

CERAMIC METAL HALIDE LAMP

TECHNICAL FIELD

[0001]

The present invention relates to a ceramic metal halide lamp, in particular, a high wattage type ceramic metal halide lamp having an outer bulb of approximately cylindrical shape.

BACKGROOUND ART

[0002]

In recent years, ceramic metal halide lamps using a ceramic discharge vessel have been widely spread.

The ceramic metal halide lamp has typically a discharge vessel (a light emitting tube) made of ceramics and a translucent outer bulb which accommodates the discharge vessel.

The shape of outer bulb includes a B type (Bulged), G type (Globular), T type (Tubular), R type (Reflector), BT type (Bulged and Tubular), and the like.

The lighting direction includes a BH type (horizontal lighting type), BU type (vertical lighting type), and the like.

The BH type is such that the lamp is installed so that the lamp axis is approximately horizontal, but actually may be installed in such a state that the lamp center axis is inclined at an angle of 0° to 75° with respect to the horizontal direction.

The BU type is such that the lamp is installed so that the lamp base is positioned at upper side and the lamp center axis is approximately vertical.

[0003]

Generally, ceramic metal halide lamps of vertical lighting type are used mostly for high ceiling lighting apparatus in factory, gymnasium, or the like but those of horizontal lighting type are used mostly for an outdoor signboard lighting apparatus or the like. Here, "high wattage type" is of a rated lamp power of 450 W or more, in particular, 500~1000 W.

[Prior Art Document]

[Patent Literature]

[0004]

[Patent Literature 1] Japanese Patent Publication No. 2014-63623

[Patent Literature 2] WO 2006/001166 (Japanese Patent No. 4129279)

SUMMARY OF THE INVENTION

Problems to be solved by the invention

[0005]

The outer bulb of B type, G type, BT type or the like is swollen around the discharge vessel, and therefore, the outer diameter of outer bulb is relatively large.

Therefore, the space between the discharge vessel and the outer bulb can be made relatively large.

However, in a cylindrical outer bulb such as T type, the outer bulb and the discharge vessel are close to each other and therefore, the temperature of outer bulb becomes high. Particularly, in a high wattage type and horizontal lighting type lamp, the temperature of outer bulb becomes locally high at a part near the discharge vessel, and thermal deformation may occur.

[0006]

The object of the present invention is to provide a technique for preventing the thermal deformation of outer bulb due to high temperature in a high wattage ceramic metal halide lamp which is provided with a cylindrical outer bulb.

Means for Solving the Problems

[0007]

The present inventors have earnestly studied a means for avoiding an elevated temperature of outer bulb in a ceramic metal halide lamp of high wattage type and horizontal lighting type having a cylindrical outer bulb.

In order to prevent the elevated temperature of outer bulb, the distance between the outer bulb and discharge vessel is to be increased.

However, in case of a cylindrical outer bulb, it is impossible to increase the distance between an outer bulb and a discharge vessel.

Then, the inventors of the present invention have conceived an idea that a sleeve is provided between the outer bulb and the discharge vessel.

In an outer bulb of the BT type, it is known that a discharge vessel is covered with a sleeve in order to prevent the breakage of an outer bulb due to rupture of the discharge vessel.

However, in a high wattage ceramic metal halide lamp which is provided with a cylindrical outer bulb, it is not known that a sleeve is provided in order to prevent the elevated temperature of outer bulb.

[0008]

Then, the inventors of the present invention have carried out a large number of experiments to confirm that by providing a sleeve between a discharge vessel and an outer bulb,

it is possible to prevent the elevated temperature of outer bulb.

[0009]

According to an embodiment of the present invention, there is provided a ceramic metal halide lamp comprising a discharge vessel for containing light emitting material and a translucent outer bulb for accommodating the discharge vessel, wherein

a sleeve is provided between the discharge vessel and the outer bulb, and assuming that a rated lamp power is P [W], a radius of an inner surface of the outer bulb being R_3 [mm], a distance between an outer surface of the discharge vessel and an inner surface of the sleeve being t_1 [mm], and a distance between an outer surface of the sleeve and the inner surface of the outer bulb being t_2 [mm], the following equations are satisfied.

$$(R_3/P) \leq 0.06 \text{ [mm/W]}$$

$$1.0 \leq t_2/t_1 \leq 2.0$$

[0010]

According to an embodiment of the present invention, in the ceramic metal halide lamp, further the following equation may be satisfied.

$$(t_1+t_2)/P \leq 0.037 \text{ [mm/W]}$$

[0011]

According to an embodiment of the present invention, in the ceramic metal halide lamp, the rated lamp power may be equal to or more than 500 W and of horizontal lighting type.

[0012]

According to an embodiment of the present invention, in the ceramic metal halide lamp, the outer bulb may be filled with an inert gas.

[0013]

According to an embodiment of the present invention, in the ceramic metal halide lamp, further the following equation may be satisfied.

$$t_1/P > 0.01 \text{ [mm/W]}$$

[0014]

According to an embodiment of the present invention, in the ceramic metal halide lamp, the sleeve may be made of quartz glass.

Effects of Invention

[0015]

According to the present invention, there is provided a technique for preventing the thermal deformation of outer bulb due to high temperature in a high wattage ceramic metal halide lamp which is provided with a cylindrical outer bulb.

BRIEF DESCRIPTION OF DRAWINGS

[0016]

[Fig. 1A]

FIG. 1A is a view for explaining an embodiment of the ceramic metal halide lamp according to the present invention.

[Fig. 1B]

FIG. 1B is a view for explaining an embodiment of the ceramic metal halide lamp according to the present invention.

[Fig. 2A]

FIG. 2A is a view for explaining an embodiment of discharge vessel of the ceramic metal halide lamp according to the present invention.

