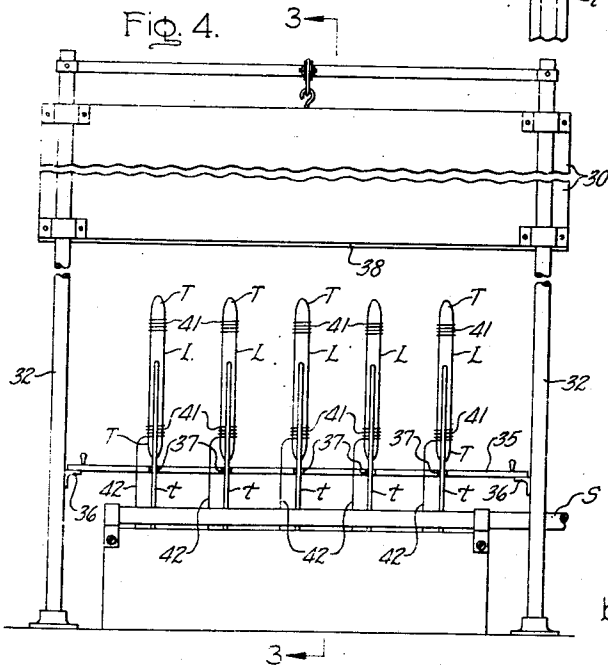


Fig. 4.



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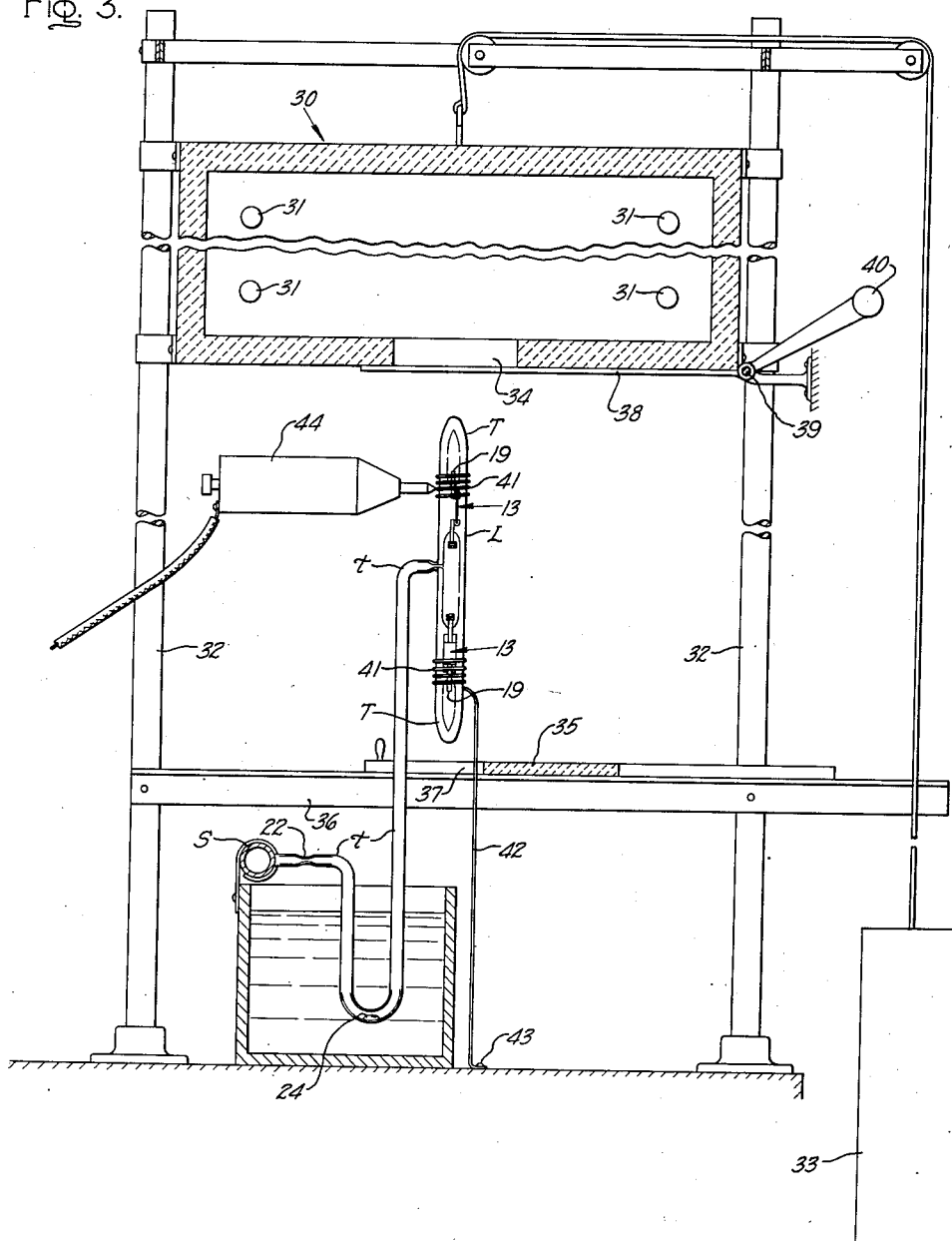
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2 Sheets-Sheet 2

