United States Patent

Kamegaya et al.

[15] 3,670,195

[45] June 13, 1972

[54] **METAL VAPOUR DISCHARGE LAMP**

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[22] Filed: **March 17, 1971**

[21] Appl. No.: **125,321**

[30] **Foreign Application Priority Data**

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March 27, 1970 Japan....................................45/25379

[52] **U.S. Cl.**..............................**313/217,** 313/212, 313/213, 313/344

[51] **Int. Cl.**..**H01j 17/06**

[58] **Field of Search**..................313/217, 210, 211, 212, 213, 313/344

[56] **References Cited**

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Primary Examiner—John Kominski
Attorney—Flynn & Frishauf

[57] **ABSTRACT**

A metal vapor discharge lamp wherein the ratio of the effective diameter to the length of the electrode body used therein and the ratio of said effective diameter to the current of said discharge lamp are so designed to have specified values.

9 Claims, 20 Drawing Figures

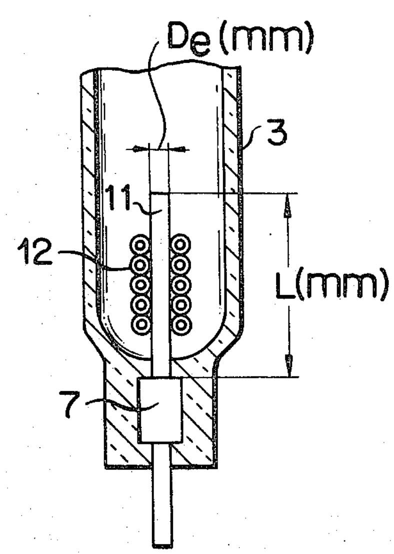


FIG. 1

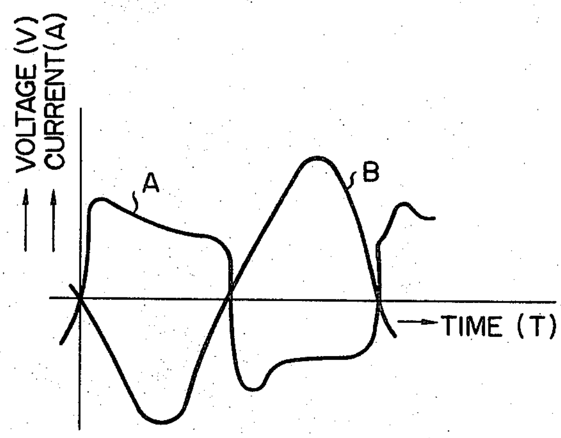


FIG. 2

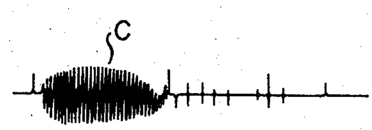
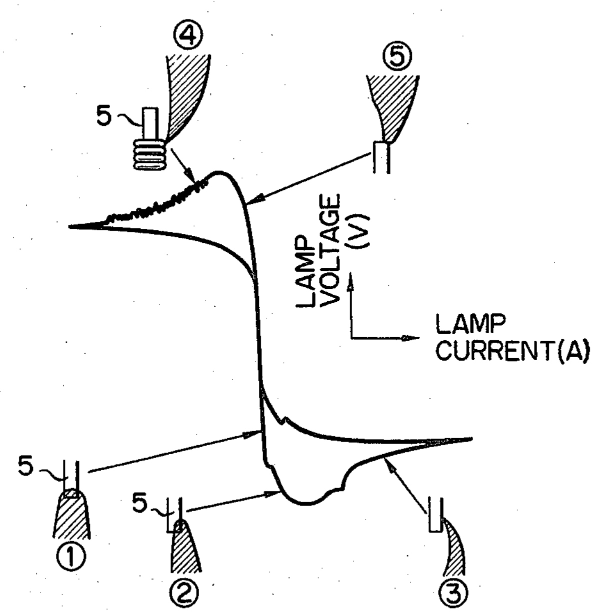


FIG. 3



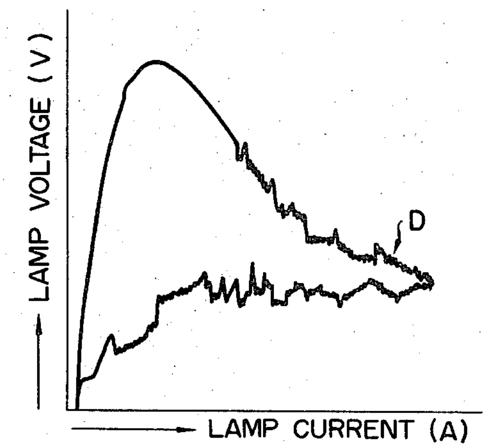

LAMP VOLTAGE (V)
D
LAMP CURRENT (A)

FIG. 4

FIG. 5

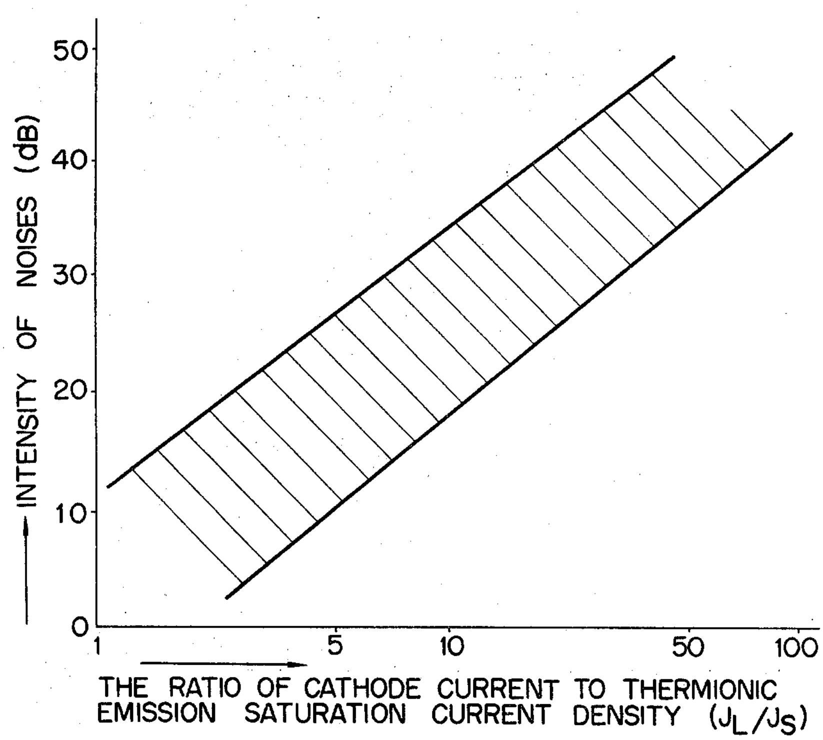

INTENSITY OF NOISES (dB)
50
40
30
20
10
0
1
5
10
50
100
THE RATIO OF CATHODE CURRENT TO THERMIONIC EMISSION SATURATION CURRENT DENSITY (J_L/J_S)