[Fig. 2B]

FIG. 2B is a view for explaining the dimensions of discharge vessel of the ceramic metal halide lamp according to the present invention.

[Fig. 2C]

FIG. 2C is a view for explaining the dimensions of outer bulb, sleeve and discharge vessel of the ceramic metal halide lamp according to the present invention.

[Fig. 3A]

FIG. 3A is a view for explaining an example of shape of T type lamp.

[Fig. 3B]

FIG. 3B is a view for explaining an example of shape of B type lamp.

[Fig. 3C]

FIG. 3C is a view for explaining an example of shape of BT type lamp.

[Fig. 4A]

FIG. 4A is a graph for showing a relationship between a rated lamp power “P” and a ratio “ R_3/P ” between inner radius of outer bulb 111 and rated lamp power, which had been obtained by the experiments by the present inventors.

[Fig. 4B]

FIG. 4B is a graph for showing a relationship between a ratio “ R_3/P ” and a highest temperature of outer bulb surface, which had been obtained by the experiments by the present inventors.

[Fig. 5A]

FIG. 5A is a view for showing a relationship between rated lamp power “P” and a ratio “ $(t_1+t_2)/P$ ”, which had been obtained by the experiments by the present inventors.

[Fig. 5B]

FIG. 5B is a graph for showing a relationship between a ratio " $(t_1+t_2)/P$ " and a highest temperature of outer bulb surface, which had been obtained by the experiments by the present inventors.

[Fig. 6]

FIG. 6 is a graph for showing a relationship between a ratio " t_2/t_1 " and a highest temperature of outer bulb surface, which had been obtained by the experiments by the present inventors.

MODES FOR CARRYING OUT THE INVENTION

[0017]

Hereafter, with respect to embodiments of ceramic metal halide lamp according to the present invention, explanations are given in detail with reference to the accompanying drawings. In addition, in the figures the same reference signs are added to the same elements and overlapped explanations are omitted.

[0018]

FIG. 1A and FIG. 1B are views for explaining the structure of ceramic metal halide lamp of high wattage type and horizontal lighting type (BH type) according to the present embodiment. FIG. 1A and FIG. 1B show the structure of ceramic metal halide lamp viewed from the two directions which are orthogonal to the center axis of the lamp, and also orthogonal to each other.

Here, "high wattage type" is of a rated lamp power of 450 W or more, in particular, 500~1000 W, typically about 600~700 W.

The horizontal lighting type (BH type) is such that the lamp is installed so that the lamp axis is approximately horizontal, but actually may be installed in such a state that the lamp center axis is inclined at an angle of 0° to 75° with respect to the horizontal direction.

[0019]

The ceramic metal halide lamp 100 has a translucent outer bulb (outer tube) 111, a discharge vessel (light emitting tube) 130 made of ceramics arranged in the inside of outer bulb and a cylindrical translucent sleeve 108 (FIG. 1A) which is arranged to cover the discharge vessel 130.

The outer bulb 111 has a top part 111b of a cylindrical container shape, a cylindrical part 111a and a neck part 111c. The outer diameter of cylindrical part 111a is substantially constant. The outer diameter of cylindrical part 111a is larger than those of neck part 111c and top part 111b respectively.

Accordingly, at the boundary between cylindrical part 111a and top part 111b and at the boundary between cylindrical part 111a and neck part 111c, a small inclined part is formed respectively. The outer bulb 111 of the present embodiment is of a cylindrical shape and is in particular referred to as TT type. The axial dimension of cylindrical part 111a is sufficiently larger than those of discharge vessel 130 and sleeve 108 respectively.

[0020]

At neck part 111c, a sealing part (not shown in the figure) is formed. An E type base 112 of screw shape is mounted to cover the sealing part. Base 112 is bonded by using a heat-resistant adhesive or engaged with the spiral screw groove which is formed by molding. At the sealing part of neck part 111c, the flare part of stem pipe 115 is sealed, in which a pair of lead-wires are air-tightly sealed.

[0021]

By stem pipe 115, a support 109 is supported which is made of a metal wire of reverse U letter shape. On support 109, a pair of mount support plates 114A and 114B are mounted. One of mount support plates 114A is arranged on top part 111b of outer bulb 111, and the other of mount support plate 114B is arranged on neck part 111c of outer bulb 111. Support 109 supports discharge vessel 130 at a predetermined position, and simultaneously has a feeding function to feed power to discharge vessel 130.

[0022]

Ceramic metal halide lamp 100 is further provided with a getter 113 and a starter 110. In this embodiment, the getter 113 is mounted to support 109 on the top side of discharge vessel 130, and starter 110 is mounted to support 109 on the neck side of discharge vessel 130, respectively. Further, a wire may be wound on the periphery of sleeve 108 in a spiral shape in order to prevent the damage of outer bulb 111 in case of rupture of discharge vessel 130.

[0023]

Outer bulb 111 is, for example, made of translucent hard glass such as borosilicate glass or the like. Sleeve 108 is made of translucent quartz glass. The inside of outer bulb 111 may be evacuated but may be filled with an inert gas such as argon (Ar), a nitrogen (N₂) or the like.

It is advantageous that the inside of outer bulb 111 is evacuated in order to hold discharge vessel 130 to a high temperature. By maintaining discharge vessel 130 to be a high temperature, the lamp efficiency (light emission efficiency) becomes high and the evaporation of light emitting material having a relatively low vapor pressure and sealed in discharge vessel 130 can be promoted.

[0024]

In a ceramic metal halide lamp 100, by mounting base 112 to a socket (not shown in the figure) and by supplying an electric current through a predetermined lighting circuit (not shown in the figure) from a power source, an electric discharge is generated between the electrodes in discharge vessel 130. Thereby a stable lighting is maintained.