Fig. 3.



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UNITED STATES PATENT OFFICE

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MANUFACTURE AND PROCESSING OF
DISCHARGE DEVICESEdward B. Noel, Cleveland Heights, Ohio, assign-
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2 Claims. (Cl. 316—18)

This invention relates to the manufacture and processing of vitreous or refractory-walled devices, such as electric discharge devices or lamps useful as sources of radiation for various purposes. The invention is especially useful in connection with devices that convert considerable energy to light or other desired radiation in very small space, and therefore usually operate with relatively high internal pressures and temperatures—such, for example, as the small tubular or "capillary" lamps marketed under the designations H-3, H-6, and AH-10, as well as certain high-pressure lamps having small spherical discharge envelopes, usually with tubular extensions or "end chambers" around their electrode leads. In some cases, the amount of energy unavoidably dissipated as heat in such devices is so great that forcible external cooling by water or air is necessary, to prevent fusion or devitrification of their envelopes. Fused quartz or quartz glass is about the most refractory light and radiation-transmitting material practically available, and is generally employed for the envelopes of lamps of this kind, though in some cases hard glass less refractory than quartz may be used, when the operating temperatures are not too high.

In the manufacture of lamps of this character, the usual envelope blank may be a vitreous tube, or a spherical vitreous bulb with opposed tubular extensions or ends. Sometimes a spherical bulb having a single tubular end or neck may be used, both inlets to the electrodes being introduced through this neck. In any case, the electrodes are mounted opposite or adjacent one another in the midst of the tube or bulb, which provides the discharge space of the completed lamp, and are attached to the inner ends of current leads which are sealed into the envelope end(s) or neck by fusing and collapsing the latter around the leads. Owing to the high softening points of vitreous materials that can stand high operating temperatures, a correspondingly high heat is necessary for this sealing-in operation, with consequent danger of oxidizing the current leads or the electrodes, which are usually of refractory but oxidizable metal like molybdenum or tungsten. During the process of manufacture, the discharge chamber for the electrodes, which is bounded by the end seal(s) around the leads, is evacuated and otherwise conditioned for operation of the device, this exhaust processing or conditioning including introduction of any desired working substance(s). For small discharge lamps of high-pressure type, the main working substance is usually mercury or other vaporizable and ion-

izable metal that provides a suitable discharge atmosphere during operation, together with a starting atmosphere of argon or other similar inert rare gas. After introduction of the working substance(s), the device is finally and permanently sealed off.

It is with the manufacture and exhaust processing of these devices as above outlined, but in a specially advantageous way, that my present invention is concerned. Various features and advantages of the invention will be better understood from the following description of species and forms of embodiment or modes of practice, and from the drawings. The invention is here illustrated and explained in connection with a small tubular lamp intended to operate at moderate internal pressure with low pressure air blast cooling—which is more fully described and claimed in application Serial No. 460,913 of Donald D. Hinman, filed October 5, 1942, and assigned to the assignee of this application—but it will be understood that the invention is also applicable to lamps and discharge devices of other types.

