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The Features and Prospects for the Development of Modern Halogen Light Sources

Irina Ivanovna Bayneva
Department of Lighting Engineering, Ogarev Mordovia State University,
68, Bolshevistskaya Str., 430005 Saransk, Republic of Mordovia, Russia

Abstract: This study analyzes the current state of thermal light sources-incandescent halogen lamps that are highly intense light sources which enables them to occupy a niche in the modern lighting technology. It reveals the advantages and benefits of these light sources, describes their operating principles and classification. We have been studied the features of the tungsten-halogen cycle in the halogen lamps that is capable of preventing from blackening shell with the tungsten evaporating from the luminous element, keeping it clean and clear throughout the lamp life cycle, described the conditions and the course of the cycle and its efficiency, the principles of selecting the composition and pressure of the filling gas mixture in the production of the halogen lamps. The elements of gas mixture, the components of chemical reactions may be in atomic or molecular state and form various binary and ternary compounds that have influence on the tungsten-halogen cycle and heat processes in the lamp. The transfer processes of heat and mass in the halogen bulbs are in turn, connected with engineering, operational and design data of these lighting sources. It has been shown that the parameter optimization of the halogen lamps must comprise search for new constructive solutions, optimum filling mixtures, ways to reduce heat losses in the filling gas. We have determined the problem aspects of developing the halogen lamps and main tendencies in their study. One of the tendencies of improvement of these lighting sources is minimization of heat losses and transport rate of the filament element in active volume. We have formulated the problems and their possible solutions which will enable to make design of the incandescent halogen lamps of maximum cost-effectiveness.

Key words: Light source, halogen incandescent lamp, halogen, halogen-containing additive, inert gas, tungsten-halogen cycle, tungsten, filament element

INTRODUCTION

The appearance of the Incandescent Halogen Lamps (IHL) in the 50s of the 20th century was a great progress in the field of heat Light Sources (LS) (Vugman and Volkov, 1980; Ivantsev, 1991). Currently, at the market of lighting engineering products, they are going through their second birth. This is largely due to the EU ban on the use and sale of the Incandescent Lamps (IL) of 100 watts and more (Bayneva and Bayneva, 2011, 2012a, b).

The IHL are more durable and reliable variations of the light sources than the traditional IL. They are high-intensity emitting sources with small dimensions, so widely used in many fields of science, technology and everyday life (Bayneva and Bayneva, 2013). The parameter optimization of the IHL including the search for new constructive solutions, efficient compositions of filling gas mixtures, ways of reducing heat losses in the gas and efficient rate of transfer of luminous element mass requires a deep understanding of physical and chemical processes in the IHL (Coaton, 1977; Kolenchic *et al*., 1989).

MATERIALS AND METHODS

Characteristics, principles and classification of the IHL: The IHL provide luminous efficacy of 25-30 lm/W. Their life cycle is longer than the traditional IL -3000-5000 h. The IHL have a continuous spectrum, mainly in the visible and infrared regions of the spectrum and high constancy of luminous flux over the entire lifetime, providing 85-95% of its initial value by the end of the service life.

The principle of operation of the IHL is to generate radiation as a result of heating a tungsten Filament Element (FE) to high temperature with electric current. The feature of IHL is mandatory presence of the tungsten-halogen cycle. To slow the evaporation of the material of FE and reduce heat losses in the gas, the IHL is filled with heavy inert gases krypton and xenon.

Today, the only comparatively economical and at the same time inexpensive light sources with a “warm” spectrum are the halogen lamps. This explains their varied range which has a tendency to expand.

Currently, the leading companies produce up to 250 dimension types of the IHL and Russia has developed and produced commercially >200 dimension types which are used for general, studio, home lighting, lamp signaling, airfield lighting, vehicles, radiant heating and so on. They can be divided into linear, small-size and IHL for optical systems (Bayneva, 2000).

The mandatory attribute for any IHL is the tungsten-halogen cycle which is defined as a complex of chemical reactions (processes) as a result of which the tungsten particles vaporized from the surface heated to a high temperature of the FE move via halogens in the opposite direction-from lower to higher temperatures. The function of such cycles is to prevent blackening of the shell with evaporated tungsten from FE to keep it clean and clear throughout the lamp life (Bayneva, 2001).

The overall picture of occurring tungsten-halogen phenomena is extremely complex and represents a system of chemical equilibrium reactions involving the five elements tungsten, halogen, oxygen, hydrogen and carbon. These elements as the components in chemical reactions can be alone in atomic or molecular state and form up to 40 different binary and ternary compounds (Bayneva, 2014).

To organize an effective tungsten-halogen cycle, the halogens such as iodine, bromine, chlorine, fluorine can be used. And the feature of the design of such LS is not only to choose a halogen but also determine its optimal concentration. It should be sufficient to prevent the cycle stop but not too high so as not to cause the destruction of cooler parts of metal elements of the lamp (Bayneva, 2013). At present, most manufacturers use hydrobromic compounds as the most technologically advanced.

