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HIGH OUTPUT DISCHARGE LAMP WITH VAPOR PRESSURE CONTROL MEANS

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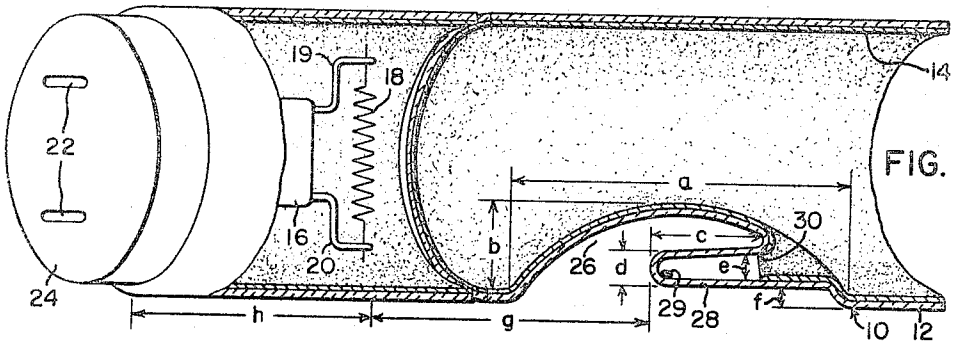


FIG. 1.

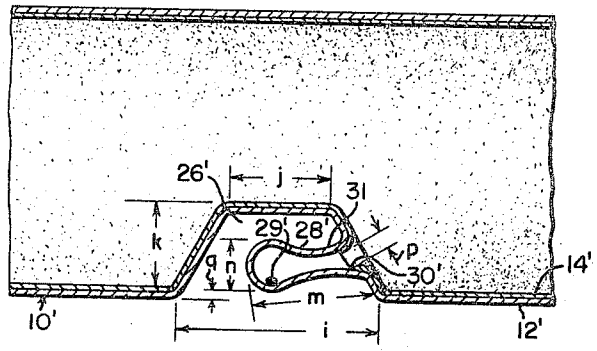


FIG. 2.

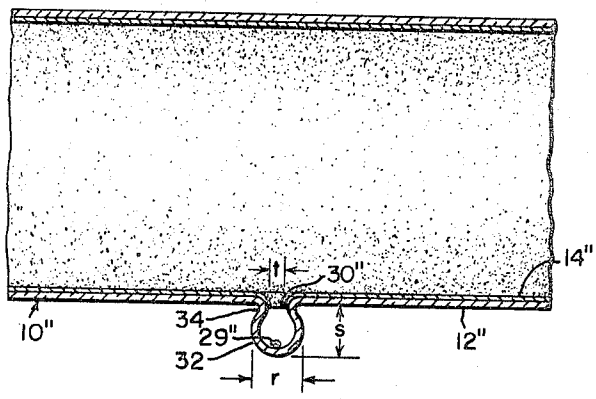


FIG. 3.

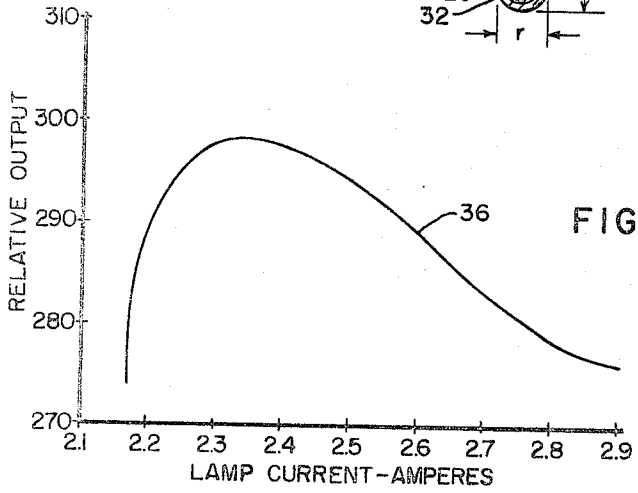


FIG. 4.

