Строительство уникальных зданий и сооружений. ISSN 2304-6295. 6 (57). 2017. 47-55

Construction of Unique Buildings and Structures

journal homepage: www.unistroy.spbstu.ru

Light Sources in Accordance with Their Quality Indicators and Energy Efficiency

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ARTICLE INFO	Articlehistory	Keywords
doi: 10.18720/CUBS.57.4	Received 04.06.2017	buildings; construction; civil engineering; energy efficiency; energy saving; artificial lighting; illuminance measurement; health protection; luminous radiation.;

ABSTRACT

With a view to implementing the state policy in the field of energy saving and energy efficiency, steps are being taken to improve of engineering networks and communications in the St. Petersburg Polytechnic University. In particular, to determine the potential for increasing the efficiency of indoor lighting systems, a test was conducted using a luxmeter in the classrooms of the administrative building. It showed that the actual lighting indicators meet modern energy efficiency requirements and sanitary standards. Nevertheless, visitors with a long stay note the discomfort of the eyes. To determine the cause of this phenomenon the light sources characteristics were considered in detail that affect the visual workability and human health as a whole: emission spectrum, color temperature, intensity of light, daylight factor and light pulsations factor. A comparative analysis of the given characteristics of some light sources showed that conventional LED lamps are undesirable for long-term use because of the increased dose of blue light in the color spectrum of illumination. In the world market today there is a large selection of alternative light sources, domestic and foreign production, which differ in the work, power consumption, spectral composition of light. The article considers optimization problem of light sources choice for specific operating conditions, taking into account the simultaneous provision of quality indicators of artificial lighting systems and their energy efficiency.

Contents

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1. Introduction

With a view to implementing the state policy in the field of energy saving and energy efficiency, steps are being taken to improve of engineering networks and communications in the St. Petersburg Polytechnic University. In particular, to determine the potential for increasing the efficiency of indoor lighting systems, a test was conducted using a luxmeter in the classrooms of the administrative building.

Annually in Russia up to 14% of energy consumption is spent on lighting [1]. According to the results of the expert assessment it was found that electricity costs could be reduced by 40% [2] by the power supply system optimization. However in addition to the energy savings should take into account other parameters: the degree of comfort, safety, effect on mood and quality of life, which are directly depend on the room illumination. Numerous laboratory and industrial researches [3–14] performed worldwide had a great impact of artificial lighting on productivity and quality of products, reduction in reject rate and accidents at work, improvement of working conditions, preservation of health and increase in life expectancy of workers.

As a result of the artificial lighting system modernization associated with the replacement of traditional light sources by modern energy efficient one such as LED, induction, compact fluorescent lamps, quantitative lighting characteristics such as illuminance and luminous flux are provided, but there are numerous complaints about eye fatigue at the end of shift, headaches, indicating an uncomfortable of light environment.

The aim of the research is to develop recommendations for improving the safety and energy efficiency of lighting systems in a non-residential building. To achieve the aim, it is necessary to solve the following tasks:

1) estimation of parameters of illumination in a space
2) retrospective of actual indicators with acceptable values
3) determination of the causes of discomfort in occupants
4) analysis of existing solutions

Basic lighting indicators are coefficients of natural and artificial illumination. Methods for determining the actual indicators are based on field measurements directly in a room to be measured, using a luxmeter [15]. The measurements allowed to quantify the basic parameters of light (coefficients of natural and artificial illumination, discomfort index and illuminance ripple ratio) and to compare them with the established federal requirements and standards.

2. Methods and results

2.1 Initial data

The object of research is the classroom of academic building located at St. Petersburg, built and put into operation in 1971. The classroom, located on the first floor of the building, was chosen for testing. Overall dimensions of the classroom are 27x11.6 m. The height from the floor to the bottom of the supporting beams is 7.1 m. The room is separated into 2 tiers in height. The height of the 2nd tier on the floor level of the 1st one is 4 m. On the 1st tier laboratory tests are conducted, on the 2nd one lectures and seminars are organized.