[0025]

With reference to FIG. 2A, a structure of discharge vessel 130 will be explained. Discharge vessel 130 has a light emitting part 130C at the center, and narrow tube parts (capillary parts) 130A, 130B on both sides of light emitting part. The present discharge vessel 130 is of so-called integrated type in which light emitting part 130C of a substantially spheroidal shape and narrow tube parts 130A, 130B on both sides of light emitting part are integrally formed. However, the discharge vessel 130 may be formed by connecting narrow tube parts 130A and 130B manufactured separately on both sides of light emitting part 130C.

[0026]

To narrow tube parts 130A and 130B, electrode systems 120a and 120b are mounted, respectively. Electrode systems 120a and 120b have a tungsten electrode 123, a current supply conductor 122 and a lead wire 121, respectively. To the tip of tungsten electrode 123, a tungsten coil is mounted. The tip of tungsten electrode 123 is disposed at the light emitting part 130C of discharge vessel 130.

[0027]

A current supply conductor 122 includes a halogen resistant intermediate member 122a and a conductive cermet rod 122b. Tungsten electrodes 123, current supply conductor 122 and lead wire 121 are connected to each other by butt welding.

[0028]

In light emitting part 130C of discharge vessel 130, an additive is sealed as a light emitting material in addition to mercury and inert gas. The amount of mercury is 100 mg at maximum, preferably, about 85 mg. The additive includes a halide of an alkali metal, a halide of an alkaline earth metal, a halide of a rare earth metal, or the like. The total amount of additives is 20 mg at the maximum. The inert gas is for example a rare gas, but is argon in the embodiment.

[0029]

When the ceramic metal halide lamp is turned on, mercury and additives are heated in the light emitting part 130C, and are evaporated partially to be excited by discharge to emit light.

The remaining part is pooled as a liquid phase state at the bottom part of light emitting part 130C. A part of liquid phase is evaporated, circulated by convection in the inside of light

emitting part 130C. and returns to its bottom part. Such a cycle is repeated during the lamp lighting.

[0030]

With reference to FIG. 2B, dimensions of discharge vessel 130 and sleeve 108 of ceramic metal halide lamp according to the present embodiment will be explained.

The axial dimension of discharge vessel 130 is assumed to be "L1", the outer diameter of light emitting part 130C is assumed to be "D1", and the effective inner diameter of light emitting part 130C is assumed to be "D". The outer diameter "D1" is the maximum outer diameter of light emitting part 130C, that is, the outer diameter of light emitting part 130C at the central part.

The effective inner diameter "D" is the maximum inner diameter of light emitting part 130C, that is, the inner diameter of light emitting part 130C at the central part. The outer diameter of sleeve 108 is assumed to be "D2", and the axial dimension of sleeve 108 is assumed to be "L2". The dimension "L2" is, at least, larger than the axial dimensions of light emitting part 130C.

[0031]

The arc length "AL" is defined by the distance between the two electrodes 123. Namely, the arc length "AL" is the distance between the tips of two electrodes 123 in the light emitting part 130C. The ratio "AL/D" between the effective inner diameter "D" and the arc length "AL" of discharge vessel is referred to as "shape parameter" of discharge vessel 130.

In case of light emitting part 130C being a long and thin type, the value of shape parameter "AL" is increased, while in case of light emitting part 130C being a thick and short type, the value of shape parameter "AL" is smaller.

[0032]

The electrode projection length "L" is defined by the length of electrode 123 projected in the light emitting part 130C. In other words, the electrode projection length "L" is the distance between the outer periphery of transitional curved surface L_s formed at a boundary between light emitting part 130C and thin tube 130A, 130B and the tip of electrode 123.

Further, in case that the light emitting part 130C is of a cylindrical shape, the electrode projection length L is the distance between an end surface of light emitting part 130C and the tip of electrode 123. The ratio "L/D" of electrode projection length L to effective inner diameter D is referred to as "electrode parameter". As a performance parameter of discharge vessel 130, a wall surface load is used. Here, the wall surface load is defined by a value obtained by dividing a rated lamp power by the whole inner surface area of light emitting part 130C.

[0033]

In the ceramic metal halide lamp of horizontal lighting type, it happens that a discharge arc 123A (FIG. 2A) generated between electrodes 123 is floated to be in proximity to or be brought into contact with the inner surface of light emitting part 130C of discharge vessel.

Thus, light emitting part 130C is locally overheated and it may cause cracks of discharge vessel.

The inventors of the present invention have carried out a large number of experiments and set conditions to avoid breakage of discharge vessel in a ceramic metal halide lamp of high wattage type and horizontal lighting type such that a rated lamp power is 500~1000 W as follows.

The arc length is of $AL = 25$ to 34 mm, the shape parameter is of $AL/D = 1.00$ to 2.00 as the unit of D is “mm”, and the electrode parameter is of $L/D = 0.60$ to 1.00 . More preferably, the shape parameter is of $AL/D = 1.20$ to 1.60 , and the electrode parameter is of $L/D = 0.70$ to 0.90 . Further, the wall surface load is $10\sim30$ W/cm², more preferably, $15\sim20$ W/cm².

[0034]

With reference to FIG. 2C, dimensions among discharge vessel 130, sleeve 108 and outer bulb 111 of ceramic metal halide lamp according to the present embodiment will be explained.

The distance between the center axis 130L of discharge vessel 130 and the outer surface of light emission part 130C of discharge vessel 130, namely, the radius of outer surface of light emitting part 130C is R_1 . The outer surface radius R_1 of light emitting part 130C is a half of outer diameter $D1$ of light emitting part 130C. The distance between the center axis 130L of discharge vessel 130 and the inner surface of sleeve 108, namely, the radius of inner surface of sleeve 108 is R_2 .