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HIGH OUTPUT DISCHARGE LAMP WITH VAPOR PRESSURE CONTROL MEANS

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This invention relates in general to electric discharge lamps and has particular reference to an improved mercury vapor pressure-regulating means for high-output type fluorescent lamps.

In an effort to reduce lighting costs there have recently been developed and marketed so-called "high-output" fluorescent lamps that operate at loadings of around 25 watts per foot of lamp length in contrast to the usual loading of about 10 watts per foot. Since the temperature, and thus the mercury vapor pressure, of a fluorescent lamp increases as the power input or loading increases, it is essential that means be provided for regulating the mercury vapor pressure within the lamp during operation. As is well known, this can be achieved by providing a cool region within the lamp at which the excess mercury vapor will condense when the lamp is operated at the loading for which it is designed. For optimum light output and efficiency the temperature at the pressure control center must be maintained at approximately 40° C.

It is known that such a vapor pressure control center can be provided by using an envelope that has a dome-shaped projection or a recessed fin-like segment which operates at a lower temperature than the envelope and thus defines a cooling chamber. Fluorescent lamps embodying cooling chambers of the aforementioned type are disclosed in U.S. Patent No. 2,939,985 issued June 7, 1960, to D. Kolkman and U.S. Patent No. 2,965,789 issued to E. Lemmers on Dec. 20, 1960.

While cooling chambers such as those defined by the aforementioned dome-shaped and fin-shaped extensions of the bulb wall provide satisfactory mercury vapor pressure control at loadings up to about 25 watts per foot, they are not suitable for use in fluorescent lamps designed for higher loadings insofar as the cooling chambers are of substantially uniform cross-section and face directly toward the envelope axis and the arc stream. The entire chamber is thus exposed to heat radiating from the hottest part of the discharge and, therefore, cannot maintain the proper vapor pressure at loadings much higher than 25 watts per foot.

It is accordingly the general object of the present invention to provide an improved low-pressure electric discharge lamp that obviates the foregoing and other disadvantages of the prior art lamps.

Another object is the provision of a high-output fluorescent lamp having a vapor pressure regulating structure that can be readily fabricated and is capable of maintaining the proper pressure at power loadings above 25 watts per foot.

Another and more specific object is the provision of a new and improved mercury vapor pressure-regulating means for a fluorescent lamp which will enable the lamp to be operated efficiently at loadings in the order of 50 watts per foot.

The aforesaid objects, and other advantages which will become apparent to those skilled in the art, are achieved in accordance with the present invention by providing a specially shaped and oriented tubulation that is integral with the lamp envelope and defines a cooling chamber that communicates with the interior of the envelope and is shielded from the arc stream.

In accordance with a preferred embodiment, the tubulation is of generally cylindrical configuration and extends in the same general direction as the discharge path. It is also recessed within a reentrant cavity formed in the envelope by indenting the underlying and adjacent segments of the envelope wall. In the case of a tubular envelope of circular cross section, the aforesaid tubulation is thus recessed within the circumference of the envelope and is shielded from the arc stream by the interposed segment of the deformed wall portion of the envelope which defines the reentrant cavity. The tubulation and the cavity are so shaped and dimensioned that the tubulation is spaced from the surrounding portion of the envelope and defines a cooling chamber which maintains the mercury vapor pressure at the proper value at loadings as high as 50 watts per foot.

In accordance with another feature of this invention the ability of the tubulation to regulate the mercury vapor pressure is enhanced by enlarging the closed end of the tubulation and constricting the opening into the lamp interior. The resulting bulbous tubulation has a larger cooling surface and is also protected from the heating effects of the arc stream by the inwardly flared segment of the tubulation that defines the constricted opening. The bulbous tubulation thus operates at a lower temperature compared to a cylindrical tubulation and insures that the desired vapor pressure will be maintained during lamp operation.

