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MAY 18, 1943	HIGH PRESSURE MERCURY VAPOR LAMP	278,742
BY. A. P. C.	Filed June 12, 1939	2 Sheets-Sheet 1

Fig. 1

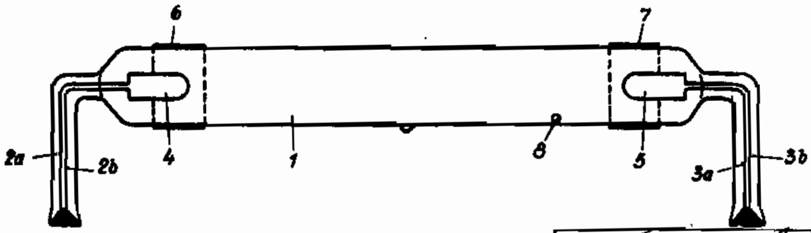

Fig 2

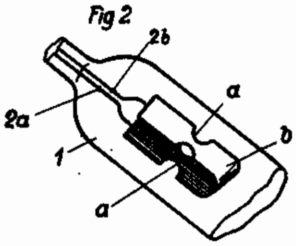

Fig. 3

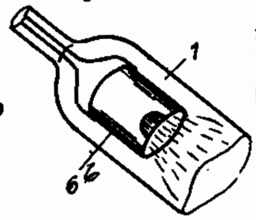

Fig. 4 Cancelled per March 10 1947.