The distance between the center axis 130L of discharge vessel 130 and the inner surface of outer bulb 111, namely, the radius of inner surface of outer bulb 111 is R_3 . Further, the distance between the outer surface of light emitting part 130C and the inner surface of sleeve 108 is referred to as inner gap “ t_1 ”, and the distance between the outer surface of sleeve 108 and the inner surface of outer bulb 111 is referred to as outer gap “ t_2 ”.

[0035]

The relationship among the outer diameter $D1$ of light emitting part 130C, outer diameter $D2$ of sleeve 108, outer surface radius R_1 of light emitting part 130C, inner surface radius R_2 of sleeve 108, inner surface radius R_3 of outer bulb 111, inner gap t_1 , and outer gap t_2 is represented by the following formulas.

[0036]

$$R_3 = R_2 + \Delta t_s + t_2 = R_1 + t_1 + \Delta t_s + t_2$$

$$D1 = 2 \times R_1 = 2 \times \Delta td + D$$

$$D2 = 2 \times (R_2 + \Delta ts)$$

Here, Δts is the thickness of sleeve 108, Δtd is the thickness of light emitting part 130C, and Δtb is the thickness of outer bulb 111.

[0037]

With reference to FIG. 3A, FIG. 3B, and FIG. 3C, examples of shape of outer bulb of the lamp will be explained.

The outer bulb of lamp of FIG. 3A is of a cylindrical shape, referred to as T type (Tubular), the outer bulb of lamp of FIG. 3B is of barrel shape, referred to as B type (Bulged), and the outer bulb of lamp of FIG. 3C is of a composite of Tubular and Bulged, referred to as BT type. A method for expressing types of lamp is defined in JIS 7710 and it is expressed as a combination of alphabets and numerals. The alphabet indicates lamp type, and the number indicates the nominal value (mm) of outer diameter of the maximum part. For example, "T48" indicates T type and the nominal value of outer diameter at the maximum part being 48 mm.

Further, the outer bulb of the lamp shown in FIG. 1A and FIG. 1B is of a composite type of cylindrical shapes and referred to as TT type. In the specification of the present application, the outer bulb of cylindrical shape indicates T type, TT type, or the like and means that the outer bulb is not swollen at least around the discharge vessel.

[0038]

As described above, the inventors of the present invention have considered earnestly a means for avoiding an elevated temperature of outer bulb in a ceramic metal halide lamp of high wattage type and horizontal lighting type which is provided with a cylindrical outer bulb.

Then, the inventors of the present invention have conceived an idea to provide a sleeve between the outer bulb and the discharge vessel.

In general, in a ceramic metal halide lamp, to provide a cylindrical sleeve between the outer bulb and the discharge vessel is known in the conventional technology.

However, in the conventional technique, the sleeve is provided in order to prevent the breakage of outer bulb when the discharge vessel is broken. Further, a sleeve is used in such a case that an outer bulb is swollen at the center part such as of BT type, and is not used in the cylindrical outer bulb such as T type.

The inventors of the present invention have carried out a large number of experiments and confirmed that by using a sleeve, it is possible to avoid the elevated temperature of cylindrical outer bulb.

[0039]

At first, the inventors of the present invention have set the upper limit of temperature

of outer bulb during lighting.

With respect to the safety standard regarding the temperature of outer bulb made of hard glass, there is no regulations in case of ceramic metal halide lamp, but with respect to high-pressure sodium lamp, there is a regulation as IEC 60662 (2011). According to it, in the case of the Japanese Specification, the upper limit of surface temperature of outer bulb during bare lighting at rated lamp power is 400 °C.

Accordingly, the inventors of the present invention have set a condition such that the maximum temperature of outer bulb during lighting at a rated lamp power is 400 °C or lower.

[0040]

Hereinafter, with reference to Tables 1, 2 and 3, explanations will be given to experiments which were carried out by the present inventors, and embodiments of the present invention.

The table 1 shows the specifications of ceramic metal halide lamps used in experiments performed by the present inventors and results thereof.

The present inventors have carried out a number of experiments, but as shown in first column of Table 1, explanations will be given to embodiments 1~4, comparative examples 1~7 and conventional examples 1~3. Further, embodiments 1~4 are based on experiments which the present inventors have carried out for the first time, and comparative examples 1~7 and conventional examples 1~3 are based on experiments which the present inventors had already carried out and known experiments respectively.

[0041]

As shown in second column of Table 1, lamps of a rated lamp power 660W are used as examples of high wattage type, and lamps of a rated lamp power of 250 W and 400 W are used as examples of middle wattage type.

As shown in third column of Table 1, shapes of lamps are mainly cylindrical (T type or TT type), but conventional examples 1 and 2 are of BT type. As described above, the lamp type is expressed as a combination of alphabets and numerals. The alphabet indicates lamp type, and the numeral indicates the nominal value (mm) of outer diameter at the maximum part. For example, “T48” indicates T type and the nominal value of outer diameter at the maximum part being 48 mm.

[0042]

[Table 1]

Table 1

	L power P[W]	Shape of Outer Bulb	Lighting Direction	Gas in Outer Bulb	Sleeve	Temp. of Outer Bulb [°C]
Embodiment 1	660	TT67	BH	GAS	YES	390
Embodiment 2	660	TT80	BH	GAS	YES	385
Embodiment 3	400	T48	BH	GAS	YES	380
Embodiment 4	400	T48	BH	NO	YES	375
Comparative Ex 1	660	TT67	BH	NO	NO	405
Comparative Ex 2	660	TT67	BH	GAS	NO	435
Comparative Ex 3	660	TT67	BH	GAS	YES	405
Comparative Ex 4	400	T48	BH	NO	NO	390
Comparative Ex 5	400	T48	BU	NO	YES	375
Comparative Ex 6	400	T55	BU	NO	YES	305
Comparative Ex 7	250	T48	BH	NO	YES	370
Conventional Ex 1	660	BT150	BU	NO	YES	160
Conventional Ex 2	660	BT150	BH	NO	NO	180
Conventional Ex 3	660	TT120	BH	NO	YES	382

[0043]

As shown in fourth column of Table 1, the lighting direction of lamps of embodiments 1~4 is a horizontal lighting type (BH type) but that of comparative examples 5, 6 and a conventional example 1 is a vertical lighting type (BU type).