In the drawings, Fig. 1 is an enlarged longitudinal sectional view of a quartz tubular or "capillary" lamp made and processed according to my invention, with a wiring diagram of suitable electric circuit connections, also showing a cooling air jet nozzle pipe; Fig. 2 is a side view of an envelope blank suitable for the fabrication of the lamp, with the inlead and electrode assemblies in place but not yet sealed in, the scale being smaller than for Fig. 1; Fig. 3 is a vertical sectional view of apparatus for processing the lamp, with a portion of one part broken out, the section being taken as indicated by the line and arrows 3—3 in Fig. 4; and Fig. 4 is a side view of the apparatus at right angles to Fig. 3, on a larger scale, also showing one part with a portion thereof broken out.

As shown in Fig. 1, the discharge device is a lamp L comprising a vitreous elongated or tubular envelope 10 of fused quartz (which is permeable to ultraviolet and visible radiation) having a substantially cylindrical form, except at its "end chambers" 11, 11, as the end portions of the discharge space where its walls are not directly heated by the arc discharge are commonly called in this art—even when (as here shown) they are not structurally distinguished in any way from the space through which the arc actually extends. At the opposite envelope ends 11, 11 are shown solid operating electrodes 12, 12 attached to the inner ends of axial inleads 13, 13 which

are sealed through vitreous external cylindrical end seal extensions 14, 14, shown as of a size approximating the external envelope diameter. The electrodes 12, 12 may be of unactivated refractory metal such as tungsten. A charge of vaporizable and ionizable working substance, such as mercury, is indicated by a droplet 15 inside the envelope 10. The envelope 10 should also contain an atmosphere of starting gas such as one of the rare gases like argon, krypton, xenon, etc., at a moderately low pressure of some 20 to 100 mm., for example, argon at about 20 mm. pressure being at present preferred. The proportions and volume of the discharge space or cavity in the envelope 10 represent a constriction of the envelope such as to result in a discharge-constricting pressure therein during normal operation, and the amount of mercury 15 may be such as to give an unsaturated mercury atmosphere of some 5 to 10 atmospheres pressure at normal operating temperature. The cavity of the envelope 10 should be without sharp corners or any irregularities sufficient to form recesses where relatively ineffective heating from the arc stream might allow mercury to condense. Accordingly, the angular hollow corners that would exist at the ends of the envelope 10 if they were flat are filled out and rounded away. The electrodes 12, 12 are coaxial with the tube bore and approximately cover these rounded apices of the end surfaces, with their inner ends about in the planes where the rounded end chambers merge with the cylindrical tube bore. They are mounted close up against the envelope ends 11, 11, almost touching the end walls, and are of such compact, squat proportions that they project relatively little into the end chambers of the envelope. As shown, each of the electrodes 12, 12 is constructed out of a helical coil of a few turns of tungsten wire, comparable in gauge to the inlead wire and wound with its own convolutions in lateral contact, fitted around an inner inlead section 17 of tungsten wire and preferably welded thereto.

It is preferred to make the lamp envelope entirely of one refractory vitreous material, such as quartz, without the employment of special lower-melting material at the end seals 14, 14. While quartz end seals around circular tungsten inlead wires have not proved satisfactory—showing objectionable leakage—this can be overcome by using ribbon type end seals such as shown in Patent 2,094,694 to Bol. As shown in Fig. 1, each seal 14 may comprise a length of molybdenum ribbon 18 whose ends are laterally welded to inner and outer lead wire sections 17 and 19, the former of tungsten and carrying an electrode 12, the latter of tungsten or molybdenum. In Fig. 1, the ribbons 18, 18 of the two seals 14, 14 are shown as lying in planes at right angles to one another, though this is not at all essential. To obviate any difficulty in welding the wires 17, 19 to extremely thin ribbon 18 without either melting the latter or failing to produce joints of adequate conductivity, it is desirable to reinforce or thicken the ends of the ribbon 18, which may be done by solidly welding on refractory sheet metal facings 20, preferably at both sides of the ribbon 18. As shown in Fig. 1, a short length of molybdenum ribbon, preferably thicker than the ribbon 18, may be folded around each end of the latter to provide its two facings 20, 20. After these facings 20, 20 have been welded on more or less solidly—or at least at numerous points over

the width and area of contact—the resulting virtually integral thickened ends of the ribbon 18 can be laterally welded firmly and solidly to the lead wires 17, 19 without difficulty. The final result is a lead and electrode assembly E such as shown in Fig. 1.