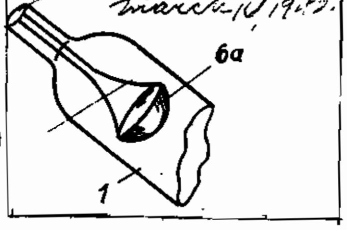

Fig. 5

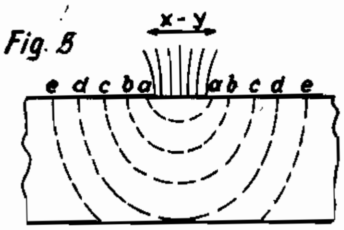

Fig. 6

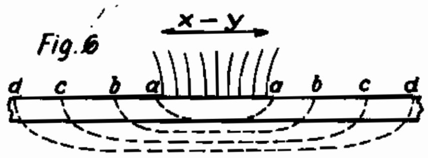

Fig 7

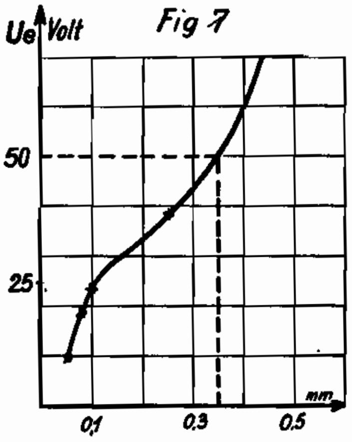

Fig 8

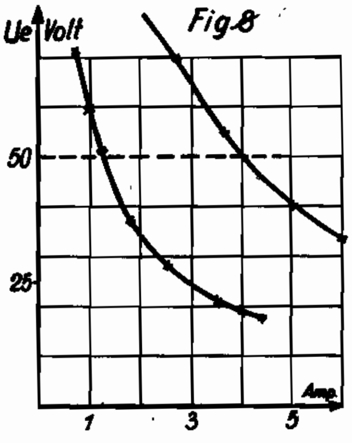

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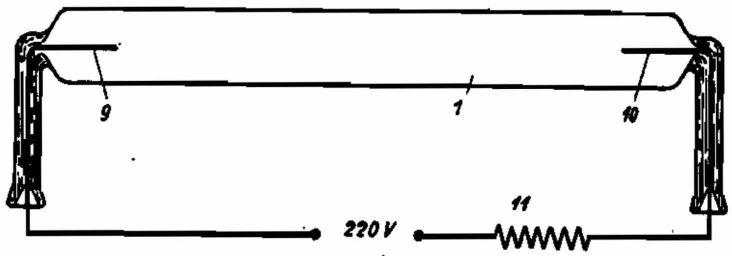
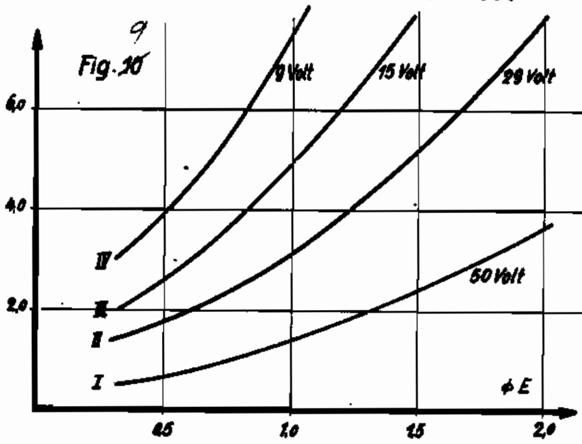
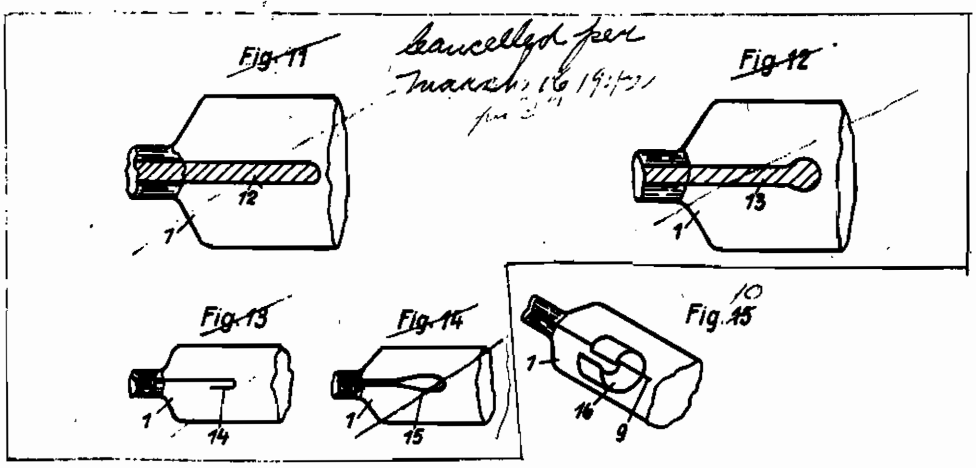
Fig. 9







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ALIEN PROPERTY CUSTODIAN

HIGH PRESSURE MERCURY VAPOR LAMPS

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Application filed June 12, 1939

This invention relates to high pressure mercury vapor lamps, such for example as are used for illumination and/or irradiation.

Such lamps are habitually provided with self-heating incandescent cathodes and a basic filling of a suitable gas, such as neon, argon, etc. As a general rule the incandescent cathodes used will be Wehnelt or similarly operating incandescent cathodes in which the electron emission is intensified by the use of alkali or alkaline earth metals.

However the use of such incandescent cathodes in which the electron emission is intensified requires the adoption of careful methods of gas evacuation in the manufacture of the lamps and the process of preparing the cathodes to intensify their electron emission is quite tedious. These lamps must also be carefully protected from too heavy current loads, as electrical overloads of even short duration may destroy the high emission layer of the cathodes. These injurious features would obviously be eliminated if high pressure mercury vapor lamps could be provided with self-heating incandescent cathodes of a refractory metal such as tungsten, tantalum or the like for example, without intensified electron emission. All attempts heretofore made to provide such a lamp have however failed owing to the impossibility of keeping the volatilization or evaporation of the electrode down to a point that would ensure a sufficiently long life to make the lamp commercial.