As shown in fifth column of Table 1, there are prepared examples such that the outer bulb is evacuated and examples such that the outer bulb is filled with an inert gas.

[0044]

As shown in sixth column of Table 1, in embodiments 1~4, there are prepared lamps in which a sleeve is mounted, and in conventional examples and comparative examples, there are included lamps in which no sleeve is mounted.

Among examples 1~4, comparative examples 1~7, and conventional examples 1~3, only examples 1 and 2, comparative example 3 and conventional example 3 are of high wattage type and horizontal lighting type having an outer bulb of cylindrical shape (TT type or T type) and being provided with sleeve 108.

[0045]

The 7th column of Table 1 shows lighting test results, namely, the results of measurement of highest surface temperature of outer bulbs. Only in examples 1~4, comparative

examples 4~7, and conventional examples 1~3, the maximum temperature of outer bulb during lighting at a rated lamp power is 400 °C or lower. In these examples, only embodiments 1 and 2 and conventional example 3 are of high wattage type and horizontal lighting type having an outer bulb of cylindrical shape (TT type or T type) and being provided with a sleeve 108.

However, the outer bulb shape of conventional example 3 is of TT120 as shown in the third column of Table 1. It means that the shape of outer bulb is a cylindrical shape, but the outer diameter at the maximum part is 120 mm. An outer diameter of outer bulb of ceramic metal halide lamp of conventional example 3 is relatively large and therefore, it is less likely that outer bulb 111 is thermally deformed by a high temperature. On the other hand, outer bulb shapes of embodiments 1, 2 are of TT 67 and TT 80, and outer diameters at the maximum part of outer bulb are at most 80 mm. Elevated temperature of outer bulb becomes a problem in such a lamp which is provided with a cylindrical outer bulb having at least outer diameter of 100 mm or less such as embodiments 1 and 2.

Embodiments of the present invention do not include such a lamp having a relatively large outer diameter such as conventional example 3.

[0046]

The presence or absence of gas in outer bulb as described in the fifth column of Table 1 will be explained.

As mentioned above, if outer bulb 111 is evacuated rather than filled with an inert gas, discharge vessel 130 can be held at a high temperature, to promote evaporation of light emitting material, and a lamp efficiency is increased. On the other hand, if outer bulb 111 is filled with an inert gas rather than evacuated, the temperature of outer bulb 111 becomes higher. This can be understood by, for example, comparing a comparative example 1 with a comparative example 2. Especially, in case of horizontal lighting type and outer bulb 111 being filled with an inert gas, the temperature of outer bulb becomes high.

However, according to embodiments of the present invention, lamps are of horizontal lighting type, and outer bulb 111 is filled with an inert gas. The reason is based on the consideration of deformation of outer bulb at high temperature as described below.

[0047]

In the case of outer bulb 111 being evacuated, an atmospheric pressure is applied on outer surface of outer bulb.

Therefore, when the outer bulb is thermally deformed, it is contracted so as to be closer to a discharge vessel. If the distance between the outer bulb and the light emitting part of discharge vessel is locally reduced, the temperature of outer bulb becomes high locally to increase the thermal deformation. On the other hand, if the outer bulb 111 is filled with an inert

gas, the outer bulb is deformed so as to be swollen outwardly by thermal deformation.

Then, the distance between the discharge vessel and the light emitting part of outer bulb is increased to lower the temperature of outer bulb, and deformation is stopped. Therefore, in order to suppress the thermal deformation of outer bulb, outer bulb 111 should be filled with an inert gas rather than evacuated.

According to embodiments of the present invention, since there is provided with a sleeve 108, it is possible to suppress the maximum temperature of outer bulb to be 400°C or lower.

Therefore, even if outer bulb 111 is filled with an inert gas or evacuated, thermal deformation of outer bulb does not occur. However, considering such a case that the outer bulb is thermally deformed by unexpected situation, the outer bulb 111 is preferably filled with an inert gas.

[0048]

[Table 2]

Table 2

	Radius [mm]			Gap [mm]		
	R ₁	R ₂	R ₃	t ₁	t ₂	R ₃ -R ₁
Embodiment 1	12.0	20.5	32.0	8.50	9.50	20.0
Embodiment 2	12.0	20.5	38.4	8.50	16.00	26.4
Embodiment 3	10.7	15.7	22.8	5.00	5.10	12.1
Embodiment 4	10.7	15.7	22.8	5.00	5.10	12.1
Comparative Ex 1	12.0	-	32.0	-	-	20.0
Comparative Ex 2	12.0	-	32.0	-	-	20.0
Comparative Ex 3	12.0	15.7	32.0	3.70	14.30	20.0
Comparative Ex 4	10.7	-	22.8	-	-	12.1
Comparative Ex 5	10.7	13.0	22.8	2.30	7.80	12.1
Comparative Ex 6	10.7	13.0	26.3	2.30	11.30	15.6
Comparative Ex 7	7.9	11.0	22.8	3.15	9.80	14.9
Conventional Ex 1	12.0	20.5	73.8	8.50	51.30	61.8
Conventional Ex 2	12.0	-	73.8	-	-	61.8
Conventional Ex 3	12.0	20.5	58.4	8.50	36.00	46.4

[0049]

Table 2 shows the results of measurement of outer surface radius R₁ of light emitting part 130C, inner surface radius R₂ of sleeve 108, outer surface radius R₃ of outer bulb 111, difference R₃-R₁ between inner surface radius of outer bulb 111 and outer surface radius of light emitting part 130C, inner gap t₁ and outer gap t₂ of ceramic metal halide lamp used in

experiments which the present inventors have performed.