Cooling air from any suitable supply may be blown against one side of the lamp envelope 10 at its mid-length through a nozzle pipe P located in close proximity to the envelope and supplied by a blower (not shown), or by any suitable means. For a lamp having a discharge cavity 22 mm. long and 3.5 mm. in diameter, having a discharge gap of 18 mm. between the proximate tips of the electrodes 12, 12, taking about 400 watts with a discharge current of about 3.6 amperes, and containing a charge 15 of 1.8 mg. of mercury to give an unsaturated mercury atmosphere of some 5 to 10 atmospheres pressure in operation, the nozzle pipe P may be of $\frac{3}{8}$ inch bore and located about 1 cm. from the axis of the envelope 10, with which the nozzle is axially aligned. An air flow of 2 cubic ft. per minute is satisfactory, and requires an air pressure of about $1\frac{1}{2}$ lbs. per square inch (above atmospheric) directly behind the nozzle opening.

In fabricating the lamp, a quartz envelope or bulb such as shown in Fig. 2 may be made, consisting of a main tubular portion corresponding essentially to the envelope 10 as shown in Fig. 1, with integral long, heavy-walled, ends T, T, just large enough to freely pass the lead and electrode assemblies, E, E, and with a lateral exhaust tube *t* opening into the envelope 10, but preferably narrowly constricted right adjacent the envelope as shown at 21. The electrode assemblies E, E are placed in the tube ends T, T, and the tube end extremities are sealed up by fusion as indicated in dot and dash lines in Fig. 2. During the sealing up of each tube end T, both the electrode assemblies E, E may be shifted into the other tube end T to prevent their being overheated and damaged; afterward they may be separated and shifted outward as far as possible into the opposite tube ends T, T. Thereupon the device L may be held horizontal and evacuated through the tube *t*, being preferably heated or baked in an oven (such as hereinafter described) to a temperature of some 1200° C. to degas the internal tube walls and the electrode assemblies E, E as much as possible. Matter expelled from the electrode assemblies E, E during this oven baking deposits on the internal walls of the tubular ends T, T, while the mid-portion 10 of the device (that afterward forms its discharge chamber) remains clean and unobscured. To facilitate subsequent steps (to be presently described), the exhaust tube *t* is now preferably sealed off at some distance from the envelope L—as suggested at 22 in Fig. 3—thus detaching the whole device L from the exhaust system S and leaving it free for convenient manipulation.

The oxidizing atmosphere being thus substantially removed and excluded from the interior of the envelope or device L, the electrode assemblies E, E are shifted inward toward one another to bring the electrodes 12, 12 to their proper positions in the opposite ends of the mid-region 10 of the envelope. The assemblies E, E being protected against oxidation by the vacuum in the envelope L, each tubular envelope end T is fused and collapsed at 14 upon its inlead 13 behind the corresponding electrode 12, as indicated in dot and dash lines in Fig. 2, thus not only em-

bedding and ensealing the inner leads 17, 17 and the ribbons 18, 18, but also forming or setting apart the discharge chamber 10 with its rounded ends 11, 11, containing the electrodes 12, 12, as well as separate outer protective end chambers 23, 23 enclosing the outer lead portions 19, 19 outside the fused seals 14, 14. Shifting and locating the assemblies E, E in this manner and making the fused seals 14, 14 is greatly facilitated by having the device L entirely detached from the exhaust system at this time, so that it can be freely manipulated by the glassworker.