One of the objects of the present invention is to eliminate this objectionable feature characteristic of self-heating cathodes without intensified electron emission, used in high pressure mercury vapor lamps, by a special forming of the cathode body and a relative adjustment or adaptation of said body and the current load, thus providing a new basis for the simple and commercial construction of high pressure mercury vapor lamps.

The present invention is based upon the discovery that in high pressure mercury vapor lamps using self-heating incandescent cathodes without intensified electron emission, volatilization or evaporation of the electrodes can be reduced practically to zero, providing care be taken that the area of the surface from which the electron emission that feeds the arc emanates be of suitable or sufficient size. Where the surface area from which the arc emanates in the case of a tantalum cathode is practically no larger than a dot, so that practically the entire electron emission is delivered from a surface area of about 0.01 cm^2, an arc of a current strength of 4A could obviously only be maintained by a purely thermal electron emission on condition that said surface area be heated to a temperature of 2750° C. or thereabout (emission 400 A/cm^2). At that temperature, however, tantalum, of which the melting point is 2900° C., evaporates or volatilizes appreciably. On the other hand if it were possible to increase said surface area from which the electrons are emitted to 0.5 cm^2, then said surface area from the time it reaches a temperature of 2350° C. would emit a purely thermic electron emission of 4A (emission 8 A/cm^2), which would enable the arc to be maintained at a much lower temperature of the cathode and with a negligibly slight volatilization of the latter.

By careful investigation and experimentation we have discovered that to secure an arc emitting surface area of sufficient size in accordance with the above example, it will not suffice simply to give the cathode a large surface, for in the case of a cathode having a large surface the area of that part of its surface from which the arc emanates will be practically restricted to a dot. It is also a striking fact that the area of that part of the surface from which the arc emanates will not be increased by the simple expedient of rounding off the heretofore used sharpened pencil-shaped electrodes or by providing them with means to secure a better heat repartition, in the hope that the heat generated will thus be distributed over a greater area of the cathode surface. On the other hand, by investigation and experiments we have discovered that the desired increase in the area of that part of the cathode surface from which the arc emanates can be secured simply by making the cathode of a sheet metal having a high melting point, such as tantalum for example, and reducing the heat losses of said thin cathode as much as possible. Such reduction of heat losses may be effected by any suitable means, a very simple means consisting of an envelope surrounding the cathode and acting as a reflector to reduce the heat losses due to radiation.

In the illustrative embodiment of the invention shown in Figs. 1 to 4 the cathode is made of thin sheet metal having a high melting point and may be given different shapes as hereinafter described.

Our investigations and experiments have also led us to the discovery that the results sought to be attained can be secured with pencil-shaped electrodes of metals having a high melting point, such as tungsten, tantalum, etc., by making the load sufficiently high relatively to the heat capacity and the radiating surface of the cathode. Thus the striking fact is established that lamps using pencil-shaped cathodes of a definite thickness, without intensified electron emission, volatilize strongly if the load be too low as well as if the load be very high, but that between these two limits there exists a mean load zone, within which the volatilization is kept within negligible limits.

The cause of this phenomenon seems to reside in the size of the area of the cathode surface from which the arc emanates and the temperature of said area. In the case of low strength currents the entire body of the incandescent cathode is subject to a relatively low degree of heat, so that only a very small arc emission area is developed. This very small area however reaches a very high temperature. Thus the point or apex of the conical end of a pencil-shaped tungsten cathode of 3 mm thickness can have a 1 mm^2 area of its surface heated by an arc of a 2A current to a temperature of over 3300° C. (emission 200 A/cm^2) without the remainder of said electrode ever reaching the incandescent temperature required for electron emission. From said apex, however, there may be emitted a jet of volatilized tungsten which very soon blackens the walls of the lamp. If the strength of the current of the arc be increased to 10 A the temperature of said cathode throughout 10 mm or thereabouts of its length will rise to 2700° C. (emission 14 A/cm^2). Instead of a point or dot like area heated to 3200° C. we therefore now have an area of about 1 cm^2 heated to 2700° C., so that the volatilization of the electrode becomes negligible. If the lamp in this condition be brought within the high pressure zone of the mercury vapor discharge, the volatilization of the electrode drops practically to zero. If the strength of the current be raised appreciably above that given, volatilization again sets in on account of the overload.