[0050]

[Table 3]

Table 3

	L power P[W]	Temp. of Outer Bulb [°C]	t_2/t_1	R_3/P	$(t_1 + t_2)/P$	FIG. 4B	FIG. 4A 5A,5B,6
Embodiment 1	660	390	1.12	0.048	0.0273	○	○
Embodiment 2	660	385	1.88	0.058	0.0371	○	○
Embodiment 3	400	380	1.02	0.057	0.0253	○	○
Embodiment 4	400	375	1.02	0.057	0.0253	○	○
Comparative Ex 1	660	405	-	0.048	-		
Comparative Ex 2	660	435	-	0.048	-	△	
Comparative Ex 3	660	405	3.86	0.048	0.0273	△	△
Comparative Ex 4	400	390	-	0.057	-	△	
Comparative Ex 5	400	375	3.39	0.057	0.0253	△	△
Comparative Ex 6	400	305	4.91	0.066	0.0340		△
Comparative Ex 7	250	370	3.11	0.091	0.0518		△
Conventional Ex 1	660	160	6.04	0.112	0.0906	□	□
Conventional Ex 2	660	180	-	0.112	-	□	
Conventional Ex 3	660	382	4.24	0.088	0.0674	□	

[0051]

Table 3 shows the calculation results of relationship among inner gap t_1 , outer gap t_2 and rated lamp power P of ceramic metal halide lamps used in experiments which the present inventors of the present invention have performed. The second column of Table 3 shows rated lamp power P, the third column showing measurement results of maximum temperature of outer bulb, the fourth column showing ratio of outer gap t_2 to inner gap t_1 , the fifth column showing ratio R_3/P of inner surface radius R_3 of outer bulb 111 to rated lamp power P, the sixth column showing ratio $(t_1+t_2)/P$ of sum of gaps to rated lamp power P. The significances of ratio R_3/P , ratio $(t_1+t_2)/P$, and ratio t_2/t_1 will be explained later on with reference to FIG. 4A~FIG. 6. In 7th and 8th columns of Table 3, drawing numbers using these data are indicated.

[0052]

With reference to FIG. 4A and FIG. 4B, explanation will be given. FIG. 4A is a graph showing the relationship between rated lamp power P and ratio of inner surface radius R_3 of outer bulb 111 to rated lamp power P. The horizontal axis indicates rated lamp power P [W], and the vertical axis indicates ratio R_3/P [mm/W].

FIG. 4A is a graph which is obtained by graphing a part of data in the second column

and fifth column of Table 3. As shown in eighth column of Table 3, circle marks indicate plotting of embodiments 1~4, triangular marks indicate plotting of comparative examples 3, 5, 6, 7 and square marks indicate plotting of conventional example 1.

[0053]

FIG. 4B is a graph showing a relationship between the ratio R_3/P and the highest temperature on surface of outer bulb. The lateral axis indicates ratio R_3/P [mm/W], and vertical axis indicates the highest temperature [°C] on outer bulb surface. FIG. 4B is a graph obtained by graphing a part of data in the third column and fifth column of Table 3. As shown in seventh column of Table 3, circle marks indicate plotting of embodiments 1~4, triangular marks indicate plotting of comparative examples 2~5 and square marks indicate plotting of conventional examples 1~3.

[0054]

Hereinafter, the significance of ratio R_3/P [mm/W] will be considered. The present inventors have focused on the rated lamp power and the outer diameter of outer bulb as factors exerting influence on the surface temperature of outer bulb.

If the rated lamp power is constant, it is supposed that when the outer diameter of outer bulb is decreased, the surface temperature of outer bulb becomes higher and when the outer diameter of outer bulb is increased, the surface temperature of outer bulb becomes lower.

Conversely, if the outer diameter of outer bulb is constant, it is supposed that when the rated lamp power is increased, the surface temperature of outer bulb is increased and when the rated lamp power is decreased, the surface temperature of outer bulb is decreased.

In other words, it can be said that the outer diameter of outer bulb and the rated lamp power give influence on the surface temperature of outer bulb inversely to each other.

The present inventors have set the ratio of the two as a parameter. The dimension of the ratio [mm/W] does not have a special physical meaning.

[0055]

In FIG. 4A, comparison will be made between examples 1~4 and comparative examples 2~5.

When rated lamp power is increased, the ratio R_3/P is reduced. However, the value of ratio R_3/P of conventional example 1 is larger than the values of R_3/P of embodiments and comparative examples. The reason of this is that shape of outer bulb of lamp of conventional example 1 is of BT type, and the outer diameter of outer bulb is relatively large.

In FIG. 4B, it can be said that there is a tendency such that if ratio R_3/P is increased, the surface temperature of outer bulb becomes lower. This is nearly coincide with the above assumption.

However, in embodiments of the present invention, such lamps having an outer diameter being relatively large are not assumed. Accordingly, it is necessary to set an upper limit of ratio R_3/P , but this will be explained later on.

[0056]

With reference to FIG. 5A and FIG. 5B, explanations will be given. FIG. 5A shows a graph indicating the relationship between rated lamp power P and ratio $(t_1+t_2)/P$. The horizontal axis indicates rated lamp power P [W] and vertical axis indicates the ratio $(t_1+t_2)/P$ [mm/W].

FIG. 5A is a diagram obtained by graphing a part of data in second and sixth columns of Table 3. As shown in eighth column of Table 3, circle marks indicate plotting of embodiments 1~4 and triangular marks indicate plotting of comparative examples 3, 5, 6 and 7, and square marks indicate plotting of conventional example 1.