FIG. 6

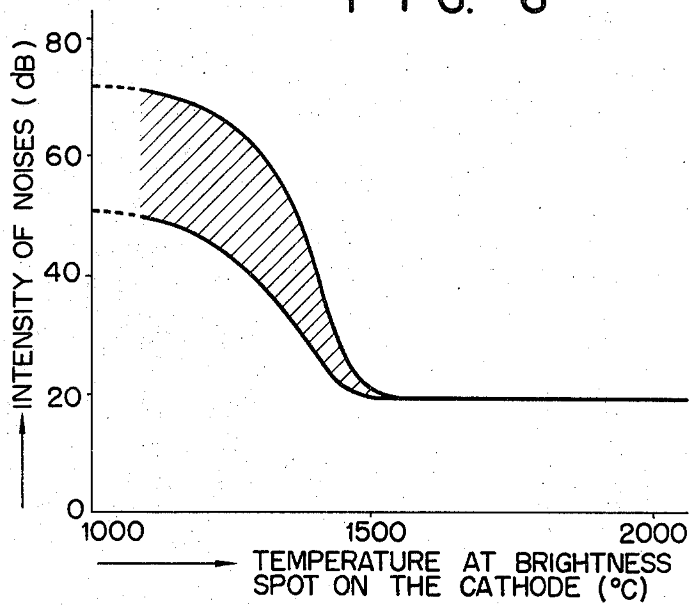


FIG. 7

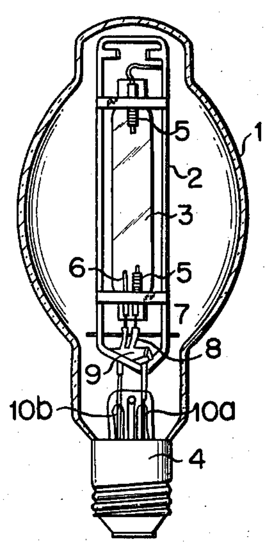


FIG. 8

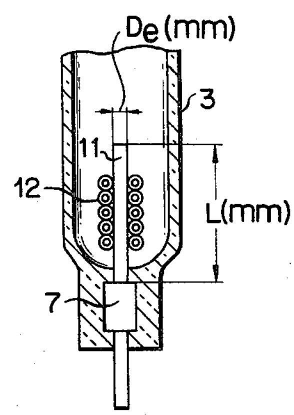


FIG. 9

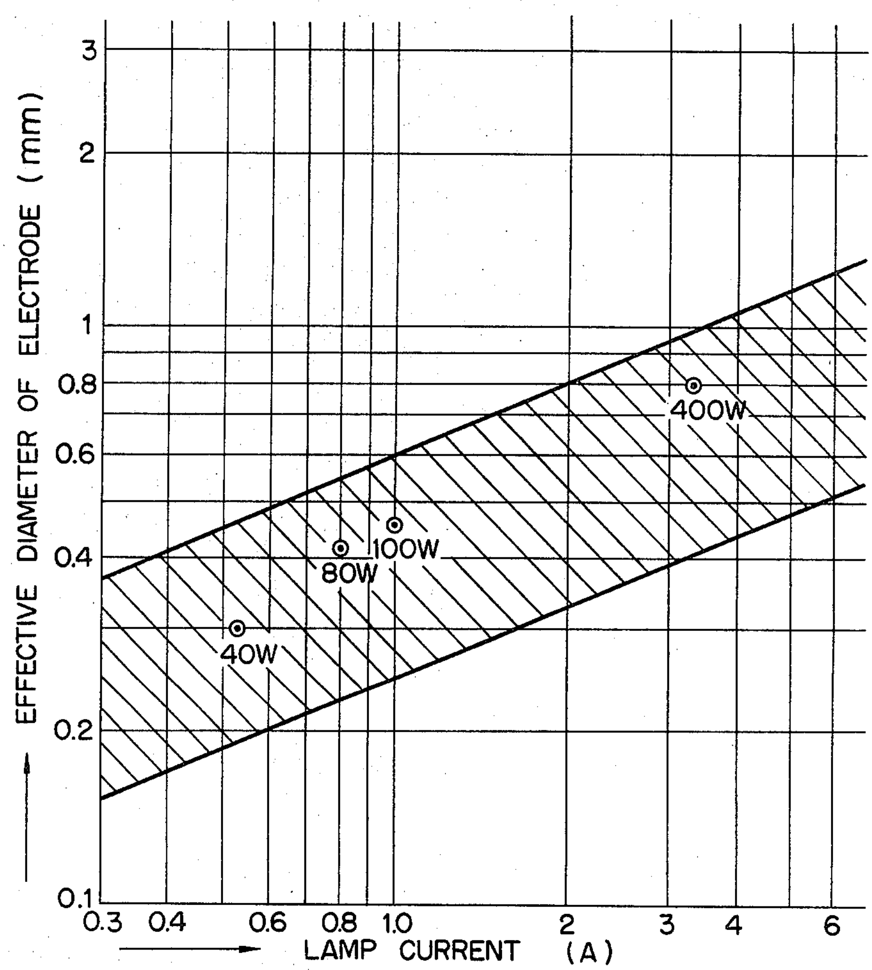

3
2
1
0.8
0.6
0.4
0.2
0.1
EFFECTIVE DIAMETER OF ELECTRODE (mm)
400W
100W
80W
40W
0.3
0.4
0.6
0.8
1.0
2
3
4
6
LAMP CURRENT (A)

FIG. 10

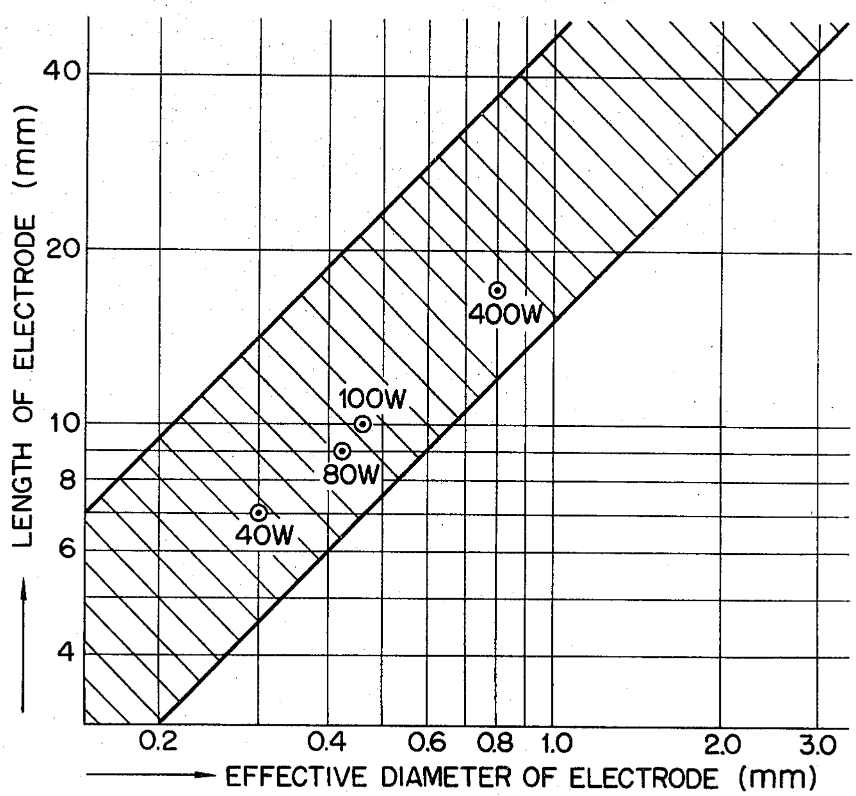

40
20
10
8
6
4
LENGTH OF ELECTRODE (mm)
400W
100W
80W
40W
0.2
0.4
0.6
0.8
1.0
2.0
3.0
EFFECTIVE DIAMETER OF ELECTRODE (mm)

