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PHOTOBIOLOGICAL SAFETY OF IMAGE PROJECTORS WITH HALOGEN INCANDESCENT LAMPS

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Abstract- The requirements for photobiological safety of lamp systems and methods for assessing the hazards of blue light and thermal hazards generated by optical radiation with wavelengths of 380-1400 nm, projectors using halogen incandescent lamps (HIL) are analyzed. The results of the levels' study of blue light photobiological danger of image projectors with HIL with a power of 210 W are presented. It is shown that the studied type of projector belongs to the risk group RG2. The safe exposure time of blue light t_B is 14.5 sec, and the safe thermal exposure time t_R is 1.2 sec. When the distance is reduced to 0.5 m, the risk of blue light and thermal hazards remains within the RG2 group (medium risk) with less safe exposure time.
Conclusions are made on the compliance of the studied image projectors with the conditions of light photobiological safety.

Keywords: Photobiological Safety, Thermal Hazard, Blue Light, Brightness, Projector.

1. INTRODUCTION

At the present stage, the solution to reduce energy consumption for lighting is a relevant problem. According to the International Energy Agency, 19% of the world's electricity production is spent on lighting [1]. Over the past decades, a large number of scientific papers have been published aimed at improving energy efficiency, limiting the use of inefficient light sources [2-6]. An equally important issue is the quality of light, although it has received less attention so far. It is known that the optical radiation of artificial light sources can create negative biological processes in the human body [7]. Light emitted in the wavelength range 400-500 nm (maximum about 435-440 nm) causes a photochemical effect on the retina. This range corresponds to blue light, so the danger associated with this spectrum range is called the danger of blue light.

The International Illumination Commission on [8, 9] clarified the term "danger of blue light". It should only be used when considering the photochemical risk of retinal damage (photo maculopathy), usually associated with fixation on bright light sources. General requirements for the classification and methods of assessing the photobiological safety of lamps and tube systems are set in [10]. With regard to projectors, which are classified as tube systems, features of assessing their photobiological hazard are set out in [11]. In addition to the danger of blue light, projectors can create thermal hazards for the retina with light wavelengths in the range of 380-1400 nm, so the study of light safety of image projectors, especially those used in various educational institutions without professional maintenance is an urgent task.

According to [11], a projector is an optical system that uses the reflection and/or refraction of light to increase the intensity of light at a limited body angle. The beams of the projectors have a high brightness (more than 10^6 kd/m^2), which can cause danger to the retina when viewed directly into the lens from a short distance. The danger of projector light, according to [12], is classified into four risk groups RG0, RG1, RG2, RG3

General group RG0. The physiological basis of the RG0 classification is that the projector light does not pose any photobiological hazard to the retina for 10000 s (more than 2.8 h). Low risk group RG1. The projector's light beam exceeds the RG0 limit, but does not endanger the retina for 100 s medium risk group RG2. This requirement is met when the RG1 limits are exceeded, but does not pose a hazard to the retina for 0.25 s. The RG2 projector can be used safely, except in cases of direct eye radiation. RG3 risk products pose a risk group even with short-term exposure (less than 0.25 s).

The blue light hazard risk assessment of projectors is based on the L_B energy luminance power in the field of view specified in standard [11]. The spectral function of the severity of the danger of blue light (B) and thermal danger (R) in the wavelength range 380-1400 nm is shown in Figure 1 [12].

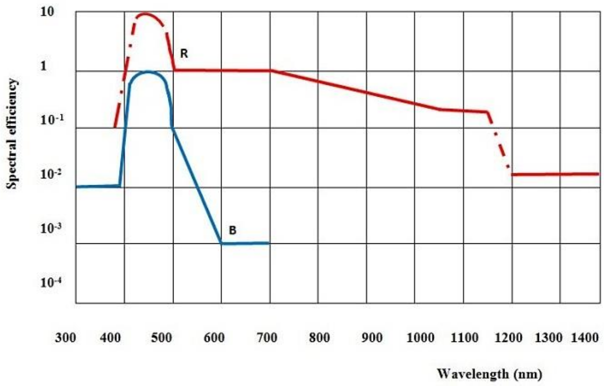

Figure 1. Spectral functions of hazard severity for retina [12]

Limit values of energy, maximum safe exposure time of blue light t_B and thermal radiation t_R (in the wavelength range 380-1400 nm), as well as recommended reception angles (fields of view) γ when measuring these energy values are shown in Tables 1-3.