In another embodiment, a bulbous tubulation is joined directly to the wall of a straight tubular envelope by means of a constricted neck portion and is thus not recessed within the envelope periphery. However, the heat shielding action of the constricted neck portion and the bulbous configuration of the tubulation enable this construction to be used in lamps designed for operation at loadings of 50 watts per foot without exceeding the practical limits as regards the length of the tubulation. In order to insure maximum cooling of the projecting tubulation, the envelope is so oriented with respect to the base and terminal components of the lamp that the tubulation faces downwardly when the lamp is placed into its socket. In the case of the recessed tubulation, the envelope and base components are so oriented that the cavity and tubulation are located at the side of the lamp when the latter is placed into its socket.

A better understanding of the invention will be obtained by referring to the accompanying drawing, wherein:

FIGURE 1 is an enlarged elevational view of one end of a high-output fluorescent lamp embodying the invention, portions of the envelope being removed for convenience of illustration;

FIGS. 2 and 3 are sectional fragmentary views of similar type lamps incorporating alternative pressure-regulating structures; and

FIG. 4 is a graph illustrating the typical output-versus-loading characteristics of a high-output fluorescent lamp having a pressure-regulating tubulation of the type shown in FIG. 3.

While the present invention can be used with advantage in various types of discharge lamps that contain a vaporizable metal and require regulating means for controlling the metal vapor pressure during operation, it is especially adapted for use in conjunction with high-output fluorescent lamps and has accordingly been so illustrated and will be so described.

EMBODIMENT I

With specific reference now to the drawing, in FIG. 1 there is illustrated one end of a high-output fluorescent lamp 10 which consists of a tubular vitreous envelope 12 having a layer 14 of suitable ultraviolet-responsive phosphor on its inner surface and the usual glass stem 16

sealed into each of its ends. A thermionic electrode **18**, such as a coil of tungsten wire that is coated with alkaline earth oxides, is supported within each end of the envelope by a pair of lead wires **19**, **20** that are sealed through the stem **16**. The outer ends of the lead wires are connected to a pair of terminals **22** carried by a suitable base **24** that is attached to the sealed end of the envelope **12** in the usual fashion. The opposite end of the lamp **10** (not shown) is of the same construction.

After it is evacuated, the envelope **12** is dosed with a predetermined quantity of mercury in excess of that required for optimum output and filled with a suitable starting gas, such as argon or the like at a pressure of from 1 to 5 millimeters, and then tipped off in accordance with standard lamp-making practice.

In accordance with the present invention, the mercury vapor pressure within the lamp **10** is maintained within the range of about 6 to 10 microns required for optimum light output and efficiency by deforming a side wall portion of the envelope near one of the electrodes **18** to form a reentrant cavity, such as an arcuate groove **26** that extends inwardly toward the axis of the envelope **12** as shown in FIG. 1, and providing an elongated hollow tubulation **28** in such groove. The groove extends across the envelope so that its line of curvature extends longitudinally along the envelope, as illustrated in the drawing. The groove **26** is therefore, disposed transverse to the envelope axis and forms a rounded depression similar to that which would be formed if a cylinder were pressed into and across the surface of the envelope at that point. The tubulation **28** is joined to the inwardly sloping segment of the deformed envelope wall that is located on the side of the groove **26** directly opposite that which faces the electrode **18**. The tubulation thus projects longitudinally into the groove toward the electrode and is preferably oriented so as to be substantially parallel to the envelope axis.

As illustrated in FIG. 1, the end of the tubulation **28** facing the proximate end of the lamp **10** is closed whereas the opposite end of the tubulation communicates with the interior of the envelope **12** through an opening **30**. Preferably, the inner surface of the tubulation **28** is kept free of phosphor since this facilitates the coating operation and lowers the operating temperature of the tubulation somewhat. A thin coating of phosphor can, however, be used if desired.