FIG. 11

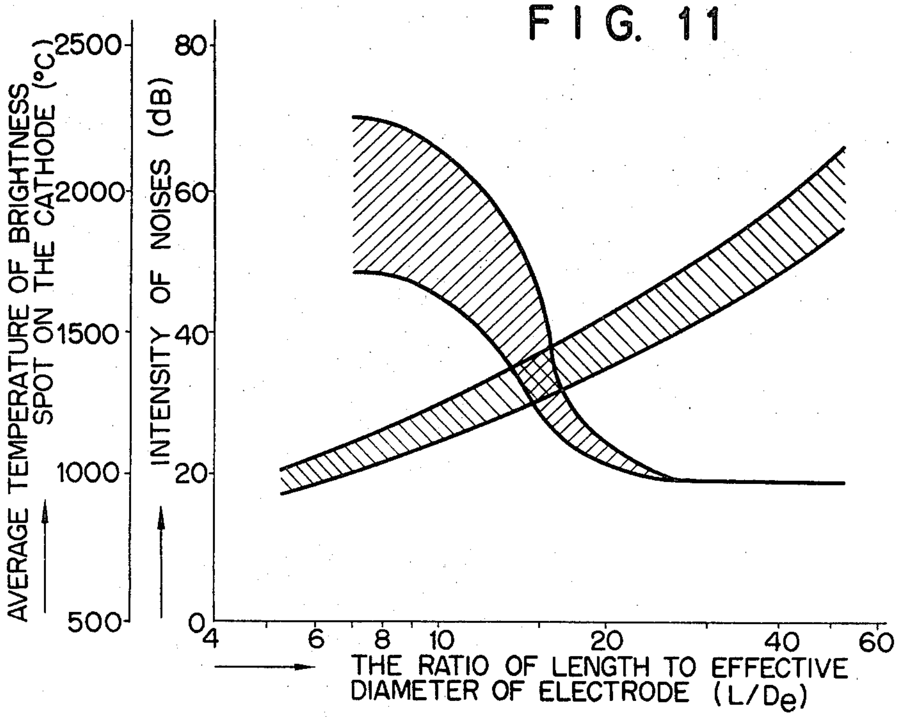


FIG. 12

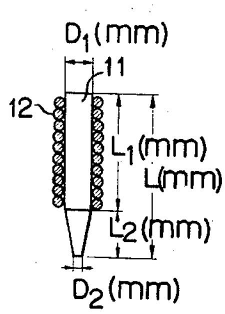


FIG. 13

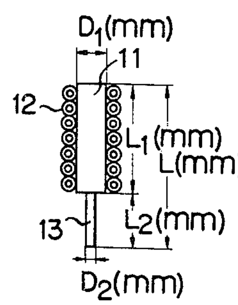


FIG. 14

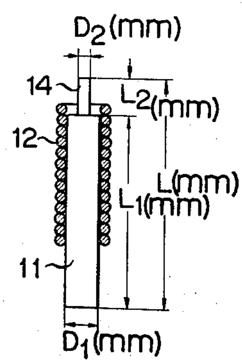


FIG. 15

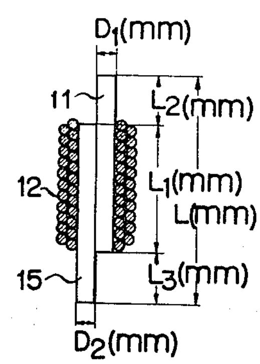


FIG. 16

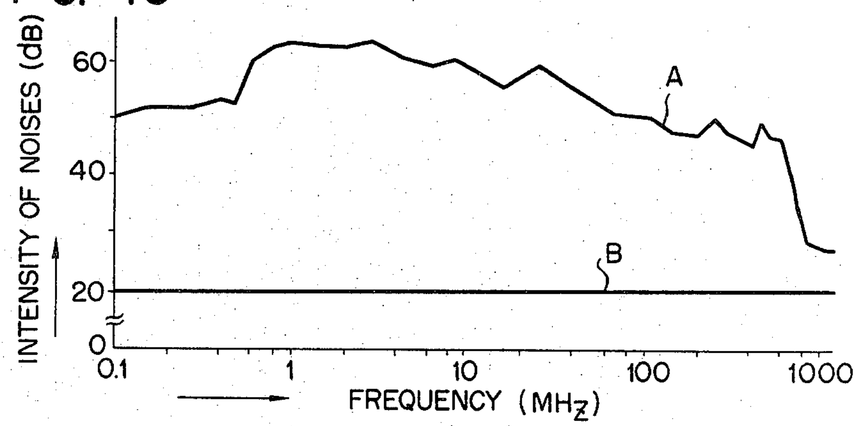

INTENSITY OF NOISES (dB)
60
40
20
0
A
B
0.1
1
10
100
1000
FREQUENCY (MHz)

FIG. 17

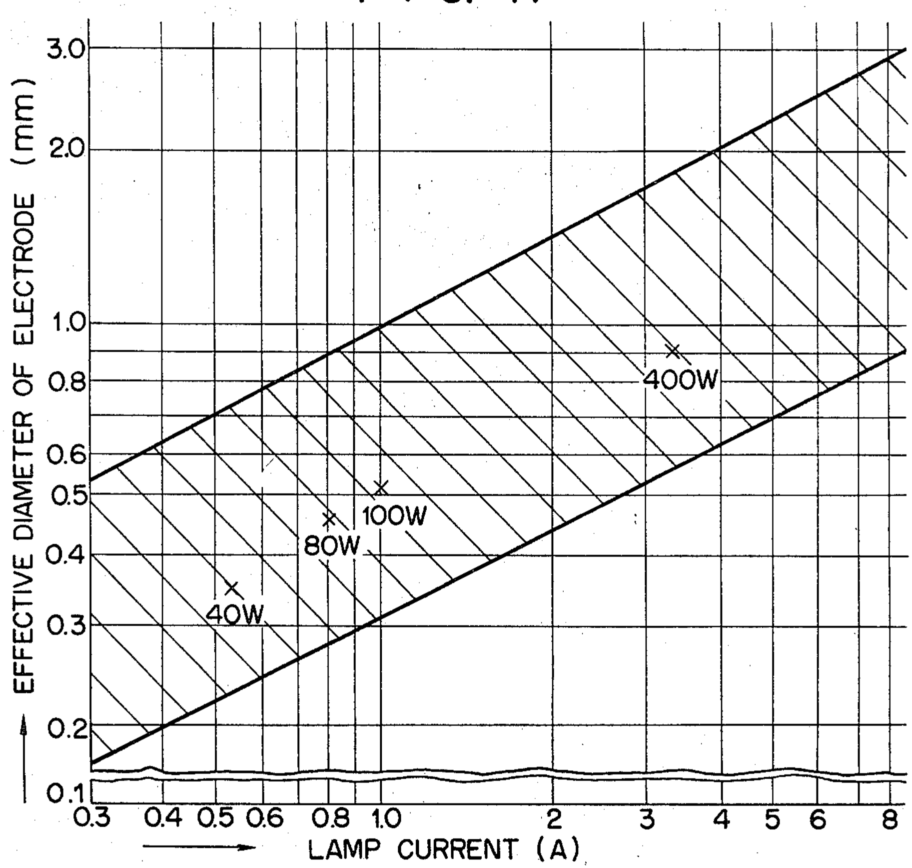

EFFECTIVE DIAMETER OF ELECTRODE (mm)
3.0
2.0
1.0
0.8
0.6
0.5
0.4
0.3
0.2
0.1
400W
100W
80W
40W
0.3
0.4
0.5
0.6
0.8
1.0
2
3
4
5
6
8
LAMP CURRENT (A)