Table 1. Limit values of energy values for different risk groups [11]

Danger	Wave length, nm	Radiation level symbol, measuring unit	Angle of view γ, rad		
			Risk group RG0	Risk group RG1	Risk group RG2
Blue light	300 to 700	L_B W/m^2·sr	100	10000	4000000
Blue light (Not big source)	300 to 700	E_B W/m^2	1.0	1.0	400
Thermal damage to the retina	380 to 1400	L_R W/m^2·sr	28000/α	28000/α	28000/α

Table 2. Exposure time limits for different risk groups [11]

Danger	Risk group RG0	Risk group RG1	Risk group RG2
Blue light	10000 s	100 s	0.25 s
Thermal damage to the retina	0.25 s	0.25 s	0.25 s

Projectors, unlike most lighting lamps and tube systems, use projection optics, which increase the intensity of light and form an imaginary image of the light source, which is perceived by the observer with changed dimensions and location. If the concentration of the light beam changes by changing the distance from the crystal to the lens, the dimensions of the imaginary image will change accordingly.

When the beam is narrowed, the position of the visible source changes by a greater distance. Measurement conditions for finding the energy brightness are shown in Figure 2.

Table 3. Receiving angles for measuring the energy brightness of projectors [11]

Danger's name	Wavelength, nm	Angle of view γ, rad		
		Risk group RG0	Risk group RG1	Risk group RG2
Blue light	300 to 700	0.11	0.011	0.011
Thermal damage to the retina	380 to 1400	0.011	0.011	0.011

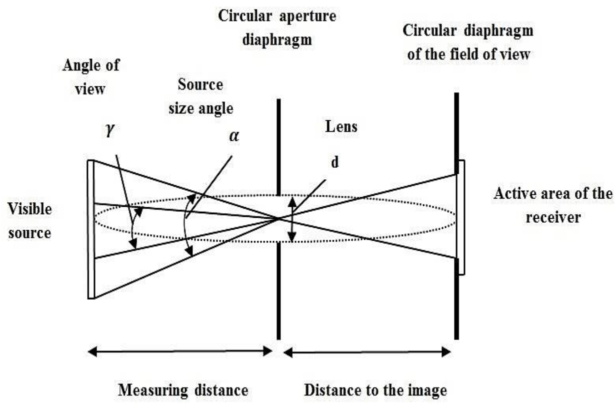

Figure 2. Measurement conditions for finding energy brightness

The peculiarities of determining the risk group of image projectors are that the energy brightness and energy illumination should be determined nearer to the light source along the axis of the light beam. For narrow, optically generated rays, the flux density within the beam increases, so the value of the irradiation (illumination) created by them also increases.

This should be taken into account when assessing the photobiological hazards of blue light in terms of exposure, because optics can significantly change its level. Assessment of photobiological safety by measuring energy illuminance is used mainly for small light sources with angular dimensions α<1.7 mrad. If the source is observed through magnifying optics, it may be that the angular size of the image will exceed 1.7 mrad and can be considered as a source of extended dimensions. In these cases, it is advisable to use energy brightness to assess photobiological safety.

When assessing the photochemical hazard of blue light by energy brightness, the optics do not affect the measurement result, because according to the law of conservation of brightness, it cannot change it. But this statement is valid only in cases where the angle of view γ is less than the angular size of the image of the source, i.e., for the actual brightness. If $\gamma>\alpha$, then the evaluation is performed on the average in the field of view energy brightness. When measuring the average brightness (when changing the measurement distance r), the value of the angle γ must remain unchanged, while the value of the angular size of the source α changes.

Spatially averaged brightness values in the "incomplete field of view" (at $\gamma>\alpha$) decreases with increasing distance from the projector, first according to the linear law, and then in the "far field" as a ratio $(\gamma/\alpha)^2$.