[0057]

FIG. 5B shows a graph showing relationship between the ratio $(t_1+t_2)/P$ and the highest surface temperature of outer bulb.

The horizontal axis indicates ratio $(t_1+t_2)/P$ [mm/W] and vertical axis indicates the highest surface temperature [°C] of outer bulb. FIG. 5B is a diagram obtained by graphing a part of data in third and sixth columns of Table 3.

As shown in eighth column of Table 3, circle marks indicate plotting of embodiments 1~4, triangular marks indicate plotting of comparative examples 3, 5, 6 and 7, and square marks indicate plotting of conventional example 1.

[0058]

Hereinafter, the significance of ratio $(t_1+t_2)/P$ [mm/W] will be considered. Further, the present inventors have focused on the dimension of gap between outer bulb and discharge vessel as a factor exerting influence on the surface temperature of outer bulb.

If the rated lamp power is constant, it is supposed that when the dimension of gap between outer bulb and discharge vessel is decreased, the surface temperature of outer bulb becomes higher and when the dimension of gap between outer bulb and discharge vessel is increased, the surface temperature of outer bulb becomes lower.

Conversely, if the dimension of gap between outer bulb and discharge vessel is constant, it is supposed that when the rated lamp power is increased, the surface temperature of outer bulb is increased and when the rated lamp power is decreased, the surface temperature of outer bulb is decreased.

In other words, it can be said that the rated lamp power and the dimension of gap between outer bulb and discharge vessel give influence on the surface temperature of outer bulb inversely to each other.

The present inventors have set the ratio of the two as a parameter. The dimension of the ratio [mm/W] does not have a special physical meaning.

Further, the sum (t_1+t_2) of inner gap t_1 and outer gap t_2 is smaller than the gap between outer bulb and the light emitting part of discharge vessel by the thickness Δt_s of sleeve 108, but it can be supposed that the former approximately corresponds to the latter.

[0059]

In FIG. 5A, comparison will be made between examples 1~4 and comparative examples 2~5. Even if the rated lamp power becomes large, ratio $(t_1+t_2)/P$ is constant or becomes smaller.

However, value of ratio $(t_1+t_2)/P$ of conventional example 1 is larger than the values of ratio $(t_1+t_2)/P$ of embodiments and comparative examples. The reason is that the shape of outer bulb of lamp of conventional example 1 is of BT type and the outer diameter of outer bulb is relatively large.

[0060]

In FIG. 5B, it can be said that there is a tendency such that when ratio $(t_1+t_2)/P$ is increased, the surface temperature of outer bulb becomes lower. This is nearly coincide with the above assumption. However, in embodiments of the present invention, lamps having a relatively large diameter are not assumed.

Consequently, it is necessary to set an upper limit of ratio $(t_1+t_2)/P$, but with regard to this, explanations will be given later on.

[0061]

With reference to FIG. 6, explanation will be given. FIG. 6 is a graph showing the relationship between ratio t_2/t_1 and the highest surface temperature of outer bulb. The horizontal axis indicates ratio t_2/t_1 , and the vertical axis indicates the highest surface temperature of outer bulb.

FIG. 6 is a graph which is obtained by graphing a part of data in the third column and sixth column of Table 3. As shown in eighth column of Table 3, circle marks indicate plotting of embodiments 1~4, triangular marks indicate plotting of comparative examples 3, 5, 6 and 7, and square marks indicate plotting of conventional example 1.

[0062]

Hereinafter, the significance of ratio t_2/t_1 will be considered. The present inventors have focused on the ratio t_2/t_1 of outer gap t_2 to inner gap t_1 as a factor exerting influence on the surface temperature of outer bulb. Even if the gap between the outer bulb and the light emitting part of discharge vessel is constant, it is supposed that when the ratio t_2/t_1 is changed, the surface temperature of outer bulb becomes different.

Further, the sum (t_1+t_2) of inner gap t_1 and outer gap t_2 is smaller than the gap between outer bulb and the light emitting part of discharge vessel by the thickness Δt_s of sleeve 108, but it can be supposed that the former approximately corresponds to the latter. The present inventors have set the ratio t_2/t_1 of the two as a parameter.

[0063]

The inventors of the present invention have carried out a large number of experiments and studied the preferable relationship between the outer gap t_2 and the inner gap t_1 as to which of the two should be larger or not.

If outer gap t_2 is smaller than inner gap t_1 , sleeve 108 becomes close to outer bulb 111. In such a case, the heat from sleeve 108 does not diffuse and is transferred directly to outer bulb 111. As a result, it is found that thermal deformation of outer bulb 111 may occur.

The inventors of the present invention have reached a conclusion that it is necessary that outer gap t_2 should be equal to or more than inner gap t_1 , namely, $t_2 \geq t_1$, or $t_2/t_1 \geq 1$.

[0064]

However, if outer gap t_2 is too large relative to inner gap t_1 , sleeve 108 becomes adjacent to light emitting part 130C. In this case, the temperature of sleeve 108 becomes high.

As a result, it was found that it is possible that the outer bulb is heated by heat radiation from the outer surface of sleeve 108 and thermal deformation of outer bulb may occur.

Accordingly, it is necessary to set a lower limit of ratio t_2/t_1 , but explanations thereof will be given later on.

[0065]

From Table 3, and graphs of FIG. 4B, FIG. 5B and FIG. 6, in a ceramic metal halide lamp of high wattage type and horizontal lighting type having a cylindrical outer bulb, values of ratio R_3/P , ratio $(t_1+t_2)/P$ and ratio t_2/t_1 will be set as conditions necessary to prevent the thermal deformation of outer bulb due to high temperature.