FIG. 18

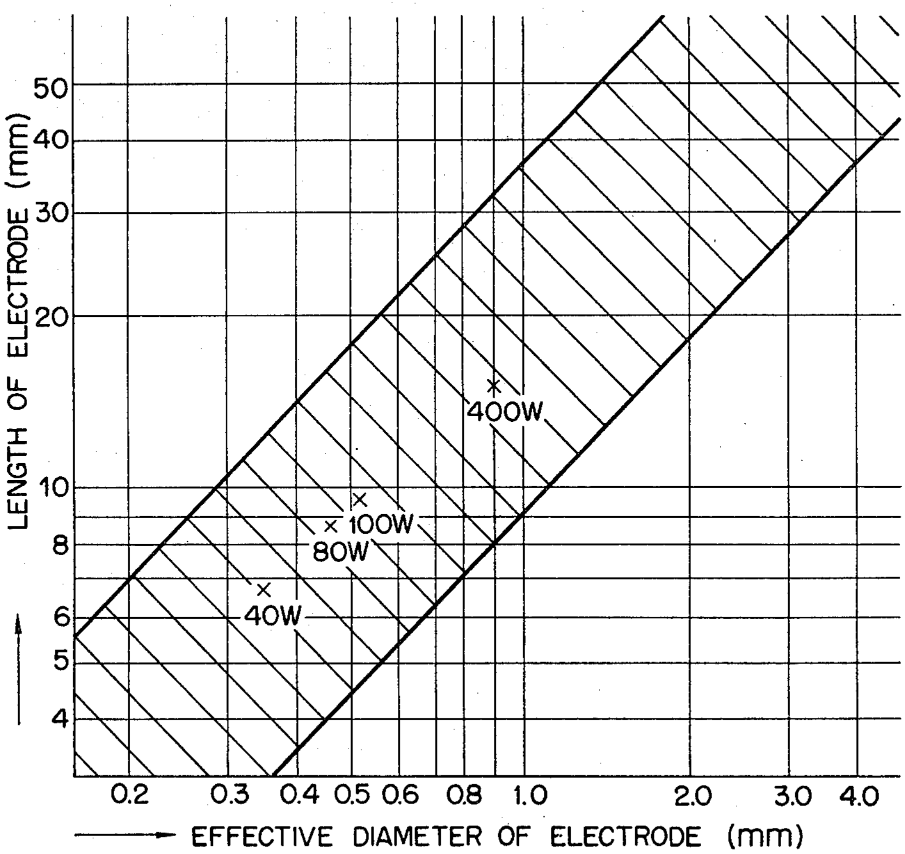

50
40
30
20
10
8
6
5
4
LENGTH OF ELECTRODE (mm)
400W
100W
80W
40W
0.2
0.3
0.4
0.5
0.6
0.8
1.0
2.0
3.0
4.0
EFFECTIVE DIAMETER OF ELECTRODE (mm)

FIG. 19

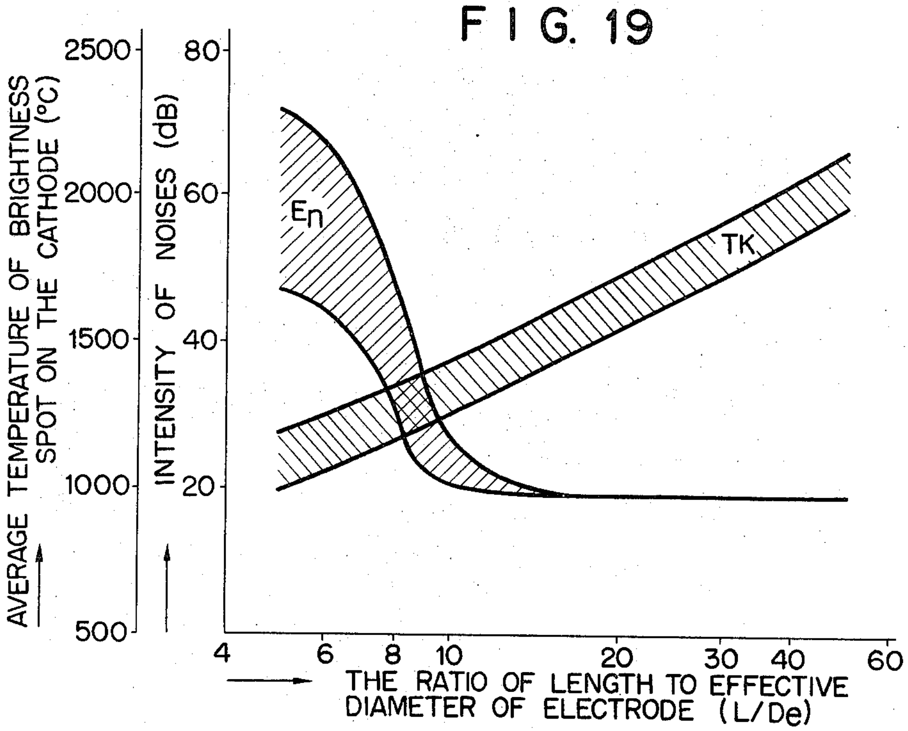
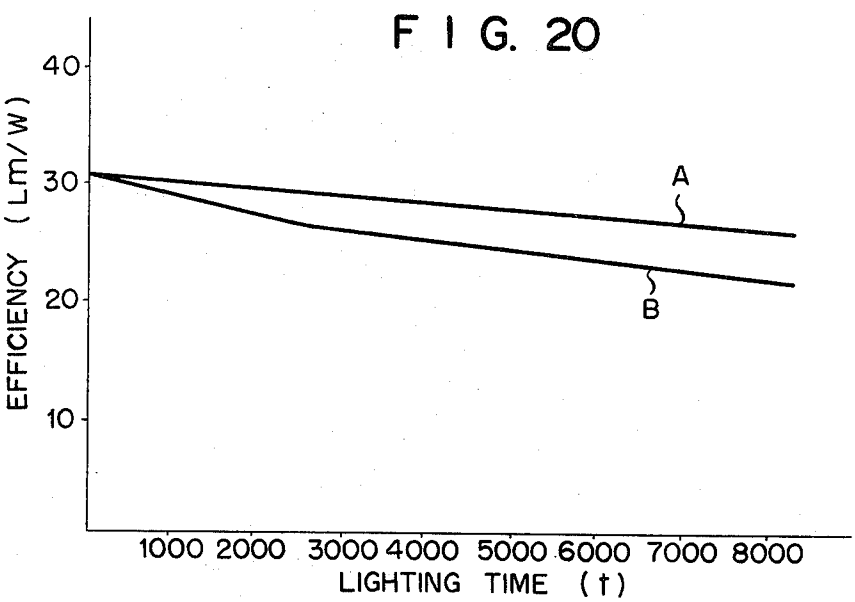

AVERAGE TEMPERATURE OF BRIGHTNESS SPOT ON THE CATHODE (°C)
2500
2000
1500
1000
500
INTENSITY OF NOISES (dB)
80
60
40
20
En
TK
4
6
8
10
20
30
40
60
THE RATIO OF LENGTH TO EFFECTIVE DIAMETER OF ELECTRODE (L/De)

FIG. 20


EFFICIENCY (Lm/W)
40
30
20
10
A
B
1000 2000 3000 4000 5000 6000 7000 8000
LIGHTING TIME (t)

METAL VAPOUR DISCHARGE LAMP

This invention relates to a metal vapor discharge lamp which is capable of reducing through improvements in the electrode construction the occurrence of noises resulting from radio frequencies to obstruct the reception of signals like those of the radio, television and FM (frequency modulated) radio in particular.