The relative dimensions and configuration of the groove **26** and tubulation **28** are critical and are so correlated that the temperature of the tip of the tubulation is approximately 40° C. when the lamp is operated at the power loading for which it is designed. The tubulation thus provides a region within the lamp at which the excess mercury vapor condenses to form a droplet **29** of liquid mercury, as indicated in FIG. 1. The tubulation accordingly defines a cooling chamber that is so oriented and dimensioned that it operates as a pressure-regulating center for the lamp. Preferably, the groove and tubulation are so disposed relative to one another that the tip of the tubulation extends just beyond (preferably ⅛ inch) the geometrical center of the groove, as shown in the drawing.

Proper pressure regulation is achieved even at loadings as high as 50 watts per foot by virtue of fact that the opening **30** into the chamber is directed toward the opposite end of the lamp rather than toward the arc stream, as in the prior art devices. The amount of heat transferred into the tubulation **28** from the arc stream by direct radiation and conduction is accordingly reduced to a minimum. In addition, the tubulation **28** is spaced from the surrounding deformed portions of the envelope wall that form the groove **26**. The tubulation is thus shielded and insulated from the nearest and hottest part of the arc stream by the interposed portion of the envelope wall and by a flow of air which circulates through the groove around the tubulation, respectively. It has been found that the circulation of air around the tubulation is greatest when the tubulation is located at the side of the envelope. For this reason, the envelope **12** is oriented with respect to the base pins **22** in such a way that the groove **26** and tubulation **28** are located in the aforesaid position when the lamp **10** is placed into its socket.

As will be noted in FIG. 1, the tubulation **28** is completely recessed within the groove **26** and thus does not project beyond the envelope circumference. The envelope **12** will accordingly roll freely and can be handled in the conventional manner during the various operations necessary to assemble, test and pack the lamp.

As a specific example of the relative dimensions and spacing of the reentrant groove **26** and tubulation **28**, the mercury vapor pressure within a high-output fluorescent lamp approximately 96 inches long and having an envelope 2⅛ inches in diameter (T17 bulb) was maintained within the desired 6 to 10 micron range when the lamp was operated in still air at 77° F. ambient and a loading of 50 watts per foot by using a groove and tubulation of the aforesaid construction having the following dimensional characteristics:

Table I

DIMENSION (AS SHOWN IN FIG. 1)	Inches
Length of groove *a*	2½
Depth of groove *b*	¾
Length of tubulation *c*	1⅜
Diameter of tubulation at tip *d*	3/16
Minimum dimension of opening into envelope *e*	⅛
Spacing between tubulation and circumferential surface of envelope *f*	1/16
Axial distance between proximate electrode and tip of tubulation *g*	5¼
Axial distance between electrode and base line of lamp *h*	1¼

An important feature of the invention resides in the fact that the closed end of the tubulation **28** faces toward the proximate end of the lamp **10** and the open end of the tubulation faces toward the opposite end of the lamp. This permits the envelope to be coated with phosphor by flushing the phosphor paint mixture through the envelope and then draining the paint by holding the envelope in an upstanding position with the tip of the tubulation pointed upwardly. The phosphor coating on the uppermost end of the envelope will thus dry first and the drying process rapidly progresses to the cooling chamber enabling a very uniform coating to be obtained at this end of the envelope. Experience has shown that if the orientation of the tubulation is reversed then the drying process has to be started at the opposite end of the envelope in order to permit the tubulation to drain properly. As a result, pronounced and unsightly streaks appear in the coating between the cooling chamber and the proximate end of the envelope by the time the drying cycle reaches this portion of the envelope.

Temperature measurements have shown that the tip of the tubulation **28** can be located up to approximately 6 inches from the base line of the proximate end of the envelope **12** before the heat generated by the electrode **18** adversely affects the temperature within the cooling chamber. The close proximity of the tubulation to the end of the envelope thus enables the tubulation to be formed from a part of the envelope wall by a suitable tool in the manner disclosed and claimed in copending application of Vernon L. Plagge, Ser. No. 439,538, filed concurrently with the present application.