The aim of this work is to study the risks of photobiological hazards of blue light and thermal hazards (for the wavelength range 380-1400 nm) HIL image projectors belonging to the risk group RG2 and used in everyday life, schools and other areas.

2. PRESENTATION OF THE MAIN MATERIAL OF THE STUDY

The levels of photobiological danger of blue light and thermal danger of 210 W HIL projectors were studied. The energy parameters of the projectors were measured using a set of test equipment for risk assessment of photobiological hazards of light OST 300. Spectro radiometric system kit includes monochromators, photoelectric detector, system for measuring spectral density and size of light sources, and a simulator of the human eye 1.7 m in the field 11 mrad and 110 mrad.

Measurement results are processed by a computer with software that allows calculating the brightness L_V (kd/m^2) and illuminance E_V (lux), energy brightness L_B (W/m^2·sr) and energy illuminance E_B (W/m^2), weighted by spectral function blue light hazards B (λ), energy brightness L_R (W/m^2·sr) and energy illuminance E_R (W/m^2), weighted spectral function of thermal hazard R (λ) correlated color temperature (CCT) and other parameters. L_B energy brightness, E_B illuminance and safe blue light exposure time are determined from the following expressions based on spectral measurement data [10]:

• light sources with an angular size greater than 11 mrad:

$$L_B t = \sum_{300}^{700} \sum L_\lambda(\lambda, t) B(\lambda) \Delta t \Delta\lambda \le 10^6 \text{ J/m}^2\text{sr}, \ t \le 10^4 \text{ s} \quad (1)$$

$$L_B = \sum_{300}^{700} L_\lambda \times B(\lambda) \times \Delta\lambda \le 100, \ t > 10^4 \text{ s} \quad (2)$$

$$t_{\max} = \frac{10^6}{L_B}, \ L_B > 100 \text{ W/m}^2\text{sr} \quad (3)$$

where, L_B energy brightness; B (λ) is a spectral function of the severity of the danger of blue light, in relative units (Figure 1); L_B is energy brightness of blue light, taking into account the function of the severity of the danger of blue light; $\Delta\lambda$ is wavelength interval in nanometers; and t is the duration of exposure in seconds;

• light sources with an angular size of less than 11 mrad [10]:

$$E_B t = \sum_{300}^{700} \sum E_\lambda(\lambda, t) \times B(\lambda) \times \Delta t \times \Delta\lambda \le 100 \text{ Jm}^{-2}, \ t \le 100 \text{s} \quad (4)$$

$$E_B = \sum_{300}^{700} E_\lambda \times B(\lambda) \times \Delta\lambda \le 1, \ t > 100 \text{s} \quad (5)$$

where, E_B energy illuminance, taking into account the function of the severity of the danger of blue light; and t is the irradiation time in seconds.

For a small source, with an energy illuminance E_B > 0.01 W/m^2, the limit values shall not exceed the levels determined by the formula [10]:

$$t_{\max} = \frac{10^2}{E_B}, \ t \le 100 \text{s} \quad (6)$$

where, $t_{\max}$ is the maximum allowable exposure time in seconds. Energy brightness levels weighted by the thermal hazard function $R(\lambda)$ were also determined according to [10]:

$$L_R = \sum_{380}^{1400} L_\lambda R(\lambda) \Delta\lambda, \ 10 \text{ mks} \le t \le 10 \text{s} \quad (7)$$

where, L_R energy brightness, weighted by the function of the danger of thermal action on the retina, W/m^{2}sr; and $R(\lambda)$ is a function of the severity of the danger of thermal action, in relevant units (Figure 1).

Measurements of parameters for assessing the danger of blue light were performed from a distance of 1 m at an angle of view of 11 mrad. The energy brightness weighted by the L_R thermal hazard function was determined for the angular size of the source 11 mrad and from the same distance at an angle of view 11 mrad. The results of measuring the average energy luminance (L_B), energy luminance the (L_R) are shown in Table 4.