There is therefore a well defined propitious zone for the regulation of the conditions of operating relatively to the dimensions of the electrode used.

By thorough tests we have found that there exists a very simple rule for keeping within this propitious zone, namely, said propitious zone is reached when the drop in voltage at the heated electrodes is less than 50 volts. As drop in voltage at the electrode should be taken that value or quantity which is obtained by deducting from the voltage at the terminals, the drop in voltage which is attributable to the arc and which is easily determined by comparison of lamps of different lengths. As a result of the favorable distribution of the space charge, the thus determined voltage drop at the electrodes will be all the smaller the greater the electron emitting area of the cathode surface is per current strength unit.

Another object of the invention therefore is to provide a high pressure mercury vapor lamp, in which the thickness of the incandescent electrodes without intensified electron emission, and the load of the lamp, are relatively adjusted or adjustable to reduce the voltage drop at the electrodes to less than 50 volts.

The invention and the objects thereof above set forth, as well as such other objects as shall hereinafter appear, will be readily understood from the following description, taken in connection with the accompanying drawing of embodiments of the invention herein given for illustrative purposes, the true scope of the invention being more particularly pointed out in the appended claims.

In the drawing:

Fig. 1 shows diagrammatically a longitudinal section of a tube embodying an illustrative embodiment of the invention comprising sheet-metal electrodes;

Figs. 2, 3 and 4 each show one end portion of a tube similar to that of Fig. 1, having sheet-metal electrodes of different shapes;

Figs. 5 and 6 are diagrams illustrating the advantage of using thin sheet-metal electrodes;

Fig. 7 is a graph showing how, for a given strength of current, the drop in voltage is dependent upon the thickness of the electrodes;

Fig. 8 is a graph showing how, for a given thickness of electrode, the drop in voltage is dependent upon the strength of current;

Fig. 9 shows diagrammatically a longitudinal section of a tube embodying an illustrative embodiment of the invention comprising pencil or wire shaped electrodes;

Fig. 10 is a graph which shows the limits of the propitious zone to be selected in accordance with the present invention, for electrodes of given thicknesses;

Figs. 11 and 12 show one end of a tube similar to that of Fig. 9, comprising thicker pencil-shaped electrodes with rounded off free ends;

Fig. 13 shows one end of a tube similar to that of Fig. 9, in which the thin pencil or wire electrodes terminate in a hook like formation;

Fig. 14 shows one end of a tube similar to that of Fig. 9, in which the free end of the thin wire electrodes is loop shaped;

Fig. 15 shows one end of a tube similar to that of Fig. 9, in which the thin wire electrodes are provided, somewhat back from their free ends, with a lateral, thin sheet-metal extension.

Referring to the illustrative embodiment of the invention, Fig. 1, a tube of suitable material, herein quartz, is shown at 1. In each of the ends of said tube, two supply wires **2a**, **2b** and **3a**, **3b**, respectively, are sealed in the molten glass. These wires carry the actual electrodes, which in this illustrative embodiment of the invention consist of thin U-shaped sheet-metal bands **4** and **5** of a thickness of approximately 0.08 mm. To reduce heat radiation from the area of the electrode surface to which the arc is attached, those portions of said tube 1 surrounding said surface areas may be provided with suitable reflecting means, herein conveniently consisting of silver plated sheet-copper sleeves or bands **6** and **7**.

Said tube 1 will be provided with a filling of suitable gas and contains a small amount of mercury, a few milligrams, the quantity of mercury being such that it will be completely vaporized when the tube is in high pressure operation. Herein argon gas is used as a filling with a pressure of about 20 to 30 mm. The mercury is indicated by the small globule **8** in Fig. 1. For operation with an alternating current of 220 volts the lamp will preferably be connected in series with suitable means for controlling or regulating the strength of the current, such as a 0.1 to 0.2 Henry choking coil, (not shown).