A metal vapor discharge lamp, for example, a high pressure mercury vapor lamp is generally prepared by sealing electrode members, readily ionizable inert gas such as argon and mercury in a heat resistant transparent tube made of, for example, quartz glass to form a luminous tube, and receiving said luminous tube in an envelope which is generally fitted at one end with a mouth piece. The aforementioned electrode member mainly consists of a rod of high melting metals such as tungsten, thallium-containing tungsten and molybdenum; a single or double coil made of similar high melting metals to those mentioned above and tightly wound in a single formation or a plurality of superimposed formations; and electron emitting materials such as oxides of barium, strontium, calcium and thallium and double salts thereof deposited on or embedded in the surface of the electrode body or the interspaces between the coils.

The above-mentioned high pressure mercury vapor lamp which has a compact form and efficiently gives forth high brightness has been used not only to illuminate highways, the interior of plants and mills and stadiums, but also in recent years has been increasingly accepted in illumination applications for dwellings including gardens and streets as well as for prevention of crimes.

However, where a high pressure mercury vapor lamp provided with an electrode member of the aforementioned construction is impressed with an alternating current for discharge, there arise continuously or intermittently during the voltage cycle high frequency oscillations ranging from a medium to an ultra short wave band. Accordingly, it often happens that such oscillating current intrudes into conductors disposed in the neighborhood, for example, service lines, and antennas with the resulting direct radiation or reradiation after transmission of disturbing waves, thereby obstructing the reception of broadcast waves such as those of AM radio, television or FM radio.

With the increasing application of a discharge lamp in recent years, the aforementioned noise disturbance raises an important problem. Though the basic cause of such noises in not fully defined, there have heretofore been taken the undermentioned countermeasures. Some of them consist in connecting external noise-preventing circuits to the discharge lamp, for example, those including a condenser connected in parallel with said lamp or those formed of R(resistor) and C(condenser) elements or L(inductance) and C(condenser) elements. Of these methods, the one using a circuit including a condenser does not effectively prevent noises, though it is easy to handle. Nor do the other methods using circuits formed of a resistor, condenser or inductance element or combinations thereof have a uniform noise-preventing effect due to actual work of application requiring, for example, different fitting position and grounding processes. The other countermeasures include the one which consists in shielding the envelope of a discharge lamp or the one which comprises providing a magnetic coil near the electrode, and introducing discharge current therethrough to generate a magnetic field, thereby preventing noise disturbances. These latter countermeasures present difficulties in reducing uniformly as well as effectively the noises whose frequencies range from a medium wave to a ultra short wave band.

This invention does not essentially consist in adding the aforementioned external circuit, but improving the electrode body itself so as fundamentally to minimize noise disturbances. Attention to improvements in the electrode body originates with the undermentioned analysis of the cause of the aforesaid radio frequency noises.

FIG. 1 presents the voltage and current wave forms of a high pressure mercury lamp when it is lighted using an alternating current of 50 to 60 Hz. The curve A denotes the voltage wave form and the curve B the current wave form of said lamp. The curve C represents a wave form appearing when there is eliminated a low frequency component from the lamp voltage by passing it through a differentiation circuit. As shown in FIG. 2, the positive half portion of the voltage wave form is observed to contain a wave form giving rise to radio frequency noises. Said noises appear at random, that is, during the entire or fractional period of a half cycle.

FIG. 3 is a Lissajous' figure showing brightness spots appearing at and near the electrodes of a lighted high pressure mercury vapor lamp and the voltage and current of said lamp. Discharge occurs in three forms (1), (2) and (3). In general, change from the states of (1) and (2) to that of (3) discontinuously takes place, and a discharge glow having the state of (3) intermittently wavers to give rise to noises.

FIG. 4 is a fractional enlarged view of a similar Lissajous' figure showing the voltage and current of a discharge lamp where there continuously occur noises, particularly at a section indicated by the arrow D.

There will now be described by reference to FIG. 3 the forms of discharge.

Form 1: This is observed in the initial phase where the lamp current begins discharge. The glow covers the considerable part of the end of the electrode body 5 and is often in a rest condition. Accordingly, the current density is as low as 100 A/cm² max.

Form 2: The glow covers the end of the electrode body 5 in a somewhat smaller area than in Form (1). That part of the electrode body which has a relatively high surface temperature is 0.1 mm min. in diameter. The brightness spot sometimes stands at rest and at other times slowly sways about the main electrode body. Under this condition, there appears no noise.

Form 3: The glow extremely contracts itself and that part of the electrode whose surface is covered with the glow is 0.05 mm or less in diameter. The glow is very much limited in area from a positive column section to an interspace between the electrodes and discontinuously sways. As mentioned above, the discharge discontinuously changes from the form (3) to the forms (1) and (2). In the form (3), the glow wavers to cause the continuous occurrence of noises.

Forms (4) and (5) represent the discharges which appear at the other electrodes disposed at positions corresponding to those of the aforesaid electrodes when the former electrodes are in a phase acting as a cathode.

The aforementioned noises are supposed to arise from the undermentioned causes. With the prior art high pressure mercury vapor lamp, combination of, for example, the effective diameter D and length L of the electrode body is not designed in full consideration of the purpose of insulating the cathode for its self-heating and causing the cathode to carry sufficient current to emit required amounts of thermal electrons, so that the cathode discharge becomes unstable, leading to the occurrence of noises. The cathode of a high pressure mercury vapor lamp does not receive heating current during operation, and the heating of said cathode is mainly effected by ion impingement and electron impingement during the half cycle period in which the cathode has a positive potential. Accordingly, the cathode is heated too low a temperature and in too small an area to supply all requirements of discharge current from thermal electrons emitted therefrom. This gives rise to the aforementioned radio frequency noises. Actual observation of the condition in which the cathode discharge appears shows that the cathode has a small brightness spot and a low temperature and that there is formed ahead of the brightness spot an extremely contracted negative glow which vigorously shifts and wavers. On the other hand, determination was made with respect to an experimental luminous tube on the relationship of the ratio J_L/J_S which the cathode current density J_L bears with the thermion emission saturated current density J_S versus the intensity of noises, the results being presented in FIG. 5. In this case, the noise appears with an intensity falling within the range of a hatching shown in FIG. 5 in case of $J_L/J_S>1$, with $J_L/J_S \approx 1$ as a border line. In case of $J_L/J_S<1$, the noise disappears. The condition in which the noise arises indicates that its intensity increases in proportion to the ratio of J_L/J_S. This fact suggests that the generation and extinction of noises associated with a high pressure mercury vapor lamp has an interrelationship with the amount of thermion emission current generated from the cathode. For further clarification of this point, determination was made of the intensity of noises using a rod electrode coated with electron emitting materials such as oxides of barium, calcium, strontium and thallium with the cathode temperature varied, the result being given in FIG. 6. With a rod cathode electrode coated with such electron emitting materials, there arose noises having a high intensity falling within the range of the hatching of FIG. 5, where the cathode end had an average temperature of less than 1400° C. At higher temperatures, however, the noise sharply decreased in intensity. In fact, the end of the rod electrode of any conventional high pressure mercury vapor lamp was observed to have an average temperature of less than 1250° C. It is assumed from the aforementioned facts that the condition of the cathode discharge, particularly the form in which the cathode current is discharged constitutes an important factor in generating noises from a high pressure mercury vapor lamp.

As mentioned above, where the thermion emission current is smaller than the discharge current, the deficiency of the cathode current is compensated, as is currently practiced, by forming a strong electric field between the cathode and other electrodes using ions generated by ionization or redistribution thereof, thereby drawing out a field emission current. In this case, the ion current or field emission current is concentratedly conducted to the brightness spot of the cathode locally to form a negative glow. However, the brightness spot, if it is ununiform, causes the negative glow to shift or waver resulting in the local variation in the plasma density, which in turn leads to disproportion of ionization or change in the ratio of the ionized to the nonionized region of a luminous tube (a sort of ionization oscillation), thereby supposedly giving rise to disturbing waves.