Translucent window structures are oriented on south-west. The total glass area is 106 m2. Solar lighting is ambient, because at a distance of 53 m from the glazed facade a building height of 23 m is located.

In 2014 fluorescent lamps were replaced by energy-saving LED. In total there are 27 lamps of 20 watts in class, located at a height of 4 m on the floor level of the 2nd tier. The total power does not exceed maximum allowable specific installed capacity [16–18].

In the work luxmeter TKA-PKM¬_09 was used for illuminance measurement. Full-scale tests carried out at lunchtime when all lighting devices were operating properly, side lighting had no barriers for the passage of light into the room.

2.2 Field result

In the classroom of Gidrokorpus-2 practical and laboratory classes are conducted in addition to the lectures. For this reason, the nature of the visual work has been selected in accordance with the Russian State Standards [16–18] as a high precision, class A, subclass 1, the relative duration of visual work in the direction of the work plane is at least 70%.

The measured results and normative indicators of lighting are shown in Table 1. For each position 3–5 measurements was made. Normative values of luminance are installed in its minimum value points on the working surface and accepted for classrooms, educational offices, laboratories, colleges and higher education institutions according to Russian State Standard [18].

Table 1. The actual and normative indicators of lighting

Plane	The actual indicators			The normative indicators		
	E, lux	K_p, %	e_x, %	E, lux	K_p, %	e_n, %
Working surface (height 0.8 m)	470	9.2	0.8	400	10	0.7
The middle of the blackboard	530	9.9	–	500	10	–
Symbols: E – luminous intensity coefficient; Kp – light pulsations factor; e – daylight factor.						

The natural lighting calculation in the room was carried out without regard to furniture, equipment, plants, and also at one hundred percent using of translucent structures of light apertures. Daylight factor indoor was determined at the design point located at the intersection of vertical room section plane and conditional working surface at a distance of 1.2 m from the wall farthest from the light apertures, at the switched off lighting devices from the ratio of luminance coefficients inside and outside [18, 21].

Comparative analysis showed that the actual indicators of lighting in a room correspond to the normative one [16–20].

2.3 Survey result

In order to explore in greater depth the issue a survey was conducted among students and teachers. The test proposed to specify the type and duration of work and assess the degree of light saturation of the room. The survey involved 63 respondents. According to the survey the dependence of a comfortable stay in a room on the duration of the work was found (Fig. 1): the longer a person stays in a room, the more he feels negative eyesight impact (pain, itching, burning, dryness in the eyes and deterioration of visual acuity).

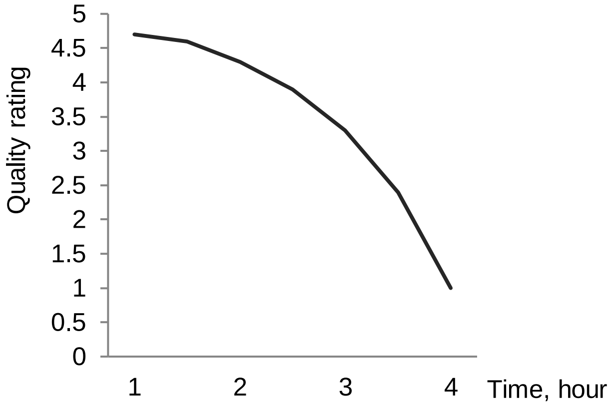

Fig. 1. Graph of the dependence of a comfortable stay in the room on the duration of the work.

Possible reasons for this phenomenon are: excessive proportion of blue light of the LED spectrum, general fatigue due long work, reducing natural light by end of the workday, dry air in a room and others.

During experiments and measurements [22] carried out in N. M. Emanuel Institute of Biochemical Physics, it has been found that with decreasing correlated color temperature (CCT) of artificial light sources, the diameter of the eye pupil increases, creating the preconditions for negative cells and retinal vessels effect of blue light. With increasing CCT of artificial light sources, the pupil diameter decreases, but does not reach values in sunlight.