Instead of the U-shaped electrodes of Fig. 1, cylindrical electrodes **6**, as shown in Fig. 3, or cup-shaped electrodes **6a**, as shown in Fig. 4, of thin sheet metal, may be used. The electrodes may be recessed as shown at *a* in Fig. 2, for example, to diminish the carrying off of heat from the emitting head. What is of capital importance in each case, however, is not only that the electrodes be made of material having a high melting point, but also that they be quite thin, of very thin sheet-metal, for example, as above.

A reference to Figs. 5 and 6 will clearly demonstrate the importance of making the electrodes of quite thin material. If as shown in Fig. 5 a quite thick metal sheet be used, isothermal lines such as *a* to *d* will be formed about the highly heated arc emission zone. But if a quite thin electrode, one made of very thin sheet metal, for example be used, the isothermal picture will be somewhat as shown in Fig. 6, from which it will be clearly seen that in this case there will be a far less abrupt drop in temperature as between the highly heated arc emission zone x—y and the cooler side zones heated mainly by the fall at anode when operating with an alternating current. In this case, therefore, the temperature necessary for thermal electron emission will be produced over a relatively greater area.

The actual size of that part of the surface of the cathode, from which the electron emission takes place can naturally not be accurately determined by observation. During the operation one distinguishes only that a definite area of the cathode surface, somewhat like that hatched in Fig. 3 becomes heated to a particularly high temperature. A means for determining the size of the surface area which actually takes part in the emission of electrons is furnished, however, by the drop in voltage which in operation occurs in the immediate vicinity of the electrodes and very materially affects the total drop in voltage of the lamp. For this drop in voltage furnishes, among other things, a means for measuring the contraction to which the path of the discharge is subjected in the immediate vicinity of the spark emission area on the cathode. If this area is very small the arc must be greatly contracted in close proximity to the cathode, and a relatively high drop in voltage occurs. On the other hand, if said area is large, only a slight contraction of the arc will occur in close proximity to the cathode, and the drop in voltage will be correspondingly less. This phenomenon is best observed when the lamp, at the beginning of its operation, for example, is still in the low pressure operating stage, that is to say before any contraction of the arc due to any other cause exists.

The total drop in voltage in the case of an arc discharge is obviously composed of the voltage drop at the cathode, the voltage drop at the anode and the voltage drop in the ionized gas column. The voltage drop at the cathode and that at the anode cannot be accurately determined separately in the case of an alternating current lamp, as they are both dependent on the distribution of the temperature over the electrodes and are therefore bound together functionally. Hereinafter they will be referred to by the single term "voltage drop at the electrodes" which includes both and is designated by "Ue". The voltage drop in the ionized gas column, designated by "Us", can, on the other hand, be determined by comparing the total voltage drop, designated by "Ug", which occurs in lamps of different lengths of arc, all other conditions being equal.

Experiments have demonstrated that volatilization or evaporation of the cathode can always be kept at a sufficiently low level for the production of lamps having a sufficiently long life to render them commercial, providing the electrodes be so thin relatively to the operating load of the lamp, that the voltage drop at the electrodes, Ue, falls below 50 volts. This operating condition can be attained either by using an electrode of predetermined thickness and varying the current load, or inversely by using a predetermined current load and choosing a suitable electrode thickness.

In the following table are given the values determined with lamps having sheet- tantalum electrodes and an argon filling of 25 mm pressure, which, with an arc 100 mm in length, and operating at low pressure (0.01 to 10 mm mercury vapor pressure) registered a mean voltage drop, Us, of 21=2.1 volts/cm in the ionized gas column:

Thickness of electrode	A	Ug	Us	Ue
		Ca.		
0.5 mm				90
0.25 mm	4	60	21	39
0.10 mm	4	75	21	24
0.08 mm	4	40	21	19
0.05 mm	4	30	21	9

These values are graphically shown in Fig. 7.