Table 4. The results of measuring

CCT, K	6565
L_V, kd/m^2	9.96×10^7
L_B, W/m^{2}sr	6.92×10^4
L_R, W/m^{2}sr	2.2×10^6
E_V, lux	8570
E_B, W/m^2	5.92
$t_{B\max}$, s	0.25
t_B, s	14.5
$t_{R\max}$, s	0.25
t_R, s	1.2
Risk group	RG2

With regard to thermal danger, the maximum energy brightness L_R, weighted by the function of thermal hazard of visible radiation $R(\lambda)$, numerically equal to the maximum allowable brightness for risk group RG2 [10]. For continuous radiation projectors, the energy luminance of L_R max shall not exceed [10]:

$$L_{R\max} = \frac{28000}{\alpha} \text{ W/m}^2\text{sr} \quad (8)$$

where, α is the angular size of the light source (in radians).

The maximum energy brightness L_R max depends on the angular size of the visible source and is calculated using the distance from the observer to the visible source. If the brightness L_R is determined with an average angle γ = 11 mrad, then the minimum angular size αmin should be α = 11 mrad, and the maximum is no more than 100 rad. At an angular size α<11 mrad to determine L_R it is necessary to take α = 11 mrad, and at α>100 mrad - limit to 100 mrad. We performed measurements at r = 1 m, $\alpha = \gamma$ = 11 mrad. For these conditions:

$$L_{R\max} = \frac{28000}{0.011} = 2.545 \times 10^6 \text{ W/m}^2\text{sr}$$

The results show that at a distance of 1 m (the distance for which the level of photobiological safety of blue light is normalized), this type of projectors belongs to the group RG2 (medium risk). The time of safe exposure of blue light at a distance of 1 m is 14.5 s, and the thermal danger of light with wavelengths in the range of 380 - 1400 nm at a distance of 1 m - 1.2 s. That is, the thermal hazard of projectors with HIL over short distances is more critical than the danger of blue light. When the distance is reduced to 0.5 m, the risk group for blue light and thermal hazard remains unchanged - RG2, but the safe exposure time is reduced. It is 5.7 s for blue light and 0.8 s for thermal danger.

3. CONCLUSION

1) The studied image projectors with HIL with a power of 210 W do not exceed the level of photobiological danger of blue light and thermal danger of light of risk group RG2 (medium risk) and meet the requirements of international standard IEC 62471-5. Image Projectors;
2) It is shown that the level of energy brightness, of thermal danger of light with wavelengths 380 - 1400 nm is normal, the safe exposure time of blue light is 14.5 s, and the time of safe thermal exposure - 1.2 s;
3) For image projectors with HIL safe exposure time of blue light t_B is much higher than safe thermal exposure time t_R.

NOMENCLATURES

1. Acronyms

HIL Halogen Incandescent Lamp
IEC International Electrotechnical Commission
CCT Correlated Color Temperature

2. Symbols / Parameters

t_B: Exposure time of blue light
t_R: Thermal exposure time
$B(\lambda)$: Blue light hazard spectral function
$R(\lambda)$: Weighted spectral function of thermal hazard
L_B: Energy brightness
L_V: Brightness
E_B: Energy illuminance
E_V: Illuminance
E_R: Energy illuminance
α: Source size angle
γ: Angle of view
$L_B(\lambda, t)$: Spectral energy brightness
L_R: Energy brightness
$\Delta\lambda$: Wavelength interval
t: Duration of exposure

