Light & Engineering
Vol. 27, No. 6, pp. 112–122, 2019 *https://doi.org/10.33383/2019-025*

TESTING AND ANALYSIS OF CHARACTERISTICS OF LOW-PRESSURE MERCURY AND AMALGAM BACTERICIDAL UV LAMPS BY VARIOUS MANUFACTURERS

Michael E. Allash[1], Leonid M. Vasilyak[2], Nikolay P. Eliseev[3], Oleg A. Popov[3], and *Dmitry V. Sokolov[4]

[1] Lighttech Kft, Budapest, Hungary
[2] OIVT RAS, Moscow
[3] NRU MPEI, Moscow
[4] NPO LIT, Moscow
**E-mail: sokoloff@npo.lit.ru*

ABSTRACT

The samples testing of bactericidal high-pressure UV lamps presented on the Russian Market showed their insufficient quality. These lamps were designed and manufactured based on the technical assignment of specific manufacturers or are copies of UV lamps by well-known brands but manufactured using own technology. Moreover, these devices do not comply with special aspects of UV irradiating equipment for water sterilisation such lamps may be used with by consumers.

Keywords: bactericidal lamps, low-pressure mercury lamps, amalgam lamps, UV radiation, water sterilising installations

1. INTRODUCTION

UV radiation (UVR) is widely applied in various areas, one of which is sterilising of water, air, and surfaces. Within the previous 15–20-years period, UVR sterilising has undergone rapid development and has allowed changing approaches to sterilising of media dramatically, but it has developed as a method of sterilising of potable and wastewater most significantly. UVR is also widely applied as a method of air and surfaces sterilising in medical institutions, in public areas, transport, and other application areas such as food, pharmacological and electronic industry, medicine, recycling water supply, fish farming, greenhouse facilities, etc. [1].

In most applications, low-pressure mercury and amalgam tube UV lamps as well as medium (high)-pressure mercury lamps are used as sources of UVR for sterilising [2]. In Russia, medium (high)-pressure lamps for water sterilising equipment have not been widely used due to their low radiant efficiency in the bactericidal UVR range [1], low lifetime [3], and high tube temperature, although they have been used, for instance, in pool facilities, ballast water sterilising installations and installations with Advanced Oxidation Processes (*AOPs*) [1, 4] for destruction of chemical trace contaminants in water.

Currently, the world's leading manufacturers such as *Philips* (the Netherlands), *Lighttech/LSI* (Hungary/USA), *Heraeus Noblelight* (Germany), and NPO LIT (Russia/Germany) offer low-pressure mercury and amalgam lamps with power ranging between 15 and 1000 W with radiant efficiency from 30 to 40 % at wavelength $\lambda = 254$ nm and lifetime from 8,000 to 16,000 hours. In Russia, mercury and amalgam UV lamps are manufactured by NPO LIT (Moscow) and OOO Lodygin A.N. NIIIS (Saransk). Based on these lamps, UV-irradiating (UVI) equipment for sterilising of water, air, and surfaces in different conditions with various performance is manufactured. The world's largest manufacturers of water UVI equipment include: *Tro-*

jan (Canada), NPO LIT (Russia/Germany), *Wedeco Xylem* (Germany/USA), *Halma group* (*Hanovia*, *Aquionics*, *Berson*) (UK/USA/the Netherlands), *Calgon Carbon* (USA), and *NewLand* (PRC). Apart from NPO LIT, Russian manufacturers of mercury or amalgam lamps-based water sterilising installations also include NPO ENT (Saint Petersburg), UFTECH (Sergiev Posad), Industrial UV Systems (Saint Petersburg), and some other companies.

Nowadays, the market of manufacturers and consumers of low-pressure bactericidal UV lamps has been formed in Russia. It includes both the above-mentioned manufacturers of UVI equipment and their customers: water network operators, food industry enterprises, manufacturers and buyers of pools and water parks, medical institutions as well as individual users of water and air sterilising equipment, the amount of which has been increasing every year.

Naturally, the so-called "relamping" market has been rapidly developing too, and suppliers of non-original accessories including UV lamps of unknown origin often work in it. A large amount of lighting equipment of unknown origin is installed in UVI equipment without taking its distinctions and maintenance regulations into account. Statistic data obtained from consumers shows large increase in the number of emergency situations and even accidents related to the application of UV lamps taken for specific equipment incorrectly. Sometimes there are funny situations when a purchased lamp has other dimensions or other electric inputs and just cannot be used in specific equipment, and sometimes there are tragic situations when the application of such lamps causes accidents: e.g. malfunctioning of supply and control systems and sometimes even inflammation of equipment, to say nothing of changing of the sterilising process mode.

Another complication of this problem is caused by the fact that certifying of such lighting equipment as UV lamps is voluntary in the Customs Union member states. The CU technical regulation conformity certificate has a declarative nature and informs a consumer on the safety of a product. At the same time, any other technical information such as electrical characteristics, UV radiant flux, results of lifetime tests, etc. remains on the conscience of a seller of UV lamps. Some companies frankly copy the technical specifications of the leaders of this market: *Lighttech*, *Osram*, LIT, etc. Radiometric measurement of UV lamps parameters is a rather complex problem that requires knowledge of UVR measurement methodology of long lamps, availability of special equipment, and skilled personnel. Bad-faith companies use it actively given that it is hard to confirm or to disprove the characteristics claimed by them in datasheets or technical specifications.