The lamp provided with an electrode of sheet tantalum of 0.5 mm in thickness could not be made to burn quietly with a current of less than 5 A. With that load there was still a very marked volatilization of its electrodes. On the other hand, when this lamp was operated with a current load of 10 A, the value of Ue dropped to 25 to 30 volts, and notwithstanding the increased load, the lamp could be operated with greatly diminished volatilization, that is to say under more favorable conditions for long life.

On the other hand, experiments with two lamps using sheet- tantalum electrodes, disclosed the following data showing the dependence of the drop in voltage on the strength of current in the arc:

Thickness of electrode	A	Ug	Us	Ue
			Ca.	
0.25 mm	1.6	105	21	84
	2.75	91	21	70
	3.6	76	21	55
	5.0	61	21	40
	6.0	55	21	34
	8.5	45	21	24
0.08 mm	0.75	93	21	72
	1.0	81	21	60
	1.25	73	21	52
	1.8	58	21	37
	2.5	48	21	27
	3.5	42	21	21
	4.0	40	21	19
	4.25	39	21	18

These values are graphically illustrated in Fig. 8. In all cases it was only when the value of the voltage drop at the electrodes, (Ue), had been reduced to less than 50 volts, by suitably adjusting or adapting the load to the thickness of the sheet-metal electrode used in each case, that the lamp gave proof that it possessed a satisfactory length of life. Thus, as an example, a lamp 100 mm in length with an argon filling (25 mm) and electrodes of the shape shown in Fig. 3, made of commercial sheet tantaum of 0.08 mm thickness could be operated for more than 1000 hours on a 220 volt alternating current network through a choking means of 0.134 Henry, and a mean current strength of 4 A, without objectionable blackening of the tube. The mean voltage of the lamp in this case rose to a round 130 volts and could have been raised to 140 volts without extinction of the lamp, that is to say, without its failing to relight within a single period.

In Fig. 9 the quartz tube *1* of the lamp has walls of about 1 mm in thickness and is about 12 to 14 cm long. Two pencil-shaped electrodes **9** and **10** are sealed in the opposite ends respectively of said tube. These electrodes are about 0.5 mm in thickness and their length from the end wall of said tube to their free end is about 15 mm. Said tube has a filling of a suitable gas, such as argon for example, with a pressure of about 20 to 30 mm and contains a small quantity of mercury, no more than will completely vaporize when the prescribed operating temperature of 300° to 500° C is reached. Said electrodes are in circuit with a resistance **11** of about 50 ohms and an alternating voltage of about 220 volts. A choking coil of about 0.1 to 0.3 Henry can be substituted for said resistance. Conventional ignition means, not shown, (ignition strip, high frequency ignition) for the first starting of the discharge may be used.

The following table gives the drops in voltage registered at the electrodes of a number of lamps of the type shown in Fig. 9, which were operated under identical operating conditions and differed from each other only in the thickness of their pencil-shaped electrodes:

Thickness of electrode pencil	Voltage drop at electrodes
	Volts
0.3 mm	7
0.6 mm	14
0.8 mm	22
1.0 mm	29
1.5 mm	39
2.0 mm	54

The lamp having electrodes of 2 mm thickness could not be brought to burn quietly with the current of the strength specified. Only when the current was raised to about 5 A did said lamp burn satisfactorily.

Fig. 10 shows the limits of the propitious or most favorable zone to be selected in accordance with the present invention, using pencil electrodes of a thickness of 0.25 to 0.2 mm. The abscissa is the thickness or diameter of the pencil electrode and the ordinate is that strength of current at which the voltage drop at the electrodes reaches a determined value. The values which lie between the two outer curves I and IV are admissible, while curve III represents about the most favorable values. Load values below curve I produce an inadmissible volatilization due to overload in the above mentioned sense. Load values above curve IV give rise to an inadmissibly short life for the electrode, due to the overload on the latter.