It remains to complete the device L by conditioning it internally and charging the discharge chamber 10 to provide the desired discharge atmosphere therein for operation. For this purpose, the tube *t* may be reconnected or resealed to the quartz tube *s* of the system S as shown at 22 in Fig. 3—incidentally, of course, opening the tube *t* to the atmosphere and losing the vacuum in the device L—after introducing the desired amount of mercury into the U bend of the tube *t* as shown in Fig. 3. The device L is then again exhausted through the tube *t*, and a preliminary filling of starting gas at suitable pressure is preferably introduced, such as argon at 20 mm. After exhaust-processing the device L as now to be described in detail, including degasing its internal surfaces and parts, withdrawing the temporary gas filling, and refilling with pure starting gas such as argon at 20 mm. pressure, the device is again tipped off at 22, and the mercury at 24 is run into it by suitable manipulation. The device L is then finally tipped off from the tube *t* close to the discharge chamber 10 as hereinafter described.

As shown in Figs. 3 and 4, a number of identical devices L are connected by corresponding tubes *t* to a common system S, to be concurrently exhaust-processed as just outlined. During the re-evacuation, the whole batch of devices L are preferably enclosed and heated in a thermo-insulative oven 30 to a temperature of some 1200° C., in order to degas their internal walls. The oven 30 may be equipped with longitudinal electric heaters 31, and may be arranged to slide up and down along guideways afforded by frame uprights 32, and suitably counterweighted as indicated at 33. For entrance and exit of the devices L and the tubes *t* to and from the oven 30, the oven has an opening 34 in its bottom wall. When the oven is down around the devices L, it rests on a thermo-insulative floor 35 which closes the bottom opening 34. As shown, the floor 35 is arranged to slide backward out of the way (or vice versa) along horizontal ways 36 carried by the frame uprights 32, and has slots 37 to pass the tubes *t* during such movement. When the oven 30 is raised to its "idle" position shown in Figs. 3 and 4, its bottom opening 34 may be closed by a swinging bottom 38 fulcrumed at 39 behind the rear uprights 32, and counterweighted as at 40 to keep it closed except when pushed down and back behind the oven by the latter as it is lowered. Thus the oven 30 is always closed and at proper internal temperature for baking the devices L. While the devices L are in the oven 30, their outer leads 19, 19 are protected from oxidation by the sealed tube ends T, T, shown in Figs. 2, 3, and 4.

After exhausting the devices L while being baked in the oven 30, it is desirable to pass current between the electrodes 12, 12 of each device L to heat and degas them thoroughly by the "bombardment" of the electrical discharge, with-

drawing the gas thus liberated through the tubes *t* and the exhaust system S. To facilitate this, the oven 30 may be raised out of the way to its position shown in Figs. 3 and 4. Capacitative couplings 41, 41 may then be applied to each of the sealed tube ends T, T, such couplings being here shown in the form of helical wire coils that can easily be slipped on these tube ends around and adjacent their ensealed inleads 13, 13. One coupling 41 of each device L being suitably grounded, as by a wire 42 connected to the machine frame at 43, the sparking end of a high-frequency high-voltage Tesla coil device 44 (here illustrated in the compact form commercially known as a "Shelton coil") may be applied or brought close to the other coupling 41 of each device L. The A. C. discharge current thus passed between the electrodes 12, 12 should not be so high or so long continued as to produce blackening of the envelope ends 11, 11, and need not be sufficient to heat the electrodes visibly, but should be as high as can be used without causing blackening. Ordinarily some 10 to 15 seconds (more or less) of such sparking is sufficient, according to the size of the electrodes 12, 12.

After the operation just described, the temporary gas filling and the gases liberated by the electrical bombardment are evacuated through the tubes *t*, and the final gas fillings are introduced through these tubes *t*. This is followed by tipping off each device L at 22 again, introducing the mercury 24 for its charge 15 as above mentioned, and finally sealing or tipping it off very close to envelope wall 10, all according to usual capillary lamp practice. Finally, the exhaust seal tip is heated and fused just enough to allow it to be forced in by the pressure of the surrounding atmosphere, thus filling the usual exhaust tip recess and producing a somewhat irregular conformation, that is suggested at 45 in Fig. 1. When the tube ends T, T are cut off beyond the fused zones to afford access to the outer lead portions 19, 19, device L is left with the end seals 14, 14 as shown in Fig. 1.