Recently, the specialists in such UVR sources are regularly being addressed by consumers aiming at conduct of expertise of UV lamps for compliance with the declared characteristics and often asking just to assess working capacity of such lamps. For example, the authors of this article were addressed by several customers of such water sterilising products with such requests: engineering companies, water network operators, service companies, and owners of several private pools.

The goal of this study was to test low-pressure amalgam and mercury UV lamps supplied to the Russian market under different brands and to analyse the fitness of the tested samples for different applications. In the course of testing, we paid the major attention to capabilities of operation of lamps in water sterilising UVI equipment. During our study, we took only the logo labelled on each specific lamp into account and we do not claim that any lamp was manufactured exactly by declared manufacturers. We would also like to note that both the testing and this article are not aiming at disparaging or dignifying of products of any specific company.

In lighting engineering laboratories of *Lighttech* (Budapest) and *LIT UV Elektro* (Erfurt, Germany), the samples of lamps with labels *Jelosil*, *JUV*, Eltos, *LightBest*, *UV Product*, and *Sean* were tested. For testing, a small number of lamps with each logo were used. The authors understand that a selection of one or two samples of lamps may provide a rather high margin of error but they think that all lamps for such vital systems as water sterilising installations should be of high quality.

2. FEATURES OF USE OF UV LAMPS IN STERILISING INSTALLATIONS

A lamp does not work in isolation in UVI equipment; it is an integral part of a UVR sterilising system. Designers of UVI equipment take such aspects into account as temperature modes of specific elements of a lamp, operational modes of amalgam, required current and pre-heating time for each type of electrodes, the required value of lighting voltage impulse, the durability and location of a lamp cap, etc. For the purpose of provision of all required operational modes of a lamp and an opportunity to provide guarantees of lifetime, decreasing of UVR flux, "unlimited" number of switching on/off, etc. to a customer, a designer of UVI equipment develops a *datasheet* for a lamp and manufactures it or cooperates with a reliable manufacturer of such lamps.

It is possible to provide a lot of examples when an installation with lamps by one manufacturer provides required UV dose and, hence, microbiological characteristics of water whereas an installation with lamps by another manufacturer with the same declared characteristics does not. It is caused by the fact that manufacturers of lamps specify their characteristics for some specific conditions. Most commonly, maximum characteristics (e.g. UVR flux or radiant efficiency) obtained during measurements in laboratory conditions at air temperature from 20 to 25 °C are specified. These maximum characteristics are provided in a technical specification or a datasheet. However, if a lamp is intended to be used for water sterilising, it should efficiently operate in a specific piece of UVI equipment, and it absolutely does not matter for a customer what UVR level the lamp showed during its testing on an air stand in the laboratory. A developer and a consumer require the maximum or quite close value of UVR flux specified in a technical specification to be obtained in the most operating modes of the lamp in an installation. It is possible to provide a lot of evidence of UVR flux decrease by several times with incorrectly selected amalgam. It occurs, for example, in the case of overcooling or overheating of a lamp. In case of decreasing of bactericidal UVR with $\lambda = 254$ nm, the UV dose of an installation also decreases, which leads to a reduction of sterilising efficiency. Changing of lamp temperature modes during water sterilising is related to the fact that a lamp of a UVI installation is placed in a quartz casing required for the provision of a specific temperature mode of amalgam operation and prevention of contact of electric circuits of a lamp with water. The gap between the lamp and the casing or, in case of the so-called pellet technology the amalgam location point, fully determines the operational mode of the whole lamp [5]. Hence, the lamps with other dimensions or other electric power will operate in another temperature mode the UVR flux depends on. One more parameter influencing operation of lamps is water temperature that may vary within the range between 1 and 40 °C. In this case, a lamp should contain a special amalgam maintaining a constant pressure of mercury vapours with a lamp wall temperature changing by approximately 30 to 40 °C. Manufacturers shall not specify this technical characteristic, that is why decreasing of UVR flux of a lamp in an installation is possible in case of replacing of specially selected or specially manufactured lamps with other ones with the same UVR flux specified in a datasheet but a smaller operating range of wall temperature change.

Another "classic" case of incorrect selection of lamps is ignorance or ignoring of parameters of electronic starter device a lamp will operate with. For instance, the power sources of high-output amalgam UV lamps significantly differ from the same for small bactericidal mercury lamps with power from 5 to 50 W. To perform a reliable start of a lamp with a power from 300 to 1000 W and to provide a sufficient number of switch-on, it is necessary to use special electronic starter devices, which sometimes have complex two-inverter designs. Manufacturers of high-output amalgam UV lamps know it well that 20 to 30 switch-on are enough for a complete failure of a lamp due to fast wearing of emission coating of an electrode unit in case of incorrect electronic starter device using. In this case, damaging the electronic starter device itself is possible too if its emergency protection does not operate timely. Understanding this problem, responsible manufacturers of lamps specify the type and manufacturer of electronic starter device they recommend to use specific lamps with. Other manufacturers of amalgam lamps do not specify such important parameter as the number of switch-on/off of a lamp since they cannot know which type of electronic starter device their product will be used with and in which operating conditions it will be used.