The curves reproduced in Fig. 10 were made in operation with an alternating current by means of an adjustable ohmic compensating resistance. Operation with a direct current produces a substantially parallel displacement of the curves in question, and the same thing occurs when operating with alternating current if a choking coil be substituted for the resistance.

The graph of Fig. 10 also enables the particular electrode dimensions, which would be suitable for any predetermined load, to be readily determined. On the other hand the present invention teaches how to determine the correct load for any given lamp, by first taking from the known tables the voltage drop attributable to the arc at a given temperature, and then calculating therefrom the voltage, which, at said temperature, must exist at the terminals, if 15 to 20 volts, for example, be taken as the voltage drop at the electrodes. Then, as soon as the arc is struck, one adjusts said resistance, or said choking coil of the lamp so as to produce said voltage at the terminals. When in this way the correct adjustment or regulation of the circuit current for said lamp has been made, said lamp can at once be connected up and allowed to operate in the high pressure zone of the mercury vapor discharge, without fear of any inadmissible volatilization occurring.

In order to prevent the formation of a dot like area of emission of the arc from the very beginning of the striking of the arc, it is advisable carefully to round off the cathode at all points, particularly at its free end, instead of providing it with pointed or toothed portions, as has been suggested by some. In the case of thicker pencil shaped electrodes **12** and **13**, this may be effected by rounding off their free ends in spherical form as shown in Figs. 11 and 12. But it would not be advisable to use the electrodes consisting of massive spheres carried by thin wires and with which certain tungsten arc lamps are equipped, as the long drawn out arc of the present type of lamp would immediately attach itself to said thin wire, which thus becoming highly incandescent, would buckle under the weight of the sphere or would be destroyed altogether.

The spherical rounding off of the free ends of thin wire pencil electrodes is difficult. To meet this difficulty these electrodes may be hook shaped, as shown at **14** or loop shaped, as shown at **15**, in Figs. 13 and 14 respectively, their thus rounded extremity being directed toward the centre of the tube.

For starting the arc, the pencil electrode **9** of Fig. 15 may advantageously be provided with a very thin sheet-metal lateral extension **16**, which is suitably secured at one edge to said electrode **9** at a suitable distance from the latter's free end. Said extension will preferably be curved spirally as shown to facilitate its introduction into the tube **1**. Said pencil and said extension may be of any suitable thickness; the thickness of the former, for example, may be 0.4 and that of the latter 0.05 mm. As the striking of the arc is always preceded by an incandescent discharge of which the heat development is in proportion to the effective area of the electrode surface, said sheet extension **16** will thus be more subject to heating during the ignition operation and will heat up very quickly. Consequently the arc is first struck upon said extension and passes on to the pencil electrode only when the latter, heated by said heated extension, has reached the required temperature. As volatilization is thus greatly reduced during the period of ignition, the arrangement in question increases materially the life of the lamp and extends the limits on the charge that is permissible.

While tantalum and tungsten have been more particularly mentioned in the illustrative embodiments of the invention herein described, it will be understood that other suitable materials, such as molybdenum and niobium, having a sufficiently high melting point, could also be used for electrodes without departing from the spirit of our invention. Tantalum lamps have proven to be best suited for general commercial use. Thus, for lamps with a current consumption usual in the trade, sheet tantalum electrodes of a thickness of only 0.08 mm to 0.04 mm have proven especially advantageous. As tungsten and molybden possess greater heat conductivity than tantalum, correspondingly thinner sheet metal must be used for electrodes for those two metals; in fact the lower specific emission capacity of those two metals makes it necessary to strive for a still greater arc emitting area on the cathode surface, that is to say, to reduce the thickness of the cathodes even below that demanded by the greater heat conductivity. This may require the sheet metal to be so thin that it would be difficult to manufacture therefrom electrodes possessing the necessary strength by the usual methods. In practice, therefore, it might be preferable to use electrodes of these two metals only in lamps subjected to relatively heavy loads.

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