REFERENCES

[1] https://shop220.ru/pdf/?id=742.
[2] K. Dursun, H. Mordt, "Effect of Led Lighting in Electricity Consumption of Norway", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 15, Vol. 5, No. 2, pp. 143-147, June 2013.
[3] A. Wilkins, B. Lehman, "Designing to Mitigate Effects of Flicker in LED Lighting: Reducing Risks to Health and Safety", IEEE Power Electronics Magazine, Vol. 1, No. 3, pp. 18-26, 2014.
[4] S.A. Baghirov, H.M. Kozhushko, Y.A. Basova, L.N. Guba, "Ways to Increase the Energy Efficiency of Lighting Products in Azerbaijan through the Development of a Technical Regulation System", Materials of the VI International Scientific and Practical Internet Conference, pp. 219-221, Poltava, 14-15 March 2019.
[5] S.A. Baghirov, S.V. Shpak, H.M. Kozhushko, S.H. Kyslytsia, N.V. Yermilova, "The Current State of Energy Efficiency and Light Quality of LED Products", Collection of Scientific Works by Materials, International Azerbaijani-Ukrainian Scientific Practical Conference III, pp. 480-482, Baku-Poltava, 1-2 June 2020.
[6] R. Ildarabadi, M.R. Gholizadeh, "Adjust Brightness of LED Lights in Accordance with Ambient Light", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 45, Vol. 12, No. 4, pp. 11-18, December 2020.
[7] S.A. Baghirov, S.S. Baghirova, S.H. Kyslytsia, H.M. Kozhushko, S.Z. Mammadzada, "Circad Efficiency of Light-Emitting Diode Radiation for General Lighting", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 50, Vol. 14, No. 1, pp. 172-176, March 2022.
[8] CIE TN 002:2014, "Technical Note: Relating Photochemical and Photobiological Quantities to Photometric Quantities", p. 4, Vienna, Austria, 2014.
[9] CIE, "Position Statement on the Blue Light Hazard", p. 1, Vienna, Austria, 23 April 2019.
[10] IEC 62471, "Photobiological Safety of Lamps and Lamp Systems", Vienna, Austria, 2006.
[11] IEC 62471-5, "Photobiological Safety of Lamps and Lamp Systems", Part 5, Image Projectors, 76/504/CDV, 2014.
[12] IEC/TR 62778, "Application of IEC 62471 for the Assessment of Blue Light Hazard to Light Sources and Luminaires", p. 37, 27 June 2014.

BIOGRAPHIES

Oleksandr Serhiyovych Pitiakov was born in Poltava, Ukraine in 1982. He received the Ph.D. degree in 2022. Currently, he is the director of Separate Structural Unit "Poltava Polytechnic Vocational College of National Technical University, Kharkiv Polytechnic Institute, Poltava, Ukraine since 2019. The direction of scientific research is lighting engineering and light sources, photobiological safety, energy-saving technologies, electrical engineering and electrical technologies. He is the author of 15 articles.

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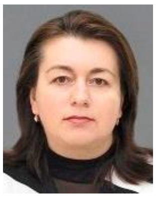
Pavel Ivanovich Neyezhmakov was born in Zhmerynka, Ukraine in 1961. He is the General Director of National Scientific Centre, Institute of Metrology (Kharkiv, Ukraine), Doctor of Sciences (Standardization, Certification, Metrology and Metrological Support), and Professor of Department of Lighting Engineering and Light Sources, Ukraine. He is also a member of International Committee for Weights and Measures (CIPM), Chair of the Working Group on Core Metrological Terms of the Consultative Committee of Units (CCU WG-CMT), Member of the Joint Committee of Guide on Metrology (JCGM). He has deep knowledge in the field of metrology formed by considerable expertise in measurement science. He has nearly 40 years of research experience in the fields of length measurements, photometry and radiometry, ionization radiation dosimetry. He is the author of more than 200 articles.

Svitlana Vasilivna Shpak was born in Poltava, Ukraine in 1969. She received Ph.D. degree in 2021. She is the chef of research center of tests of electric lamps and technological equipment SE "Poltavastandartmetrology", Ukraine since 2006. The direction of scientific research is lighting engineering and light sources, photobiological safety, energy-saving technologies, electrical engineering and electrical technologies. She is the author of 20 articles.



Svitlana Hryhorivna Kyslytsia was born in Poltava, Ukraine in 1970. In 1993, she graduated from the Kharkiv National University of Urban Economy, Ukraine with degree in electrical engineering. In 2001, she received the Ph.D. degree from Kharkiv National University of Urban Economy, Ukraine. Since 2002, she has been an Associate Professor at Department of Automation and Electric Drive at Poltava National Polytechnic, Ukraine. Currently, she works at Department of Automation, Electronics and Telecommunications of the same university. She continues his research in the field of light engineering and energy-saving technologies of light sources, control systems in electric power.

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