
Low Pressure Amalgam Bactericidal Lamps

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Received: 25th February 2019, Accepted: 01st April 2019, Published: 30th April 2019

Abstract

This paper describes low pressure amalgam bactericidal lamps for disinfection purposes. The thermal regime of the lamp system - coating - disinfectant liquid is analyzed. Based on the solution of the heat balance equations, the temperature of the cold zone of the radiation source is estimated, which provides the basis for choosing either a mercury or amalgam lamp. Recommendations and basic formulas for calculating the thermal regime of the system are presented.

Keywords

Lamp, Amalgam, Low Pressure, Efficiency, Power, Temperature of the Cold Zone, Radiation Source, Heat Balance, System.

Introduction

The creation of low-pressure mercury lamps for disinfection purposes over the past 20 years [1–2] has been further developed through the development of high-power lamps [3, 4]. This was implemented by introducing amalgams that provide the necessary pressure of mercury vapor in the discharge gap at temperatures well above the optimum for pure mercury. The ideas of replacing pure mercury with other metals were tested in the 1950s and 1960s, but, unfortunately, they did not give positive results. At the same time, work began on the development of the first powerful amalgam fluorescent lamps, which in those years, and especially now, turned out to be very popular. In the eighties of the last century there was an attempt to place a high-pressure lamp in ultraviolet disinfecting systems, but the low efficiency in the ultraviolet reduced the rest of their advantages to a minimum. Another attempt to use low-pressure lamps with mercury alloys - amalgam - made it possible to obtain several technical advantages at once. Thus, we can literally state that a certain technological breakthrough has arisen - the power of amalgam lamps has increased, so has the output of the ultraviolet and its efficiency in this area. It should be particularly noted that amalgam is more environmentally friendly, although it is more difficult to manufacture and dispose of, especially since the process of making amalgam is also associated with the use of pure mercury, its high-temperature treatment [5 - 8].

Methods

The existing instrument fleet of disinfection equipment is designed for mercury lamps up to 120 W, all other sizes of lamps, as a rule, are amalgamic. The use of high power lamps made it possible not only to reduce the weight and dimensions of equipment, but also to reduce the operating costs of cleaning lamps, replacing them, etc. However, neither in the special literature, nor in practice, there are clear and unambiguous concepts and recommendations on which initial powers (specific electrical loads) should be used in amalgam systems, and which final power values should be used in mercury systems. This issue is also relevant because most of the modern disinfecting technology with low-pressure lamps has a capacity of from 15 to 600 W, that is, "on the border of the issue". A further increase in power leads to a sharp increase in length, mass diameter, etc. Moreover, the existing methods for calculating such radiation sources are focused only on mercury; amalgam, its selection methods and principles of use have not yet been applied in calculations. One of the main dependencies is the relationship between temperature and pressure of saturated mercury vapor, not just known, but used in the calculation of all types of mercury lamps, both high and low pressure.

Main Part

Analysis of the situation will start with consideration of the thermal field of the inner surface of the low-pressure amalgam lamp. As follows from [2], the main source of heat determining the formation of the thermal regime of the lamp is the electrode, but at the same time, for a horizontally operating lamp:

- trans-electrode zone is overheated and only high-temperature amalgam can be placed there;
- the temperature of the cold zone is in the central part of the flask;
- such dependences are typical for tubular lamps and are the basis for choosing the location of the amalgam.

However, these data will vary significantly if the lamp is placed in an airtight protective sheath (the so-called "cover") in contact with a disinfectable liquid, such as water. According to the calculation recommendations proposed by G.N. Rokhlin in [9], the amount of heat removed from the lamp in the interval "lamp-shell" per unit length shall be

$$Q_1 = a_i(T_1 - T_2)\pi D_l \quad (1)$$

where the total external heat transfer coefficient of the lamp sheath a_i can be determined from the data given in the same paper. Temperature difference in the thickness of the protective sheath and, accordingly, the amount of heat transferred through it shall be

$$Q_2 = 2 \pi \lambda (T_1 - T_2) / \ln(R_1/R_2) \quad (2)$$

In this case, the heat removal from the surface of the sheath into the disinfectable liquid will be described by expression (1) with the corresponding indices. In all three cases, the amount of heat will be approximately equally (within the accepted assumptions and approximations)

$$Q_1 = Q_2 = Q_3 = Q \quad (3)$$

and equals

$$Q = k P_l \quad (4)$$

where

$$k = 1 - F_l/P_l \quad (5)$$

The coefficient k is determined experimentally, depending on the type of lamp, characteristics of quartz glass, and filling.

Formulas (1-5) are valid for cylindrical (extended) lamps operating horizontally, per unit length.

Thus, by solving the above equations, for the corresponding elements of the lamp-case-water system, it is possible to determine how the temperature of the cold zone on the inner surface of the lamp changes when it is placed in a protective sheath, and the whole system is placed into a liquid to be disinfected. If the resulting temperature on the inner surface of the lamp (the temperature of the so-called "cold zone") is 40–60°C, it is possible to uniquely identify such a lamp as purely mercury; if it is higher, the lamp must be made of amalgam. Solving such problems is easy now; moreover, it is possible to make nomograms for rapid assessments of a wide variety of options.

During the service life of the disinfecting system, equations (1-5) will change. Knowing the nature of changes in its elements, during operation, it is possible to determine the behavior of the disinfecting radiation during a fairly long period of operation.

As follows from [2], the stable temperature (it is also the temperature of the "cold zone") on the inner surface of the central part of the flask (the lamp operates horizontally) is here, that is, at $t=const$ which requires applying a base nanolayer of gold or indium under the amalgam top layer. The choice of amalgam composition is a rather difficult specific task and is not considered in this paper.

Summary

Thus, the thermal regime of the entire disinfecting system will depend both on the supplied electrical power and on a number of factors, which include the design of the lamp and the sheath (their diameters and wall thickness), as well as the temperature of the disinfectant liquid, the properties of the gas gap between the lamp and protective sheath. Consequently, the task of choosing the filling (mercury or amalgam) will be complex, taking into account the operating conditions and design features of the system.

Conclusion

The direction of the design estimates (from the fluid to the lamp and otherwise) depends on the solution of direct and inverse problems. It should also be emphasized that such practical issues arise in a wide variety of ways quite often, and specialists in this field need ready-made standard solutions. Such tasks with solutions on water and air disinfection with a mercury lamp assembly are widely practiced by A.L. Wasserman in his works [10], they greatly simplify the work of designers. The authors hope that the proposed work will serve similar purposes, but they believe that examples of practical calculations, the arising errors, and assumptions are the subject of another work; this work is rather preliminary and defines a range of existing tasks and problems.

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