EMBODIMENT II

In FIG. 2 there is shown an intermediate segment of a lamp **10'** embodying another form of mercury vapor control center which uses the same basic construction as that shown in FIG. 1. In this case, however, the reentrant

cavity or groove **26'** is of angular rather than arcuate configuration and is defined by a series of inturned flat portions of the envelope wall. In addition, the tubulation **28'** is of bulbous (preferably "tear-drop") configuration and thus has an enlarged closed end. The tubulation is also joined to one of the inwardly sloped wall segments and is thus slightly tilted toward the envelope axis, as shown in the drawing. The amount of heat transferred from the arc stream directly into the cooling chamber is materially reduced according to this embodiment by joining the open end of the tubulation **28'** to the envelope wall by an inwardly flared segment such as a neck portion **31** that defines constricted opening **36'**.

Following is a specific example of the various dimensions of a pressure-regulating structure of the type shown in FIG. 2 which provided satisfactory pressure control in a 96 inch fluorescent lamp operated in still air at a loading of 50 watts per foot and having an envelope 2⅛ inches in diameter:

Table II

DIMENSION (AS SHOWN IN FIG. 2)

	Inches
Length of groove—at entrance *i*	1½
Length of groove—at bottom *j*	¾
Depth of groove *k*	5/8
Length of tubulation *m*	¾
Diameter of tubulation at tip *n*	⅜
Diameter of opening into envelope *p*	3/32
Spacing between tubulation tip and circumferential surface of envelope *q*	1/16

The tip of the tubulation **28'** was spaced at least six inches from the base line of the proximate end of the lamp **10'**, as in the previous embodiment, and the lamp was so oriented in its socket that the tubulation and groove were located at the side of the envelope. The inner surface of the envelope **12'** was also coated with phosphor **14'**.

EMBODIMENT III

In FIG. 3 there is shown a section of a high-output fluorescent lamp **10''** incorporating still another embodiment of the present invention wherein the cooling chamber is defined by a tubulation **32** that projects beyond the envelope periphery instead of being recessed within a reentrant cavity as in Embodiments I and II. The tubulation **32** according to this embodiment is also of bulbous configuration and is joined to the envelope **12''** by a neck portion **34** which defines a constricted opening **30''**. The tubulation is preferably shaped in the form of a tear-drop so as to have a large cooling area and enable the neck portion **34** to shield the sides of the tubulation from heat radiated by the arc stream. Thus, even though the opening into the tubulation **32** faces directly toward the axis of the envelope and the discharge, only a small portion of the tubulation is directly exposed to the arc stream thereby materially reducing the amount of heat transferred into the cooling chamber.

As in the case of the previous embodiments, the inner surface of the envelope **12''** is coated with a layer **14''** of phosphor, which can be extended into the tubulation **32** if desired.

By virtue of the heat shielding action of the neck portion **34** and the increased cooling surface provided by the tear-drop configuration, satisfactory pressure-regulation can be achieved with a very small tubulation, even at loadings as high as 50 watts per foot. The tubulation thus extends only a small distance beyond the envelope and can easily be accommodated by the square protective wrappers that are customarily slipped over fluorescent lamps prior to shipment.

It has been found that optimum results are obtained by orienting the envelope and base terminals in such a way that the tubulation **32** faces downwardly when the lamp is placed into its socket.