In flow-through air sterilising systems, a lamp usually operates without a quartz protective casing and operating temperature of its body will be less than during laboratory tests in the still air environment, especially in cold airflows of air-conditioning systems. Some manufacturers specify that a lamp may efficiently operate in the airflow but the UVR flux value may become significantly lower than the one specified in a datasheet after replacement with a lamp by another manufacturer.

We would like to underline it once more: UV lamp is a part of a UVI system just like an electronic

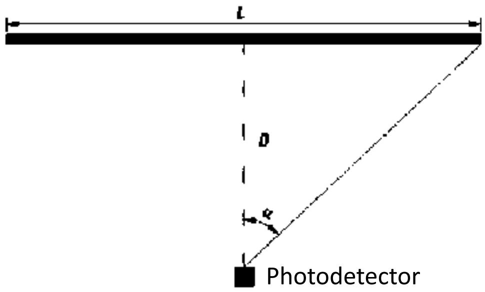

Fig. 1 Keitz method measurement scheme

Fig. 2. Labels of the *Jelosil* and *JUV* lamp samples

starter device and its other parts. The above-mentioned leaders of the markets of UVI equipment and UV lamps pay great attention to collaborative cooperation in the course of the design of their products. For instance, for the purpose of cooperative promotion of products in the Western European markets, *LIT UV Elektro GmbH* (Germany) and *Lighttech Kft* (Hungary) have developed a product range of water UVI equipment and the relevant range of UV lamps for it. Of course, the selection and replacement of a lamp or an electronic starter device in UVI installations by a customer is a common and normal practice in conditions of a competitive market. However, we think that such selection and replacement of accessories should be performed taking distinctions of specific equipment into account and on the basis of recommendations of specialists.

3. METHODOLOGY OF MEASUREMENT OF LOW-PRESSURE UV TUBE LAMPS AND TESTING INSTALLATION

Low-pressure quartz mercury lamps, low-pressure mercury lamps made of uviol glass (the so-called *soft glass lamps*) and low-pressure amalgam lamps with bactericidal UVR may be considered as sources of monochromatic radiation at $\lambda = 254$ nm. Generation of UVR at 254 nm line in low-pressure mercury plasma is well-known studied experimentally [1, 3, 59]. For the Lambert surface source like a low-pressure mercury or amalgam tube lamp (in respect of the said UVR), Keitz-method measurement scheme [10, 11] (Fig. 1) is the simplest and the most correct one for measurement of UVR flux with specific assumptions.

In accordance with it, the lamp is installed in a room without UVR-reflecting surfaces ("dark room"). The photo detector is located opposite to the centre of the lamp (Fig. 1). To obtain the value of UVR flux (Φ_e) of the lamp with the length of irradiating part L, it is necessary to measure the value of irradiance (E_e) on the entry window of the photo detector located at distance D from the axis of the lamp:

$$\Phi_e = \left(2\pi^2 DLE_e\right) / \left(2\alpha + \sin 2\alpha\right),$$

where α is the one-half angular size of the radiating part of the lamp in relation to the centre of the entry window of the photo detector sensor (Fig. 1).

For the study, two dark rooms with dimensions (7×3×3) m and (6×3.5×3) m (L×W×H) were used. Measurements of E_e were conducted by means of *SED240* sensor of *IL1700* radiometer (*International Light Technologies*) with a special cosine cap. It should be emphasized that *IL1700* with *SED240* or its analogues (*GigaHerz optik*, *Dr. Groebel*, etc.) are generally accepted for measurement of irradiance from low-pressure lamps. The error of *SED240* itself does not exceed 6.5 %.

A universal *EVG2001000W/3,510APHplus R3* electronic starter device, which allows setting the required current and duration of pre-heating and lamp current, was used for the lamps (with lamp power and maximum current of 1 kW and 10 A respectively). For monitoring of parameters, *YOKOGAWA PZ400* and *ZES LMG640* power digital analysers were used. After switching the lamp on, the maximum value of E_e (if any) is registered as well as the so-called "shelf" steady-condition mode. Then Φ_e is calculated using the acquired data.

For some samples of lamps, lifetime tests in conditions of operation in water sterilising installations were performed. For this purpose, the lamps in quartz casing were installed in UDV300/900TESTMST test-stand (manufactured by LIT) with recycling water, the temperature of which was artificially maintained by means of the *FT31180*

Table 1. Parameters of the *Jelosil* and *JUV*-labelled Lamps

Sample	U**, V	I, A	P**, W	Φ_e**, W	cap t, °C	Φ_v, W, after 12,000 hours
JUV	153.1	1.81	272	110.0	138	
Jelosil	121.6	1.81	218	57.5	73	
TU*	***	1.85 ± 0.05	235 ± 10	87 ±3	70	at least 74

* We consider it correct to compare the presented samples with the original LIT lamps since the *Jelosil* and *JUV* lamps were applied with the equipment manufactured by NPO LIT. The original LIT lamps are manufactured in accordance with TU3467003581832292002. The technical and operational characteristics of the lamps of other manufacturers also should comply with the standards of this TU for correct operation in NPO LIT sterilising installations.
** Maximum values were measured.
*** Not standardised.

thermostat. Electric parameters, UVR flux, and exterior of the lamps were inspected at the beginning of testing, then in 100 hours of continuous operation and then each regular time interval (usually each 1000 hours). Using the obtained data, it was possible to identify decreasing of UVR flux and changing of exterior of the lamps.