Referring to FIGS. 5 and 6, the noise intensity is defined to be zero dB when the noise voltage indicates 1 micro volt, using a noise intensity measuring apparatus specified in the report submitted by the Electric Wave Examination Council. (This applies to further indication of dB values.)

The object of the invention is to provide a mercury vapor discharge lamp wherein the electrode body is made to have an optimum construction by specifying the dimensional relationship so as to satisfy the required conditions, thereby reducing the occurrence of noises obstructing the reception of signals like those of the radio and television.

In the drawings:

FIG. 1 illustrates the voltage and current wave forms of a conventional metal vapor discharge almp when it is lighted by an alternating current;

FIG. 2 presents the current wave form of FIG. 1 from which there is removed a low frequency component;

FIG. 3 is a Lissajous' figure showing the voltage and current of the discharge lamp together with the discharge conditions appearing around the electrode from time to time;

FIG. 4 shows that part of the Lissajous' figure where there occur noises;

FIG. 5 shows the intensity of noises plotted with the operating condition of the lamp cathode used as a parameter;

FIG. 6 illustrates the intensity of noises varying with the temperature of the brightness spot of the lamp cathode;

FIG. 7 is an elevation of a metal vapor discharge lamp according to an embodiment of this invention;

FIG. 8 is an enlarged view of the electrode section;

FIG. 9 presents the specified range of the ratio of the effective diameter of the electrode body to the lamp current;

FIG. 10 indicates the specified range of the ratio of the effective diameter to the length of the electrode body;

FIG. 11 shows the relationship of the ratio of the effective diameter to the length of the electrode body versus the average temperature of the brightness spot and the intensity of noises;

FIGS. 12, 13, 14 and 15 are the sectional views of electrode members according to other embodiments of this invention;

FIG. 16 presents the frequency distribution of noises plotted with respect to the intensity thereof as compared between the metal vapor discharge lamps of the invention and prior art;

FIG. 17 illustrates another specified range of the ratio of the effective diameter of the electrode body to the rated current passing through a discharge lamp according to said another embodiment of the invention;

FIG. 18 indicates still another specified range of the ratio of the effective diameter to the length of the electrode body defined on the basis of the range of FIG. 17;

FIG. 19 shows with respect to said another embodiment of the invention the relationship of the ratio of the effective diameter to the length of the electrode body versus the average temperature of the brightness spot of the cathode and the intensity of noises; and

FIG. 20 is a curve diagram showing the performance characteristics of lumens per watt as compared between the metal vapor discharge lamp according to said another embodiment of the invention and the prior art type.

There will now be described by reference to FIGS. 7 to 20 a metal vapor discharge lamp using the electrode of this invention. FIG. 7 is an elevation of a metal vapor discharge lamp, for example, a high pressure mercury vapor lamp using an electrode according to an embodiment of the invention. This discharge lamp consists of an envelope 1 evacuated or filled with inert gas, a luminous tube 3 fixed to a support member 2 concurrently acting as a lead line and a mouth piece 4 fitted to the end of the envelope 1. The luminous tube 3 has a pair of the later described main electrodes 5 sealed to both ends of said envelope 1 and an auxiliary electrode 6 sealed to one end thereof. These main and auxiliary electrodes 5 and 6 are connected to one end of conductor foils 7 respectively sealed to the seal end of the luminous tube 3. The other end of these conductor foils 7 is connected to one end of lead lines 8 respectively, the other end of which is connected to lead-in lines 10*a* and 10*b* respectively through the support member 2 or said support member 2 and a starting impedance element, for example, a resistor 9. In the luminous tube 3 are sealed, for example, mercury and inert gas such as argon.

FIG. 8 is a fractional longitudinal sectional view of a luminous tube using a typical electrode according to an embodiment of this invention. The electrode 5 is comprised of a rod electrode body 11 made of high melting metal such as tungsten, thallium-tungsten and molybdenum; a single or multiple coil 12 similarly made of high melting metals such as tungsten, thallium-tungsten and molybdenum and wound about the electrode body 11; and electron emitting materials (not shown) disposed in the interspace between the rod electrode 11 and coil 12 or coated on the coil 12.

Now let the effective diameter *De* of the elongate rod electrode 11 and its length *L* extending from the end facing the discharge space to the end contacting the conductor coil 7 be expressed in units of millimeters and the current *Il* of the high pressure mercury vapor lamp lighted under stable condition be denoted in units of amperes (A). Then all these factors are assumed to have relationships falling within the ranges represented by the following formulas:

$$15 \leqq L/De \leqq 46 \qquad 1$$

$$1.7 \leqq Il^{0.4}/De \leqq 4 \qquad 2$$

In the interspace between the elongate rod electrode body constructed as described above and the helical coil 12 wound thereabout is embedded at least one of electron emitting materials such as oxides of, for example, barium, strontium, calcium and thallium or double slats thereof.

When a high pressure mercury vapor lamp of the aforementioned arrangement is lighted, the average temperature at the end of the main electrode body always rises above 1400° C during operation, causing the current resulting from thermions released from said electron emitting materials to increase over the discharge current, so that the form in which the brightness spot is generated across the electrodes presents little change during each cycle of A.C. discharge. Accordingly, high frequency oscillations due to discontinuous variations in the cathode discharge current are controlled to minimize the occurrence of disturbing noises.

When the ratio of the effective diameter De(mm) to the lamp current Il(A) satisfies the formula (2), then said ratio falls within the range of the hatching of FIG. 9, regardless of the magnitude (W) of the rated lamp current, thereby attaining the object of minimizing noises. Similarly, when the ratio of the effective diameter De(mm) to the length L(mm) of the electrode body satisfies the formula (1), then said ratio is considered to fall within the range of the hatching of FIG. 10, that is, to limit the occurrence of noises.

The relationship of the ratio of the effective diameter De(mm) to the length L(mm) of the electrode body versus the average temperature TK(° C) of the brightness spot of the cathode and the intensity En(dB) of noises is indicated by the hatchings of FIG. 11. In case of L/De = 15 to 46 (provided De satisfies the formula $1.7 \leqq Il^{0.4}/De \leqq 4$), the average temperature of the brightness spot of the cathode falls within the range of 1400° to 1900° C. Further, if said ratio L/De indicates 15 or over, the intensity of noises will be reduced to an extremely low level. Conversely, where the ratio of $Il^{0.4}/De$ is smaller than 1.7, the brightness spot of the cathode will have too low a temperature, most likely leading to the discontinuous sway of the brightness spot of the cathode while the discharge lamp is lighted, and in consequence the increased occurrence of noises, failing to attain the object of this invention. Where the ratio $Il^{0.4}/De$ rises beyond 4, the temperature of the brightness spot will excessively increase, resulting in the vigorous scattering of electron emitting material to blacken the inner wall of the luminous tube and in consequence shorten the life of the discharge lamp, though noises may be appreciably eliminated. If the ratio L/De is less than 15, even though the formula of $1.7 \leqq Il^{0.4}/De \leqq 4$ may be satisfied, then the brightness spot of the cathode will have too low a temperature, presenting undesirable results for the same reason as given above. On the other hand, if the ratio of L/De exceeds 46, it will also be objectionable due to the unduly high temperature of the brightness spot. For the purpose of this invention, therefore, it is required that the lamp current and the effective diameter and length of the electrode body be so defined as to satisfy both formulas at the same time.