At first, the upper limit of R_3/P will be considered. In embodiments of the present invention, lamps having a cylindrical outer bulb with a relatively small diameter are assumed.

Considering the ratios R_3/P of embodiments 1~4, the upper limit of ratio R_3/P is set to be 0.06 [mm]. By setting the upper limit of ratio R_3/P to be 0.06 [mm], the shape of outer bulb in embodiments of the present invention is determined to be cylindrical such as T type, TT type or the like, and does not include BT type.

Next, the lower limit of ratio R_3/P will be considered. The lamp rated power is 600~700 W or the like and it can be assumed that rated power is constant. Considering the minimum outer diameter of cylindrical outer bulb, ratio R_3/P is at most 0.010 or the like.

[0066]

Then, ratio t_2/t_1 will be considered. As described above, the lower limit of ratio t_2/t_1 has been set, such as $t_2/t_1 \geq 1$. Therefore, upper limit of ratio t_2/t_1 will be set hereinafter. As described above, if ratio t_2/t_1 is too large, sleeve 108 is close to the light emitting part of discharge vessel. Accordingly, the upper limit of ratio t_2/t_1 is set to be 2.0.

[0067]

Next, ratio $(t_1+t_2)/P$ will be considered. At first, the upper limit of ratio $(t_1+t_2)/P$ will be studied. Generally, the larger is the outer diameter of outer bulb, the larger becomes ratio $(t_1+t_2)/P$.

However, in embodiments of the present invention, cylindrical outer bulbs having a relatively small diameter are assumed.

Therefore, considering ratio $(t_1+t_2)/P$ in embodiments 1~4 in Table 3, the upper limit is set to be 0.037 [mm/W]. By setting the upper limit of ratio $(t_1+t_2)/P$ to be 0.037 [mm/W], the shape of outer bulb in embodiments of the present invention is determined to be cylindrical such as T type, TT type or the like, and does not include BT type. Then the lower limit of ratio $(t_1+t_2)/P$ is studied. Generally, the lower limit is to be 0.010.

The reason is that considering the minimum outer diameter of cylindrical outer bulb, the lower limit of ratio $(t_1+t_2)/P$ should be at most 0.037 [mm/W] or the like.

[0068]

The inventors of the present invention have focused on rated lamp power and inner gap t_1 as factors exerting influence on surface temperature of outer bulb.

If the rated lamp power is constant, it is supposed that when the inner gap t_1 is decreased, the surface temperature of outer bulb becomes higher and when the inner gap t_1 is increased, the surface temperature of outer bulb becomes lower.

Inversely, if the inner gap t_1 is constant, it is supposed that when the rated lamp power is increased, the surface temperature of outer bulb becomes higher and when the rated lamp power is decreased, the surface temperature of outer bulb becomes lower.

In other words, it can be said that rated lamp power and inner gap t_1 give influence on the surface temperature of outer bulb inversely to each other. The present inventors have set the ratio of the two as a parameter. The dimension of the ratio [mm/W] does not have a special physical meaning.

[0069]

Calculating ratio t_1/P from embodiments 1 and 2 in Table 2, the ratio t_1/P is about 0.013. Accordingly, in a ceramic metal halide lamp of high wattage type and horizontal lighting type having a cylindrical outer bulb, the value of ratio t_1/P is set as " $t_1/P > 0.01$ " as a condition necessary to prevent the thermal deformation of outer bulb due to high temperature of outer

bulb.

[0070]

While ceramic metal halide lamps according to the embodiments of the present invention have been described so far, these lamps have been explained by way of example and do not limit the scope of the present invention. Addition, deletion, variation and improvement made on the embodiments of the present invention by those skilled in the art may fall within the scope of the present invention. A technical scope of the present invention may be determined by the descriptions of the attached claims.

EXPLANATION OF REFERENCE NUMERALS

[0071]

100...ceramic metal halide lamp, 108...sleeve, 109...support, 110...starter, 111...outer bulb, 112...base, 113...getter, 114A, 114B...mount support plate, 115...stem pipe, 120a, 120b...electrode system, 121...lead wire, 122...current supply conductor, 122a...halogen resistant intermediate member, 12b...conductive cermet rod, 123...tungsten electrode, 123A...discharge arc, 130...discharge vessel, 130A, 130B... arrow tube part, 130C...light emitting part.

CLAIMS

[Claim 1] A ceramic metal halide lamp comprising a discharge vessel for containing light emitting material and a translucent outer bulb for accommodating the discharge vessel, wherein

a sleeve is provided between the discharge vessel and the outer bulb, and assuming that a rated lamp power is P [W], a radius of an inner surface of the outer bulb being R_3 [mm], a distance between an outer surface of the discharge vessel and an inner surface of the sleeve being t_1 [mm], and a distance between an outer surface of the sleeve and the inner surface of the outer bulb being t_2 [mm], the rated lamp power is equal to or more than 500 W, the following equations are satisfied.

$$(R_3/P) \leq 0.06 \text{ [mm/W]}$$

$$1.0 \leq t_2/t_1 \leq 2.0$$

[Claim 2] The ceramic metal halide lamp according to claim 1, wherein further the following equation is satisfied.

$$(t_1+t_2)/P \leq 0.037 \text{ [mm/W]}$$

[Claim 3] The ceramic metal halide lamp according to claim 1, wherein the ceramic metal halide lamp is of horizontal lighting type.

[Claim 4] The ceramic metal halide lamp according to claim 1, wherein the outer bulb is filled with an inert gas.

[Claim 5] The ceramic metal halide lamp according to claim 1, wherein further the following equation is satisfied.

$$t_1/P > 0.01 \text{ [mm/W]}$$

[Claim 6] The ceramic metal halide lamp according to claim 1, wherein the sleeve is made of quartz glass.