The above identified effects of inadequate management of pupil diameter of the eye apply to LED, fluorescent and energy-saving lamps. Thus, a dose of blue light 460 nm in the spectrum of LED light with CCT of

4200 K It will be significantly (40%) greater than the dose of blue light 460 nm in the spectrum of solar light with CCT of 4000 K at the same luminance level (Fig. 2). This difference between the doses amounts to excess dose of blue light of LED relatively sunlight with the same CCT and a given luminance level [3, 13].

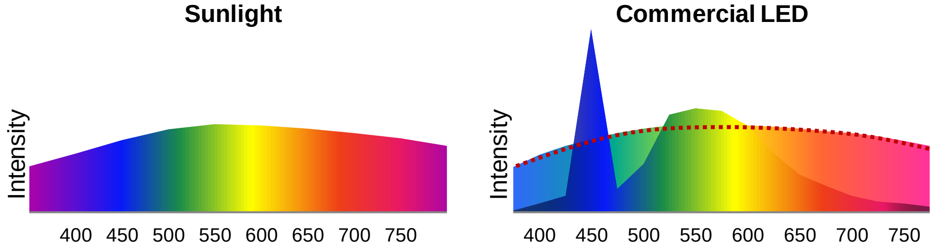

Fig. 2. The color spectrums of sunlight and LED.

Increased dose of blue light in the spectrum of artificial light affects human health and function of the visual analyzer, which increases the risk of vision loss in working age [3, 4].

2.4 Solutions

Important discoveries in physiology of light perception, made in the last decade [5–7], lead to the revision of "right" illumination concepts, mainly taking into account until the implementation of standards for lighting.

The concept of creating a semiconductor white light sources with a biologically adequate light acquires supporters worldwide. For example, in Japan LEDs made by TRI-R technology by Toshiba Material Co., LTD.

TRI-R Project started since 2008 by Toshiba Materials Co., LTD., to achieve in developing “Optimum LED light Source for Our Body” [10]. TRI-R succeeded in producing natural and smooth continuous spectrum with the combination of Purple LED and original phosphor technology, those convert all emission from LED to excitation ray to generate white emission to maintain degree of emission intensity. The submitted data analysis shows that in the spectrum of the white LED light on the TRI-R technology the failure at 480 nm is eliminated and there is no excessive dose of blue light (Fig. 3).

Another example of a biologically adequate light spectrum is the halogen lamps. Halogen lamps radiate white light with CCT of 3200 K, increased luminous efficiency and excellent color reproduction. The light they radiate close to the sunlight on the color spectrum (Fig. 3).

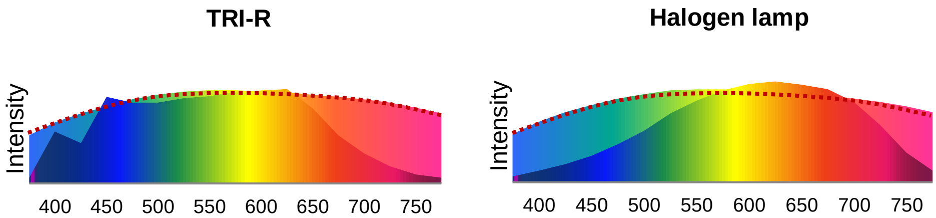

Fig. 3. The color spectrums of TRI-R and halogen lighting.

In the US the main prospect of a healthy light environment associated with the new lighting technologies based on LED light sources, changing a spectrum (CCE and light intensity) during the day: warmer colors are at the morning and evening and colder are in the middle of the day. US Department of Energy published [11] positive results in optimizing sleep/wake cycles for inhabitants of a senior living center located in Sacramento, CA.

When using white LEDs on the basis of color mixing (RGB-principle) for the first time in the illumination technique the possibility of dynamic management of their emission chromaticity (smart light) is realized [11, 12]. This makes it possible to simulate the daily changes of natural light or vice versa to create a special light environment to actively influence the biological processes in the human organism. In the study [13] conducted by the Scientific and Technological Centre of Microelectronics and Submicron Heterostructures, of biological effect of the modern light sources on the human organism depending on their type and CCT, it shows that illumination by light sources with the phosphor LEDs cold-white light (with CCT > 6000 K) is potentially dangerous violation of melatonin concentration in the blood, which, in turn, leads to a number of disease.