However, the aforementioned ranges simply represent those in which this invention can generally prove its effect. The most preferred ranges capable of minimizing noises and extending the life of a discharge lamp and in consequence rendering a discharge lamp well adapted for practical application stand at $1.8 \leqq Il^{0.4}/De \leqq 3.85$ and $19 \leqq L/De \leqq 46$ respectively. The present invention displays a prominent effect in a metal vapor discharge lamp consuming relatively small amounts of power, for example, 100 to 200 watts. It will be apparent that in the case of a discharge lamp requiring larger power, the present invention also enables the cathode temperature to be easily raised and displays a favorable effect.

For the object of this invention, the cross sectional form of the electrode body is not limited to a circle, but may be noncircular, for example, elliptical or polygonal. Needless to say, the electrode body need not have a uniform diameter in its lengthwise direction but may be formed into various modifications. In such case, determination of the effective diameter De of the electrode body is carried out by equivalently computing the diameter of a circle having the same area as the cross sectional area of said various modifications.

FIGS. 12 to 15 illustrate the various arrangements of an electrode member according to this invention. Referring to FIG. 12, the electrode body 11 is tapered along its end portion having a length L_2 so as to facilitate its contact with a conductor foil (not shown). The present inventors have experimentally confirmed that from a practical standpoint, the effective diameter De of the electrode body, as used in this invention, should be proportionate to the projected area of the longitudinal side of the electrode body 11. Accordingly, the effective diameter De of the electrode body 11 shown in, for example, FIG. 12 may be expressed as

$$De=\left[(D_1L_1(D_1+D_2)\frac{1}{2}L_2\right]/L$$

(where L denotes the entire length of the electrode body 11, L_1 the length of that part of said body 11 having a diameter D_1, and L_2 the length of the tapered portion having a diameter D_2 at one end and a diameter D_1 at the other).

The electrode body of FIG. 13 is substantially the same as that of FIG. 12, except the the tapered portion of FIG. 12 is replaced by a straight narrow portion 13 having a small diameter D_2. In this case, the effective diameter De may be computed from the equation:

$$De=[(D_1L_1+D_2L_2)]/L$$

The electrode body of FIG. 14 has a narrow portion 14 formed at the end. With the diameter of said narrow portion 14 represented by D_2 and its length by L_2, the effective diameter De of the electrode body 11 as a whole may be determined form the same equation as used in the case of FIG. 13.

The electrode body assembly of FIG. 15 consists of a pair of rods 11 and 15 lengthwise abutting against each other at that part of said electrode body assembly about which there is wound a multiple coil 12. Let the length of the joined portion substantially at the central part of the electrode body assembly be represented by L_1, the length of the upper portion of said assembly by L_2, the length of the lower portion thereof by L_3, the diameter of rod 11 by D_1, the diameter of the rod 15 by D_2 and the entire length of the electrode body assembly by L. Then the effective diameter of said electrode body assembly may be determined from the equation:

$$De=\{D_1L_2+(D_1+D_2)L_1+D_2L_3\}/L$$

FIG. 16 displays the extent to which there are actually reduced noises with respect to a metal vapor discharge lamp using an electrode member arranged as described above. The curve A of this figure is an envelope representing the intensity of noises arising from the prior art discharge lamp. The curve B relates to that of the present invention, showing that the intensity of noises decreased to as low a level as 20 dB max.

When an electrode member according to the present invention was applied in actually prepared discharge lamps consuming a rated power of 40, 80, 100 and 400W under the conditions where the equations (1) and (2) were satisfied, it was disclosed that the intensity of noises was reduced to 20 dB-max., as presented in Table 1 below, in contrast to 50 to 65 dB indicated by the intensity of noises originating with the prior art discharge lamp.

TABLE 1.

Performance of the electrode of the present invention

Rated lamp power (W)	40	80	100	400
Rated lamp current (A)	0.53	0.8	1.0	3.3
Effective diameter De(mm) of electrode body	0.3	0.42	0.46	0.8
Length L(mm) of electrode body	7	9	10	17
Intensity of noises (dB)	20 max.	20 max.	20 max.	20 max.

As apparent from the foregoing description, this invention requires that the effective diameter and length of the electrode body be defined within a specified range. However, the electrode body may or may not be wound with a coil.

The present invention is not limited to a high pressure mercury vapor lamp described in the foregoing emnodiments, but may be applicable to, for example, a metal halide lamp wherein there are incorporated halogens and luminous metals in the mercury placed in the laminous tube.

There will now be described by reference to FIGS. **17** to **20** an electrode member according to another embodiment of this invention. According to this embodiment, the electrode body is comprised of a porous high melting metal having 5 to 30 percent porosity. Accordingly, the ratio of the effective diameter to the length of the electrode body, and the ratio of the effective diameter of the electrode body to the current of the lamp when it is lighted under stable condition are defined within a different range from that used in the preceding embodiment. Still the object of this invention can be attained by effectively controlling the occurrence of noises.

The discharge lamp and electrode body used in this embodiment have substantially the same construction as those described in the preceding embodiments of FIGS. **7** and **8** and FIGS. **12** to **15**, though the electrode body has different dimensions. The electrode member according to this embodiment comprises a rod electrode body prepared by compressing powders of porous high melting metals having 5 to 30 percent porosity such as tungsten, thallium-tungsten and molybdenum and sintering the mass in an atmosphere of hydrogen; a single or multiple coil similarly made of high melting metals such as tungsten, thallium-tungsten and molybdenum and wound about the electrode body; and electron emitting materials comprising oxides of, for example, barium, strontium, calcium, thallium as well as of the salts of barium and aluminum or the double salts thereof, impregnated in or mounted on the electrode body, and disposed in the interspace between the electrode body and coil or deposited on the coil. Where there is to be used the above-mentioned electrode, the ratio of the effective diameter to the length of the electrode body and the ratio of said effective diameter to the current of a discharge lamp when it is lighted under stable conditions are so designed as to fall within the ranges represented by the following formulas (3) and (4) instead of the formulas (1) and (2) used in the preceding embodiments.

$$1 \leqq Il^{0.5}/De \leqq 3.16 \quad (3)$$

$$9 \leqq L/De \leqq 35 \quad (4)$$

When there is lighted a metal vapor discharge lamp using such electrode, the end of the main electrode body always has an average temperature of 1350° C min., restricting high frequency oscillations caused by discontinuous variations in the cathode discharge current with the resulting prominent decrease of disturbing noises. The ratios establishing the formulas (3) and (4) are graphically presented in FIGS. **17**, **18** and **19**. When the effective diameter *De*(mm) of the electrode body and the lamp current *Il*(A) have a ratio defined in the range of a hatching of FIG. **17**, then the object of this invention can be attained, regardless of the magnitude of the rated power of the discharge lamp.