A suitable operating and starting circuit for the lamp L is illustrated in Fig. 1 as comprising a step-up autotransformer A whose secondary is connected across the leads 19, 19, while its primary is connected across a supply line 50. One of the leads 19 includes a choke coil or ballast 51, while the other includes the switch-opening electromagnetic coil 53 of a normally closed and self-closing relay vacuum switch 54 in a shunt circuit 55 connected across the leads 19, 19. A control switch 56 is shown connected in one side of the supply line 50. When the control switch 56 is closed to energize the lamp supply circuit 19, 19, the relay switch 54 opens suddenly, producing a high-voltage surge across the discharge gap between the lamp electrodes 12, 12 that initiates discharge between them.

In operation, the arc discharge takes place between the proximate inner ends of the electrodes 12, 12, and the main body of the envelope 10 around the electrode gap is heated directly by radiation and conduction from the arc stream, as well as by convection currents in the gas and vapor atmosphere of the lamp. The arc also heats directly the active inner ends of the electrodes from which it takes off, and this heat is partly transmitted back through the electrodes 12, 12 and their leads 13, 13 to the walls of the end chambers 11, 11. Heat is also transmitted from the electrodes 12, 12 to the end chamber walls by radiation and by gaseous or vaporous

conduction and convection. Thus the discharge maintains the electrodes 11, 11 at a temperature of ample electron emission which obviates serious sputtering of the electrodes, and hot enough throughout to keep the end chambers 11, 11 from anywhere falling below a temperature corresponding to the desired mercury pressure. At the same time, the very large radiation of energy from the very hot electrodes 12, 12 (which increases according to the fourth power of their temperature, measured on the Kelvin scale) prevents them from attaining a temperature at which the metal would vaporize freely and seriously blacken the envelope 10 in a short time—even under a rise of lamp voltage above rated normal amounting to as much as 10 to 20 per cent. The most favorable operating temperature for tungsten electrodes 12, 12 is around 3000° K., with a leeway of several hundred degrees above or below this figure. This high temperature of the unactivated electrodes 12, 12—considerably higher than would be practicable with activated electrodes, because of the vaporization of the usual activating oxides at such high temperature—greatly increases the heating of the end chambers 11, 11 from the electrodes. In combination with the low thermal conduction of the silica of the end seals 14, 14, the low thermal conduction of the thin ribbon lead sections 13, 13 limits the loss of heat along the leads 13, 13, and thus contributes to the adequate heating of the end chambers 11, 11 and to maintaining the electrodes 12, 12 at a temperature of adequate thermionic emission. The rough or interstitial surfaces of each electrode 12 (due to the V-grooves between its coil convolutions) greatly facilitate the starting of the arc discharge, making it possible to start at a much lower effective voltage across the arc gap. The squat configuration of the electrode 12 and its small mass and thermal

capacity enable it to be heated up very quickly when the discharge is started, so as to become adequately emissive from its arcing area before appreciable sputtering can occur.

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

10 1. The method of manufacturing electric discharge devices which comprises hermetically sealing portions of lead-in conductors carrying electrodes at their inner ends into an envelope of vitreous material with the electrodes extending into the interior of the envelope, and also hermetically enclosing the outer ends of said conductors in vitreous material, evacuating the envelope and heating it to a temperature sufficient to oxidize the said outer ends of the conductors in the absence of the enclosing vitreous material, permitting the device to cool, and then removing the vitreous material enclosing the said ends of said conductors.

20 2. The method of manufacturing electric discharge devices which comprises hermetically sealing portions of lead-in conductors carrying electrodes at their inner ends into an envelope of vitreous material with the electrodes extending into the interior of the envelope, and also hermetically enclosing the outer ends of said conductors in vitreous material, evacuating the envelope and heating it to a temperature sufficient to oxidize the said outer ends of the conductors in the absence of the enclosing vitreous material, applying capacitative couplings to said envelope adjacent the lead-in conductors and connecting said couplings to a source of alternating potential to induce current flow between said electrodes and thereby electrically bombard and heat the electrodes, permitting the device to cool, and then removing the vitreous material enclosing the said ends of said conductors.

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