4. LAMP TESTING RESULTS

4.1. DB300 Lamps with *Jelosil* and *JUV* Labels

Two samples of DB300 lamps were tested: the one with the *Jelosil* (*JL19235*) label and the second one with *JUV* (DB300) label (Fig. 2). At the moment of testing, the latter was new and the *JL19235* lamp had been in operation for approximately 3000 hours. Since the electrodes of these lamps are significantly “deepened” in the cap, additional measurements of temperature in the middle point of cap length (by means of *ATT2000* thermometer with the *K*-type thermo-couple) were taken after 15 minutes of continuous operation of the lamps. The results of the measurements are listed in Table 1.

Despite the fact that the samples of products were generally functional (as a separate source of UVR), there are the following comments based on the results of visual examination and measurement of their characteristics.

JUV-labelled DB300 lamp:

The power consumption of the *JUV* lamp significantly exceeds the allowable value, which may lead to a shutdown of the electronic starter device supplying the lamp (activation of emergency protection after exceeding the threshold voltage by the lamp) and even to its breakdown.

The technical specification of LIT-manufactured water sterilising installations (TU4859021302158382014) specifies that the lamp cap temperature should not exceed 70 °C. The cap temperature of this sample was out-of-tolerance (140 °C), as a result, melting and destruction of elements sealing and fixing the lamp in the quartz casing is highly likely, which will lead to fouling of the lamp and the casing and breakdown of the sterilising installation.

Therefore, operation of such lamps in LIT water sterilising installations is not admissible and even dangerous since it may lead to overheating and breakdown of electronic starter device, destruction of sealing elements and even inflammation of equipment. The lifetime tests of this sample were not conducted due to the above-mentioned safety precautions.

Jelosil-labelled lamp (JL19235):

According to NPO LIT, for efficient operation in a water sterilising installation, the value of the UVR flux of the DB300-type lamp at λ = 254 nm shall be at least 74 W by the end of the lifetime, but it was already equal to 58 W after 3000 hours of continuous operation, which is unacceptably low. (Using lamps with low UVR flux provides an insufficient degree of water sterilisation.)

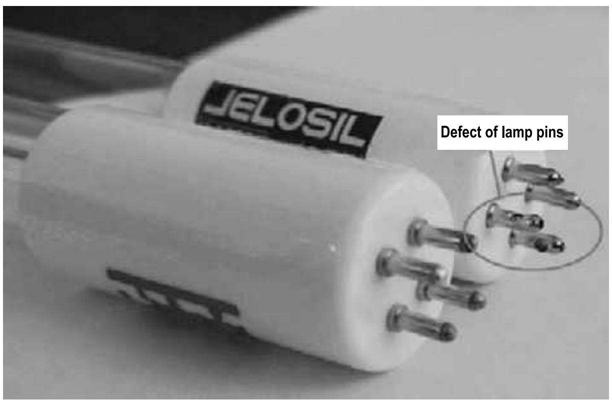

Fig. 3. Crimping of the *Jelosil*-labelled (*JL19235*) lamp sample

Table 2. The Parameters of the *ELTOS*-labelled DB350V Lamp Samples

Sample	*I*, A	Shelf			Maximum		
		U, V	*P*, W	Φ_e, W	*U*, V	*P*, W	Φ_e, W
1	3.2	100.7	322.4	129.6	109.2	349.4	132.7
2	3.2	101.9	326.0	134.5	111.5	357.3	134.1
TU	3.2 ± 0.1	*	*	*	*	325 ± 10	125 ± 5

* Not standardised.

Moreover, the method of connection of a wire with the lamp cap contacts by means of a crimp (Fig. 3) gives rise to doubts. Such connection method is rather well applied for mercury lamps with current from 0.4 to 0.8 A but is not applied for high-output amalgam lamps since, with such type of connection, it is complicated to provide sufficient reliability and mechanical strength of connection, which may lead to lack of electric contact in the lamp pins (and switching-off the lamp) and their breakdown in connection plugs of a sterilising installation. Careless application of cap cement may be also called a disadvantage (Fig. 3).

As a result of testing of the lamp in the UDV300900TESTMST water sterilising installation with a quartz casing (with an inner diameter of 25 mm), it was discovered that drips of melted amalgam had been generated on the inner surface of the tube, which is non-acceptable. Especially if the lamp is positioned vertically, the melted amalgam may reach the hot electrode area, which causes a release of a large number of mercury vapours in the discharge with the subsequent critical decreasing of the UVR flux at λ = 254 nm. The lifetime tests of this sample were not conducted since its flux value was already lower than the low threshold value according to TU3467003581832292002.