The hatching of FIG. **18** represents the range in which the ratio of the effective diameter *De*(mm) to the length *L*(mm) of the electrode body satisfies the aforementioned formula. The hatching of FIG. **19** denotes the preferred relationship of the ratio of the effective diameter *De*(mm) to the length *L*(mm) of the electrode body versus the average temperature TK(° C) of the brightness spot of the cathode and the intensity En(dB) of noises. Where the ratio of *L*/*De* indicates 9 to 35 (provided *De* satisfies the condition of $1 \leqq Il^{0.5}/De \leqq 3.16$), then the brightness spot of the cathode will have an average temperature TK of 1350° to 2000° C to reduce the intensity of noises to an extremely low level with *L*/*De* set at 9 min. In contrast, where the ratio of $Il^{0.5}/De$ is smaller than 1, the brightness spot of the cathode will have too low a temperature and be likely to present discontinuous waverings while the discharge lamp is lighted with the resulting failure to attain the object of the invention due to the prominent occurrence of noises. Again, where the ratio of $Il^{0.5}/De$ rises beyond 3.16, the brightness spot will have an unduly high temperature to cause the electron emitting material to be vigorously scattered and the inner wall of the luminous tube to be blackened with the resulting shortened life of the discharge lamp, though noises may be appreciably reduced. If *L*/*De* is smaller than 9, though the formula of $1 \leqq Il^{0.5}/De \leqq 3.16$ may be satisfied, then the brightness spot will have too low a temperature, presenting undesirable results for the same reason as given above. On the other hand, where *L*/*De* increases over 35, the temperature of the brightness spot will excessively increase, exerting an unfavorable effect. Accordingly, the present invention requires that the lamp current and the effective diameter *De* and length *L* of the electrode body be defined within such a range as to satisfy the aforesaid two formulas at the same time.

The foregoing embodiment relates to the case where the electrode body in comprised of a porous high melting metal having 5 to 30 percent porosity. Where the porosity exceeds 30 percent, heat transfer will be reduced, causing the temperature of the electrode body to rise higher than desired with the resulting decreased lumens and shortened life of the discharge lamp. Further such great porosity weakens the mechanical strength and raises the specific resistivity of the electrode body. Conversely, if the porosity falls to below 5 percent, then the electrode body will display larger heat transfer and be prevented from being heated to a desired level, leading to the occurrence of noises or presenting difficulties in removing impure gases occluded in the electrode body itself and further to decrease in the amount of electron emitting material impregnated in or deposited on the electrode body. The experiments conducted by the present inventors show that the porosity of 10 to 18 percent gave particularly preferred results. Where there were prepared high pressure mercury vapor lamps of various rated powers such as 40, 80, 100 and 400 W wherein the size of the electrode body and the lamp current fall within the aforementioned range, the intensity of noises was reduced to 20 dB max. in each case. The embodiment of FIGS. **17** to **20** also enabled the intensity of noises to be decreased with respect to the frequencies shown in FIG. **16**.

FIG. **20** indicates changes in the performance characteristics of lumens per unit of power power during the life time of a high pressure mercury vapor lamp, as compared between this invention and the prior art. The ordinate represents lumens per unit of power (*Lm*/*W*) and the abscissa the lighting time of said lamps. The conventional discharge lamp (curve B) using an electrode body made of compact tungsten wire had a residual efficiency of 75 to 80 percent as measured after 6000 hours of lighting time, whereas that of the present invention (curve A) was elevated to 90 percent, effectively reducing the occurrence of noises and improving the performance characteristics of lumens per unit of power.

According to the embodiment of FIGS. **17** to **20**, the electrode member is comprised of an electrode body made of a porous high melting metal having 5 to 30 percent porosity, wherein the ratio of the effective diameter *De*(mm) to the length *L*(mm) of said body and the ratio of said diameter *De*(mm) to the lamp current *Il*(A) satisfy the conditions of $9 \leqq L/D \leqq 35$ and $1 \leqq Il^{0.5}/De \leqq 3.16$ respectively, capable of prominently reducing radio frequency noises whose waves range from a medium wave to ultra shortwave band. The electrode body made of a porous high melting metal having a relatively large heat capacity permits firm deposition of electron emitting material and is adapted to be manufactured on an industrial scale due to a relatively simple construction like that of the prior art. Further, the material of the electrode body is little evaporated to minimize the blackening of the inner wall of the luminous tube, thereby extending the life of a discharge lamp.

What we claim is:

1. A metal vapor discharge lamp comprising a pair of electrodes placed in a heat resistant transparent luminous tube in which there are sealed readily ionizable inert gas and mercury, characterized in that the ratio of the effective diameter *De*(mm) to the length *L*(mm) of the electrode body and the ratio of said effective diameter *De*(mm) to the current *Il*(A) of said lamp when it is lighted under stable conditions satisfy the following formulas respectively:

$$15 \leqq L(\text{mm})/De(\text{mm}) \leqq 46$$

$$1.7 \leqq Il^{0.4}(\text{A})/De(\text{mm}) \leqq 4$$

2. A discharge lamp according to claim 1 wherein the electrode body has an entire length L and is formed into a tapered shape, the diameter D_1(mm) part of said body having a length L_1(mm) and the tapered part having a diameter D_2(mm) at the end and a length L_2(mm) and the effective diameter of said body being defined as

$$De=\{D_1L_1+(D_1+D_2)\times \tfrac{1}{2} L_2\}/L$$

3. A discharge lamp according to claim 1 wherein the electrode body comprises a broad portion having a diameter D_1(mm) and a length L_1 and a narrow concentric integral portion having a diameter D_2(mm) and a length L_2(mm) to form an entire length L(mm), the effective diameter of said body being defined as

$$De=[(D_1L_1+D_2L_2)]/L$$

4. A discharge lamp according to claim 1 wherein said electrode assembly comprises two electrode bodies, one of which has a diameter D_1(mm) and the other of which has a diameter D_2(mm), the end portions of said bodies lengthwise abutting against each other over a length L_1(mm), the free end portion of the diameter D_1 body having a length L_2(mm) and the free end portion of the diameter D_2(mm) body having a length L_3(mm) to form an entire length L(mm), the effective diameter of said electrode body assembly being defined as

$$De=\{D_1L_2+(D_1+D_2)L_1+D_2L_3\}/L$$

5. A metal vapor discharge lamp comprising a pair of electrodes placed in a heat resistant transparent luminous tube in which there are sealed readily ionizable inert gas and mercury, characterized in that the electrode body is comprised of a porous high melting temperature metal having 5 to 30 percent porosity and the ratio of the effective diameter De(mm) to the length L(mm) of the electrode body and the ratio of said effective diameter De(mm) to the current of the discharge lamp when it is lighted under stable conditions satisfy the following formulas respectively:

$$9 \leq L(\text{mm})/De(\text{mm}) \leq 35$$

$$1 \leq I^{0.5}(\text{A})/De(\text{mm}) \leq 3.16$$

6. A discharge lamp according to claim 5 wherein the porous high melting temperature metal of the electrode body is prepared by sintering the powders of tungsten, thallium-tungsten or molybdenum.

7. A discharge lamp according to claim 5 wherein the electrode body is partly formed into a tapered shape, the non-tapered part having a diameter D_1(mm) and a length L_1(mm) and the tapered part having a diameter D_2(mm) at the end and a length L_2(mm) to form an entire length L(mm), the effective diameter of said electrode body being defined as

$$De=\{D_1L_1+(D_1+D_2)\times \tfrac{1}{2}L_2\}/L$$

8. A discharge lamp according claim 5 wherein said electrode body comprises a broad portion having a diameter D_1(mm) and a length L_1(mm) and a narrow concentric integral portion having a diameter D_2(mm) and a length L_2(mm) to form an entire length L(mm), the effective diameter of said electrode body being defined as

$$De=[(D_1L_1+D_2L_2)]/L$$

9. A discharge lamp according to claim 5 wherein said electrode assembly comprises two electrode bodies, one of which has a diameter D_1(mm) and the other of which has a diameter D_2(mm), the end portions of said bodies lengthwise abutting against each other over a length L_1(mm), the free end portion of the diameter D_1(mm) body having a length and the free end portion of the diameter D_2(mm) body having a length L_3(mm) to form an entire length L(mm), the effective diameter of said electrode body assembly being defined as

$$De=\{D_1L_2+(D_1+D_2)L_1+D_2L_3\}/L$$

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