Satisfactory mercury vapor pressure-regulation in a 96 inch fluorescent lamp having an envelope 2⅛ inches in diameter has been achieved at a loading of 50 watts per foot with a control center of the type shown in FIG. 3 having the following dimensions:

Table III

DIMENSION (AS SHOWN IN FIG. 3)

	Inches
Maximum diameter of tubulation *r*	5/16
Length of tubulation *s*	7/16
Diameter of opening into envelope *t*	3/32

The graph in FIG. 4 illustrates the variation in the relative light output of a 48 inch high-output fluorescent lamp (T17) provided with a "tear-drop" type pressure-control tubulation of the character shown in FIG. 4 and operated at various current loadings. The tubulation in this particular case was 5/16 of an inch long, ¼ inch in diameter and had an opening 3/32 of an inch in diameter. The lamp contained a fill gas consisting of 5% argon-95% neon at a pressure of 2.5 millimeters of mercury and was operated at an ambient temperature of 26° C. in still air with the tubulation facing downwardly.

As indicated by the curve **36**, the light output reaches a peak somewhere between 2.3 and 2.4 amperes and tapers off gradually at higher current loadings. The output drops off sharply, however, at current loadings below 2.3 amperes. Other tests have shown that lamps with tubulations ½'' long stabilize at approximately peak output (2.3 to 2.4 amperes). However, in order to avoid the sharp drop off of light output in this part of the curve, tubulations approximately 7/16'' long are preferred. Lamps with such tubulations stabilize at current loadings of approximately 2.5 to 2.6 amperes and 26° C. ambient.

It will be appreciated from the foregoing that the objects of the invention have been achieved in that a simple inexpensive pressure-regulating means has been provided which enables high-output fluorescent lamps to be operated at loadings in excess of 25 watts per foot and as high as 50 watts per foot.

While several embodiments have been illustrated and described, it will be understood that various modifications in both the construction and configuration of the cooling chambers can be made without departing from the spirit and scope of the invention.

I claim as my invention:

1. A low-pressure electric discharge lamp adapted for operation at a predetermined power loading comprising,

an elongated vitreous envelope containing an ionizable gaseous medium and a predetermined quantity of a vaporizable metal in excess of that required for optimum efficiency at said predetermined power loading,

a pair of spaced electrodes sealed within said envelope, and

means for regulating the metal vapor pressure within said lamp during the operation thereof comprising a tubulation that is integral with and extends from a side wall of said envelope and defines a chamber which communicates with the interior of said envelope and provides a cool region at which excess metal vapor condenses,

a side wall portion of said envelope adjacent said tubulation extending inwardly from the envelope periphery and being disposed between the discharge and said tubulation and thus providing a shield that reduces the amount of heat transferred by radiation into the vapor-pressure regulating chamber.

2. The electric discharge lamp set forth in claim **1** wherein said tubulation extends from the inwardly-disposed side wall portion of said envelope and said side wall portion is located between said electrodes.

3. A fluorescent lamp comprising,

a tubular phosphor-coated envelope containing an ionizable fill gas and a quantity of mercury in excess of

that required for optimum efficiency at a predetermined power loading,

an electrode sealed into each end of said envelope, and

means for regulating the mercury vapor pressure within said lamp during the operation thereof at said loading comprising (1) a deformed side wall portion of the envelope that extends inwardly toward the envelope axis and defines a reentrant cavity, and (2) a tubulation joined to said deformed wall portion and extending into the cavity formed thereby,

said tubulation defining a chamber that communicates with the interior of said envelope through an aperture in the envelope wall and provides a cool region at which the excess mercury vapor condenses when the lamp is operated at said loading,

said cavity and tubulation being of such configuration and being so oriented relative to the envelope axis that a segment of the deformed portion of the envelope wall is disposed between the tubulation and the discharge and thus serves as a heat shield for the pressure-regulating chamber.

4. The fluorescent lamp set forth in claim **3** wherein said tubulation is completely recessed within said cavity and is spaced from the surrounding deformed wall portion of the envelope.

5. The fluorescent lamp set forth in claim **3** wherein said electrodes are connected to terminals that are carried by a base member fastened to the respective ends of the envelope, and the envelope is so oriented with respect to said terminals that the cavity and tubulation are located on a side of said lamp when the latter is placed into its socket.