Conclusion of clause 4.1

The presented samples of lamps are presumably manufactured in one of the Asian countries. The *JUV*-labelled sample is manufactured more qualitatively than the *Jelosil*-labelled sample in general, but these lamps (both types) may not be applied in LIT installations and similar ones due to non-compliant parameters and non-qualitative design of the cap and contact pins.

4.2. DB350V Lamp with the ELTOS Label

Inspection of the two new samples of DB350V lamps with ELTOS label showed that they are manufactured with rather high quality and have the original constriction of the tube near the electrode. Their measured characteristics are shown in Table 2.

The samples have a high radiant efficiency at λ = 254 nm (37.54 %) and shelf-mode characteristics close to those specified in TU34670035818 32292002, but the maximum power consumption of the lamps was approximately 8 % higher. After 500 hours of the lifetime testing, it was discovered that the isolation of the wires was actively destructing, due to which the inner surface of both quartz casings was covered with a non-washable film. It is obvious that the manufacturer used some other type of wires instead of *PTFE*-isolated ones. Further testing was continued without the quartz casing on an air test stand in order to determine the decreasing of UVR in laboratory conditions. One of the samples stopped working in 200 hours due to breakdown of the electrode, and the other one stopped working after cumulative time of 4000 hours and spending of the emission layer of the electrodes. Fig. 4 shows the exterior of the samples after 2000 hours of operation. It can be seen that the isolation of their wires was destructed by UVR, which made operation of these products dangerous. Decreasing of UVR flux of both samples of the lamp was about 22 % after 2000 hours of operation.

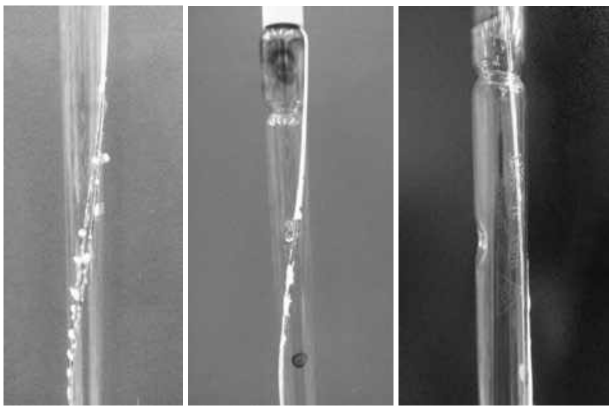

Fig. 4. The exterior of the ELTOS-labelled DB350V lamp sample after 2000 hours of operation

Table 3. The Parameters of the *Lightbest*-labelled Samples of the GPH436T5L/4 Lamp

Sample	I, A	Maximum		
		U, V	P, W	Φ_e, W
1	0.43	47.0	20.2	8.8
2	0.43	46.8	19.9	8.8
According to the *Lighttech* datasheet	0.425	*	21	7.3

* Not standardised.

Conclusion of clause 4.2

The characteristics of the new ELTOS-labelled lamps are close to those specified in TU34670035818322920002, their radiant efficiency at λ = 254 nm is high, and the exterior is rather good. Nevertheless, decreasing of the UVR flux of both samples was equal to 22 % after 2000 hours of lifetime with the maximum allowable decreasing of UVR of 20 % for lamps of this type after 12,000 hours of operation. The error-free running time was much lower than the required value of lifetime. Such lamps cannot be used in UVI installations for water sterilisation due to low lifetime, unacceptably fast decreasing of the UVR flux, danger of fouling of casings with the melted isolation and danger of short-circuit of wires after destruction of the isolation.

4.3. The Lamp with the *LightBest* Label

The authors of the article were requested to test two new samples of the *GPH436T5L/4* mercury lamp with the *LightBest* label (Figs. 5 and 6). For comparison, the specification of the original *GPH436T5L/4* lamp by *Lighttech* was used. The tested lamps are manufactured with the lacking quality, the caps are fixed unevenly, the electrodes are crimped tightly, but the dimensions are compliant with those of the original lamp. The measured parameters of both samples with the *EF23701 FL Golden Way* electronic starter device, which provides the lamp current from 0.40 to 0.45 A, and power of up to 70 W, are listed in Table 3. The UVR flux value of the tested samples of the lamp at λ = 254 nm is a little higher than the nominal value for the similar lamp by *Lighttech*. The decreasing charts of the said UVR flux of the samples during the lifetime on the UDV121NBSC water sterilising installation are shown in Fig. 7.