3. Discussion

As seen from the foregoing, for artificial lighting should use energy-efficient light sources, giving preference for equal-power light sources with the greatest luminous efficiency and lifetime, but at the same time taking into account their qualitative characteristics: radiation spectrum, correlated color temperature, color rendering index, luminance ripple rate.

Studies [22–27] show that modern light sources used for indoor and outdoor illumination, can significantly, up to 6-fold, vary on the biological equivalent of the generated light, depending on their type and CCT. Especially sources of harmful effects are light sources containing phosphor LEDs cold-white light (with CCT > 6000 K). The real threat extent of an irradiation light overdose of these lamps is still the subject of intense debate and requires further biomedical research.

4. Conclusions

According to the results of a pilot study of illumination in the room at university it was found that actual indicators of illumination in a room correspond to the standard. However a survey revealed the dynamics of deterioration of the physiological state of health of the respondents during prolonged work in the room. Hypotheses of illumination impact on human health, in particular on the eyesight, were confirmed by scientific studies. Excess dosage of blue light results in acceleration of degradation processes which increase the risk of early deterioration of eyesight. In this regard, we have proposed the following recommendations:

1) replacement of the current energy-saving LED lamps by light sources with biologically adequate light spectrum and passed the mandatory hygienic certification;

2) when replacing lighting, give preference for equal-power light sources with the greatest luminous efficiency and lifetime, at the same time taking into account their qualitative characteristics: radiation spectrum, correlated color temperature, color rendering index, luminance ripple rate;

3) ensuring proper organization of the lighting device operation, which provides a systematic cleaning of windows, skylights and lamps from contaminants, timely replacement of blown bulbs, repair and preventive maintenance of equipment;

4) maintaining the quality of electricity in accordance with standard [28] and eliminating the causes of losses and voltage fluctuations;

5) ensuring a uniform and sufficient illumination by lighting layout optimization relatively natural light sources and workplaces.

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Источники света с учетом их качественных показателей и энергоэффективности

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ИНФОРМАЦИЯ О СТАТЬЕ	История	Ключевые слова
научная статья **doi: 10.18720/CUBS.57.4**	Подана в редакцию: 04.06.2017	строительство; энергосбережение; энергоэффективность; искусственное освещение; люксметр; охрана здоровья; спектр излучения; цветовая температура;

АННОТАЦИЯ

С целью реализации государственной политики в области энергосбережения и повышения энергетической эффективности в Санкт-Петербургском Политехническом университете Петра Великого реализуются мероприятия по совершенствованию инженерных сетей и коммуникаций. В частности, для определения потенциала повышения эффективности систем внутреннего освещения было проведено испытание с использования люксметра в учебных аудиториях административного здания. Было выявлено, соответствие фактических показателей освещения современным требованиям энергоэффективноси и санитарным нормам. Тем не менее, при долгом пребывании большинство людей отмечают дискомфорт глаз. Чтобы определить причину этого явления были рассмотрены характеристики источников света, оказывающие влияние на зрительную работоспособность и здоровье человека в целом: спектр излучения, цветовая температура, коэффициенты естественной освещенности и пульсаций освещенности. Сравнительный анализ по приведенным характеристикам некоторых источников света показал, что привычные LED-лампы нежелательны для продолжительного использования из-за повышенной дозы синего света в цветовом спектре освещения. На мировом рынке сегодня существует большой выбор альтернативных осветительных приборов отечественного и зарубежного производства, которые отличаются принципом работы, потребляемой мощностью, спектральным составом света. В статье рассматривается проблема оптимизации выбора источников света для конкретных условий эксплуатации с учетом одновременного обеспечения качественных показателей систем искусственного освещения и их энергетической эффективности.

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