6. A fluorescent lamp comprising,

a tubular phosphor-coated envelope containing an ionizable fill gas and a quantity of mercury in excess of that required for optimum efficiency at a predetermined power loading,

an electrode sealed into each end of said envelope, and

means for regulating the mercury vapor pressure within said lamp during the operation thereof at said loading comprising a tubulation of tear-drop configuration that extends from the side of said envelope at a point located between said electrodes and is joined to said envelope by a neck portion having a constricted opening that communicates with the interior of said envelope,

the length and maximum diameter of said tear-drop tubulation and the dimension of said constricted opening being so correlated with respect to the envelope dimensions that said tubulation has a lower operating temperature than said envelope and provides a region at which the excess mercury vapor condenses when the lamp is operated at said power loading.

7. The fluorescent lamp set forth in claim **6** wherein; said electrodes are connected to terminals carried by base members attached to the respective ends of said envelope, and the envelope is so oriented with respect to said terminals that the tear-drop shaped tubulation faces downwardly when the lamp is placed into its socket.

8. A fluorescent lamp adapted for operation at power loadings in excess of about 25 watts per foot comprising,

an elongated phosphor-coated vitreous envelope of substantially circular cross-section that contains an inert fill gas and a quantity of mercury in excess of that required for optimum efficiency at said loading,

an electrode sealed into each end of said envelope, and

means for regulating the mercury vapor pressure within said lamp during the operation thereof at said loading comprising (1) a deformed side wall portion of the envelope that defines a reentrant cavity which extends inwardly toward the envelope axis and is located between said electrodes, and (2) an elongated tubulation that is joined to an inwardly extending part of said deformed envelope portion and projects into and is entirely recessed within said cavity,

said tubulation being spaced from the surrounding segments of the deformed wall portion of said envelope and defining a chamber that communicates with the interior of said envelope through an opening in the said inwardly extending part of the envelope wall and, by virtue of the heat shielding action of the deformed envelope wall segment that is interposed between said tubulation and the arc stream, providing a cool region at which the excess mercury vapor condenses when the lamp is operated at said loading.

9. The fluorescent lamp set forth in claim **8** wherein said tubulation extends in substantially the same direction as the envelope axis.

10. The fluorescent lamp set forth in claim **8** wherein said tubulation is of generally cylindrical configuration and extends substantially parallel to the envelope axis.

11. The fluorescent lamp set forth in claim **8** wherein said tubulation is of substantially tear-drop configuration and communicates with the interior of said envelope through a neck portion that defines a constricted opening.

12. In a high-output fluorescent lamp having a tubular vitreous envelope that contains an inert fill gas and a vaporizable metal, the combination comprising,

an electrode sealed into one end of said envelope,

means for regulating the metal vapor pressure within the envelope when said lamp is operated comprising (1) a deformed side wall portion of the envelope that defines a reentrant cavity located proximate the end of said envelope containing said electrode and (2) an elongated vitreous tubulation that is joined to the inturned segment of said deformed envelope wall portion which defines the side of the cavity located opposite that which faces said electrode, and

a coating of ultraviolet-responsive phosphor on the inner surfaces of said envelope and a portion of said tubulation,

said elongated tubulation being entirely recessed within said cavity and extending toward said electrode in substantial alignment with the envelope axis,

the end of said tubulation facing said electrode being closed and the opposite end of said tubulation being accessible to the interior of said envelope through an opening in the adjoining segment of said deformed wall portion,

the dimensions of said tubulation and the spacing between the closed end thereof and said electrode being so correlated that said tubulation provides a cool region within the lamp at which the excess metal vapor condenses when the lamp is operated.

13. The combination set forth in claim **12** wherein said cavity comprises an arcuate groove that extends across the envelope, and said tubulation is spaced from the surrounding side wall portion of said envelope throughout substantially its entire length and terminates at a point a short distance beyond the geometric center of said groove.

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