Fig. 5. The exterior of the *Lightbest* label of the *GPH436T5L/4* lamp sample

Fig. 6. The exterior of the electrode and the cap

Conclusion of clause 4.3

The initial value of the UVR flux of the *GPH436T5L/4* lamp at λ = 254 nm was a little higher than the nominal value of the original lamp manufactured by *Lighttech*, but the time decreasing of their UVR flux was too high. The normal decreasing for the original lamp of this type is (15–20) % after a standard lifetime of 8000 hours. As it can be seen in Fig. 7, the tested lamps reached

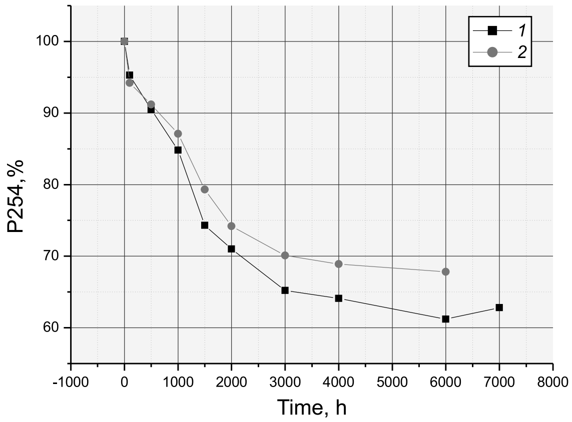

Fig. 7. The UV radiation flux decreasing curves of both samples of the *GPH436T5L/4* lamp with the *Lightbest* label

Table 4. The Parameters of the *UV Product*-labelled Samples of DB300 and DB800V Lamps

Type	I, A	Shelf			Maximum		
		U, V	P, W	Φ_e, W	U, V	P, W	Φ_e, W
DB300	1.80	143.9	259.6	98.6	151.8	272.3	102.9
TU	1.85 ± 0.05	*	*	*	*	235±10	87±3
DB800V	4.91	170.1	835.2	242.4	172.5	847.3	251.1
TU	5.0 ± 0.1	*	*	*	*	710 ± 15	240 ± 10

* Not standardised.

15 % in the water sterilising installation already after 1000 hours of operation, (25–30) % after 2000 hours, and (30–35) % after 3000 hours of operation. The lifetime testing of these lamps was stopped after 8000 hours of operation. Such increment of decreasing means that the installation with the tested lamps will not provide the required degree of sterilisation in 1000 hours of operation.

4.4. DB300 and DB800V Lamps with the *UV Product* Label

The exterior of the two tested lamps DB300 and DB800V is good, the dimensions comply with TU3467003581832292002, the electrodes have a sufficient weight increment (assessed visually), the amalgam is fixed correctly, and there is a laser label on the quartz glass (Fig. 8). The results of measurements of both lamps are listed in Table 4, the results of lifetime tests are shown in Fig. 9.

The UVR flux and the electric parameters of both lamps do not comply with TU3467003581832292002. Both *UV Product*-labelled lamps have a higher value of the UVR flux than that specified in TU but, unfortunately, a higher value of power too. It is worth noting that an increasing of the UV dose is not mandatory in case of the replacement of lamps in the existing equipment: UVI installations are designed with the technological reserve of the UVR bactericidal dose; however, the increased power consumption of lamps may lead to their additional heating in an installation as compared to the designed one, and the increased power consumption means additional financial costs. For instance, the tested DB800V amalgam lamp with the *UV Product* label consumes approximately 130 W more than the original lamp. With the price of electricity of 4 roubles per kWh, additional financial costs for a year of continuous operation of 100 such lamps (in WDI 100 type installations) will be equal to 455 thousand roubles.

The electronic starter devices in sterilising installations with such lamps are designed for a power load not exceeding 800 W. Its exceeding may lead to overheating and, therefore, to reduction of lifetime of the electronic starter device and even to the activation of protection and shutdown of this device.

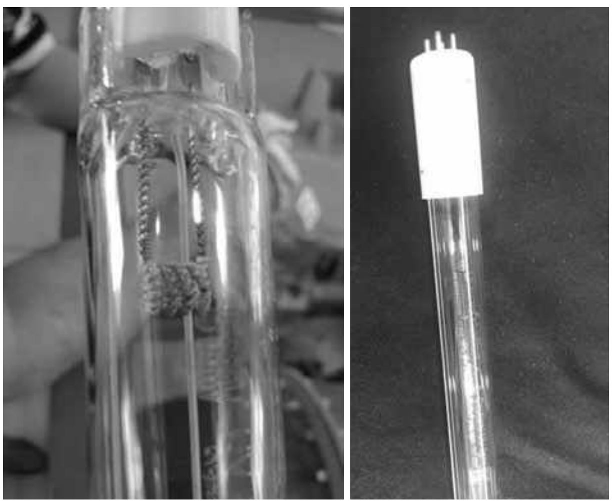

Fig. 8. *UV Product*-labelled samples of the *DB800V* and *DB300* lamps

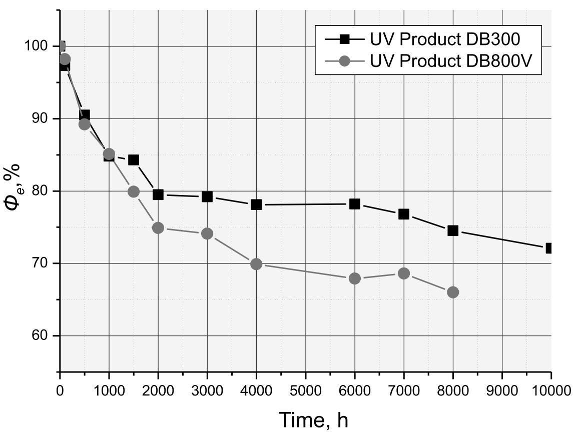

Fig. 9. Lifetime dependence of the UV radiation flux of *DB800V* and *DB300* lamp samples with the *UV Product* label

Table 5. The Parameters of the Samples of the *SeaN*-labelled DB350 Lamp

Sample	*I*, A	Shelf			Maximum		
		U, V	*P*, W	Φ_e, W	*U*, V	*P*, W	Φ_e, W
1	3.13	97.7	304.1	118.6	97.7	304.1	118.6
2		98.6	307.0	120.5	98.6	307.0	120.5
TU	3.2 ± 0.1	*	*	*	*	325 ± 10	125 ± 5

* Not standardised.