Thus, the choice of the composition and pressure of the filling gas mixture is a multi-factor and complex problem.

Problems and prospects of development of incandescent halogen lamps: Despite the fact that the light-emitting diodes, LED lamps and lighting devices based on the LEDs are more persistently breaking into our lives and gradually replacing the traditional LS. The IHL are not losing their positions. Today, the leaders of the lighting engineering market in particular on the production of IHL are the well-known companies as OSRAM, PHILIPS, GENERAL ELECTRIC, SYLVANIA, NAVIGATOR, NARVA.

Owing to a number of advantages over the IL (small size, light stability over the life, the possibility of using for different purposes) the IHL are used in many areas of human activity. At the same time, they have a number of drawbacks such as low efficiency and improper assembly of the lamps. Therefore, the tasks of improving the characteristics of the IHL, product quality assurance in manufacture and operation continue to be valid (Bayneva, 2008, 2013). The prospects of development of IHL of all groups consist in increasing the light output, combustion duration, reducing the overall dimensions, expanding the nomenclature. The increased light output and combustion duration are due to optimizing the lamp design, improving the properties of tungsten wire, quartz glass, increasing heat resistance and other parameters of filling and process gases.

Technical, operational and design parameters of the IHL are closely connected with the physical parameters conditioned by the processes of heat and mass transfer in the lamp bulb. The gas filling substantially reduces the mass transfer rate of the FE and increases lamp life. Developing cost-effective variants of the IHL, it is necessary to seek for new constructive decisions to design lamps with high luminous efficiency at the same cost of power; find effective compounds of filling gas mixtures; minimize heat losses and rate of transfer of the FE material, etc.

RESULTS AND DISCUSSION

The study of transfer processes in the IHL according to the conditions of their actual occurrence presents considerable difficulties. The comprehensive data about the distribution of temperature, velocity and concentration of the components that fill gas media in the lamps, the influence of composition and pressure of gas filling on the heat loss and mass of FE have not been obtained so far.

Thus, the development of work on the improving the characteristics of the IHL and increasing their efficiency largely depends on the degree of reliability of the research processes of heat and mass transfer in the lamp (Bayneva, 2008, 2013). This, in turn, determines the relevance of the development of an adequate mathematical model of the processes of heat and mass transfer of sublimating particles in FE in the lamp bulb (Bayneva, 2014). Based on these studies, the practical problems of creating more sophisticated designs of the IHL and defining effective compositions filling their gas mixtures can be solved.

A feature of the IHL is the presence of the circular transport chemical reactions in their working volume for the organization of which it is necessary to strive for the proper selection of a halogen additive and its optimal concentration that should be sufficient to prevent the cycle stop and not too high, so as not to lead to the destruction of cooler metal parts of the lamps.

The development of the halogen lamps based on empirical approach is complex and time-consuming task, the success of which depends largely on the experience and intuition of the developer. Widespread application of the IHL in various special installations and devices requires the development of many new types of the lamps with specific, predetermined characteristics. In these circumstances, important computing methods which would allow to solve emerging engineering problems promptly and with the required accuracy gain in special importance. Among the most important are:

- The choice of material, the determination of the shape and dimensions of structural elements lamps ensuring the maintenance of the required operating conditions
- The establishment of methods for selecting the optimum ratio of the source characteristics depending on the requirements and operating conditions
- The definition of various characteristics changes in varying structural and technological parameters, the operating conditions
- The assessment of the limiting possibilities of changing the basic parameters of the lamp according to the real constraints imposed by the source design and material properties
- The assessment of the role of various halogen compounds in organizing effective tungsten-halogen cycle

With the development of various types of the lamps, we have to consider rather varied and often conflicting requirements. The processes taking place in the IHL are complex and diverse, many of them are highly dependent upon the lamp embodiment, the materials. The model computing of the IHL with physico-chemical processes in them taken into account must be based on the principle of generating and solving a set of functional equations that establishes the link between the basic lighting, electrical, energy characteristics as well as the design factors of the IHL (Bayneva, 2014).

In determining the best variant of the IHL, it is required to consider the physical and chemical processes in them. It is sometimes very difficult and sometimes impossible to obtain the value of some variables by calculation, such as determining the heat and mass transfer processes in the IHL, so modeling of processes is advisable to be performed with the help of modern computer technology by combining experimental and computational work (Bayneva, 2012, 2014).

CONCLUSION

Although, the rapid development of the IHL fell on the years 70-90s of the twentieth century, the works on designing new lamps and improving their production which are based on the upgrade of the FE, the use of reflectors, screens, coatings, various getters, seeking for new halogen compounds and their concentrations have still been continued. In many ways, they are based only on experimental designs which consumes time and resources. Thus, the construction of the models of processes in the IHL involving modern software, computational and experimental studies of the halogen incandescent lamps, their perfection and optimization is an essential problem of modern lighting engineering.

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