Conclusion of clause 4.4

The *UV Product*-labelled lamps have rather high quality of structure, the value of their UVR flux is higher than that of the original lamps by LIT (according to TU3467003581832292002), but their application in the installations manufactured by LIT will lead to an increase of power consumption by (15–18) % of the specified values. The lifetime tests show that the UVR decreasing of such sources reaches from 25 to 35 % after 8000 hours of operation, which is significantly higher that the recommended value of (15–20) %. Therefore, despite the higher UVR flux in the beginning of the lifetime, it may be significantly lower than the parameters specified in TU3467003581832292002 in the end of the lifetime. Higher power will cause overheating of the electronic starter device and its possible shutdown.

4.5. The Lamp with the *SeaN* Label (NTC SeaN)

Two samples of the DB350 lamp with the *SeaN* label (NTC SeaN) (Fig. 10), which were sent by a customer operating the potable water sterilising equipment manufactured by LIT, were tested. The samples have rather high quality of structure and their dimensions comply with TU3467003581832292002, but connection of the pins with the lamp wire by means of stamping, like in the case of the *Jelosil*-labelled lamps, is not acceptable for amalgam lamps of such power due to the low reliability. The measured characteristics of these samples are listed in Table 5.

It was discovered that the *SeaN* samples are underheated at an air temperature of 25 °C, therefore, their characteristics were lower than the maximum possible ones witnessing that the manufacturer selected the amalgam incorrectly. For checking of capability to apply such type of lamps in water sterilising installations, these samples were installed in the LIT-manufactured UDV300900TESTMST installation, and the values of the UVR flux with water temperature changing over a wide range were measured (Fig. 11). Fig. 11 shows that the maximum (optimal) value of the UVR flux is reached only after the water temperature reaches approximately 30 °C. Therefore, the *SeaN* lamp may be efficiently operated in LIT installations with a rather high water temperature of at least 30 °C. Probably, the tested samples of the lamp are designed for operation in another type of UVI equipment (e.g. with another diameter of the quartz casing), we would also like to note that the value of electric power of the lamp *P* significantly increases and in such conditions it becomes higher than the one specified in TU3467003581832292002. When using these

Fig. 10. The sample of the *SeaN*-labelled DB350 lamp

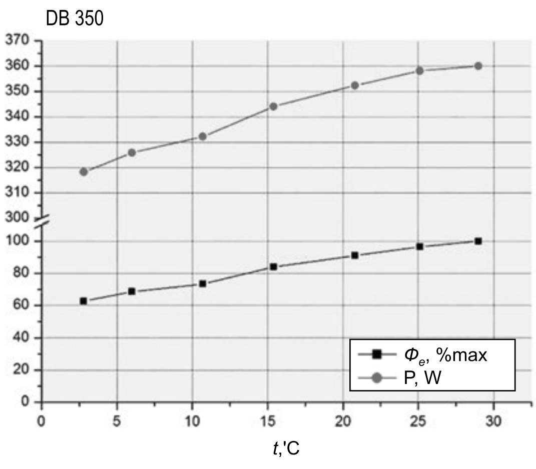

Fig. 11. Water temperature dependence of the UV radiation flux of the DB350 lamp sample

lamps for sterilisation of potable water at indicative values of temperature of 1 to 10 °C, the value of UVR flux of the lamps significantly decreases by 40 % of the maximum one. The lifetime test of these samples of the lamps in a water sterilising installation was not conducted since interpretation of the results of such tests would have been complicated by complexity of correct comparison of the obtained results.

Conclusion of clause 4.5

The *SeaN*-labelled lamp was probably designed for another manufacturer of UVI equipment and was probably supplied from one of the Asian countries. It cannot operate efficiently at water temperatures less than (10–15) °C significantly decreasing its UVR flux value.

5. CONCLUSION

The quality of the tested samples of low-pressure bactericidal lamps introduced in the Russian market under *Jelosil*, *JUV*, ELTOS, *LightBest*, *UV Product*", and *SeaN* (NTC SeaN) labels is low. Some manufacturers use stamping or crimping for connection the lamp wire with the cap pins. Such method of connection is used for mercury bactericidal lamps and FLs with the discharge current from 0.4 to 0.8 A, but does not fit for high-output amalgam lamps due to its low reliability. Instead of the *PTFE*-isolated wire, other type of wires had been used for the ELTOS-labelled DB350V lamps, which led to destruction of the isolation. Operating such samples is dangerous: the electronic starter devices and casings may breakdown and even inflammation of equipment may be caused. The value of the UVR flux at λ = 254 nm of all new tested samples of lamps complied with the declared nominal values, but its decreasing appeared to be too high and could reach (25–30) % after 2000 hours of operation, which is significantly higher than the recommended value of (15–20) % after 8000 hours of operation. Such decreasing means that the installation will not provide the required degree of sterilisation after 2000 hours of operation. The power consumption of all tested samples of lamps was higher than the one specified in the TU for the original similar lamps, which witnesses their lower value of the radiant efficiency at λ = 254 nm. Too high power of a lamp leads to its overheating and, therefore, to the decrease of the electronic starter device lifetime. Overconsumption causes additional financial costs compensating economy from purchasing cheaper lamps by an unknown manufacturer. The presented lamps were designed and manufactured based on design specifications of specific manufacturers or are copies of UV lamps by well-known brands, but manufactured using own technology. At the same time, the quality of their protective layer (apparently very low) accelerates the temporary decline of UVR; and the features of ultraviolet irradiation equipment for water disinfection were not taken into account. This may lead to numerous problems in the course of operation of the UVI equipment and negatively affect the reputation of the UVR sterilisation method. In the conditions of the competitive market, the consumers have the right to select and to replace the lamps or electronic starter devices in UVI installations by themselves. However, these actions should be taken only with the consideration of operation distinctions of a specific type of equipment and based on the recommendations of specialists.

REFERENCES

1. Karmazinov F.V., Kostyuchenko S.V., Kudryavtsev N.N., Khramenkov S.V. Ultrafioletovye tekhnologii v sovremennom mire: Kollektivnaia monografiia [Ultra-violet technologies in the modern world: Collective monography] // Intellect Publishing House, Dolgoprudny, 2012, 392 p.

2. Vasilyev A.I., Kostyuchenko S.V., Kudryavtsev N.N., Sobur N.N., Sokolov D.V. Tekhnologii UF obezzarazhivaniia dlia obrabotki vody, vozdukha i poverkhnosti [UV sterilisation technologies for treatment of water, air and surface] // Svetotekhnika, 2017, No. 5, pp. 6–11 // Light & Engineering, 2018, Vol.26, #1, pp. 25-31.

3. Veselnitski I.M., Rokhlin G.N. Rtutnye lampy vysokogo davleniia [High-pressure mercury lamps] // Energiya, Moscow, 1971, 328 p.

4. Parson S. Advanced Oxidation Processes for Water and Wastewater Treatment // IWA Publishing, 2004, ISBN: 1843390175.

5. Pirovich A.L. Germicidal low pressure mercury vapor discharge lamp with amalgam location permitting high output // Patent US2004/0195954, 07.10.2004.

6. Rokhlin G.N. Razryadnye istochniki sveta [Discharge light sources] // Energoatomizdat, Moscow, 1991, pp. 60–80.

7. Levchenko V.A., Vasilyev A.I., Vasilyak L.M., Kostyuchenko S.V., Kudryavtsev N.N. Uvelichenie fizicheskogo sroka sluzhby moshchnykh gazorazriadnykh lamp

nizkogo davleniia [Increasing of service life of high-output low-pressure discharge lamps] // Prikladnaia fizika, 2015, No. 5, pp. 90–94.

8. Levchenko V.A., Vasilyak L.M., Kostyuchenko S.V., Kudryavtsev N.N., Svitnev S.A., Sharanov E.P. VUF izluchenie rtutnogo razriada pri davlenii bufernogo gaza menee 1 Torr [UV radiation of mercury discharge at buffer gas pressure of less than 1 torr] // Uspekhi prikladnoi fiziki, 2016, No. 3, pp. 256–264.

9. Svitnev S.A., Popov O.A. Raschet funktsii raspredeleniia elektronov po energiiam v statsionarnom razriade nizkogo davleniia [Calculation of electron energy distribution function of a low-pressure stationary discharge] // MEI Bulletin, 2012, No. 3, pp. 100–105.

10. Keitz H.A.E. Light Calculation and Measurements // Macmillan and Co Ltd, London, 1971.

11. Vasilyak L.M., Drozdov L.A., Kostyuchenko S.V., Kudryavtsev N.N., Sobur D.A., Sokolov D.V., Shunkov Yu.E. Metodika izmereniia potoka UF izlucheniia trubchatykh bakteritsidnykh lamp ND [Methodology of measurement of UV radiation flux of low-pressure tube bactericidal lamps] // Svetotekhnika, 2011, No. 1, pp. 29–32 // Light & Engineering, 2011, Vol. 19. #1, pp. 81-86.

Michael E. Allash,
employee of Lighttech Kft

Leonid M. Vasilyak,
Dr. of Phys. and Math. Science, Professor. Chief Researcher of the United Institute of High Temperatures (OIVT) of the Russian Academy of Science

Nikolay P. Eliseev,
Ph.D. in Tech. Science. Associate Professor of the Lighting Engineering department of NRU MPEI

Oleg A. Popov,
Dr. of Tech. Science. Professor of the Lighting Engineering department of NRU MPEI

Dmitry V. Sokolov,
Ph.D. in Tech. Science. Head of the Lighting Engineering Department of NPO LIT