



# Analysis of two different approaches to the design of industrial lighting equipment

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## Abstract

This paper examines two approaches that are relevant today in the design of industrial lighting fixtures. The first concerns the development of new modifications of traditional fixtures with discharge lamps. The authors considered the methodology proposed by the authors for calculating the profile of a specular reflector, which, together with a selected light source of fixed type and power, forms an optical system of the device that provides regulated light distribution of the luminaire as a whole. The method allows you to quickly and effectively obtain the necessary simple and technologically oriented designs of mirror reflectors for lamps, is amenable to automation and is flexible when switching from one type of discharge lamps to another, taking into account different types of their power. The second approach is focused on the use of LED modules, which are created specifically for industrial lighting tasks and are available for production and sale. A feature of designing an LED device is that it requires a reflector as such, that is, the light source is a complete optical system of the designed device, which fully ensures the regulated light distribution of the lamp. The purpose of this work is an unbiased comparative study of the applicability of these engineering approaches in the development of modern lighting devices, which will have practical value for developers of lighting systems. An impartial and thorough analysis of the application of these approaches in the design of optoelectronic devices was performed, and the advantages and disadvantages of such design for both the manufacturer and the consumer were consistently considered. The main advantage of designing luminaires with discharge lamps is the comprehensive development of devices, storage of proprietary technologies and engineering and design developments, and independence from foreign suppliers of components, the main advantages of LED-based devices are that new developments meet modern requirements for energy efficiency and environmental friendliness.

## INTRODUCTION

Currently, optoelectronic devices with two different types of light sources are used to solve the problem of lighting industrial facilities for various purposes. The first type is lamps with discharge lamps of approximately cylindrical shape – mainly sodium lamps [19]. The second type is LED devices [4, 13, 21]. Luminaires with traditional discharge lamps have long been used as the only option for lighting industrial facilities, their design has a fairly solid theoretical basis, and the practical component of design is also well studied. Until recently, luminaires with such lamps were the most progressive and energy-efficient, as high-pressure discharge lamps were without alternative in terms of high light output, a fairly long service life and satisfactory maintenance

of lighting characteristics in various climatic conditions, in particular when operating in a fairly wide temperature range. Since the entry of LEDs into the lighting equipment market (in Ukraine, this is approximately 2004-2006), the situation with the lighting concept began to gradually change. The first industrial samples of LEDs, which were intended to replace traditional light sources, competed for a long time (2005-2015) only with incandescent lamps and low-pressure discharge lamps. Based on the experience of our observations and constant certification work with industrial samples of lamps for various purposes, we can note that during this period, LED lamps gradually occupied such segments of the lighting products market as table lamps [11], exclusive decorative lamps [9], luminaires for transport lighting, emergency and signal lighting and, especially,

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for architectural and design lighting [13]. In the next 10 years, LED modules began to replace lamps with traditional light sources for street lighting [8, 10], and today we can see that the design of street lighting has seriously reoriented towards the use of LED modules [5]. On the websites of leading Ukrainian manufacturers, you can still find models of lamps with sodium lamps, but the range of such lamps is quite limited. Interestingly, our analysis showed that today, manufacturers of Chinese origin are beginning to play a major role in the production and sale of such lamps, noticeably crowding out the products of Ukrainian manufacturers from the market of traditional street lamps. That is, while Chinese manufacturers are actively supplying components for Ukrainian LED lighting, they are not only displacing the products of Ukrainian manufacturers focused on the use of discharge lamps from the market, but also replacing them with their own products. The great advantage of LED modules, in our opinion, is the fact that their appearance has actually destroyed the concept of developing lighting devices as such – the LED module fully provides the necessary light distribution of the luminaire, and the reflector as such has lost its function in forming the photometric body of the luminaire. That is, there is no need to certify a lighting device for light distribution; it is enough to simply choose a ready-made certified LED module. In addition, the function of the designed luminaire is now greatly simplified, in fact, all elements that do not relate to the LED module itself play the role of a large circuit board with the functions of fastening to external supports, power supply and heat dissipation from the modules (which ensures their long service life and the stability of their regulated operating technical characteristics [14-16]). Of course, such a design is extremely convenient for manufacturers, and evidence of this is the rapid growth of the range of LED lamps for various purposes. Such design does not require a significant industrial base and special production capacities; it is focused on limited technologies that do not require special equipment.

As for the industrial lighting market, competition is currently ongoing between luminaires with high-pressure discharge lamps and luminaires based on LED modules. In principle, the only major drawback of traditional luminaires is their low energy efficiency compared to LED ones. This is precisely why the industrial lighting market is being transformed. But the operation of lamps, in addition to other maintenance, involves periodic replacement of light sources. If the life of a sodium lamp is approximately 25 thousand hours, and the life of an LED module is approximately 75-100 thousand hours, then it becomes clear that when an LED lamp loses the life of its module (while sodium lamps can be replaced three times without any problems), the light source

in it cannot be replaced. The fact is that all elements of the LED lamp are functionally oriented specifically for the thermal regime [2, 17-18], optics and geometry of a particular module. This means that replacing the LED module as such is impossible – you simply have to replace the entire lighting fixture. And this is effectively a cost for lighting from scratch, a cost of such a level that it is unlikely to be compensated by the money saved on the electricity consumed. That is, changing the fleet of luminaires every 100 thousand hours of operation is, in our opinion, a dubious prospect for users of LED lighting. We predict that after the rapid rise of LED street and industrial lighting, a review of the lighting concept will take place in the near future and lamps with discharge lamps will be re-considered as a reliable lighting tool and their development will get a “second wind”. Our analysis of the websites of modern Ukrainian lighting equipment manufacturers showed that the lion's share of industrial lighting fixtures is made up of LED devices. The only generally recognized manufacturer of lighting products that still pays significant attention to the development of industrial luminaires with discharge lamps is Vatra OJSC. The authors have no doubt that the specialists of Vatra OJSC have vast experience in designing lighting devices and are aware of the limitations of LED luminaires [3] and wisely retain the industrial and technological base for returning to mass production of luminaires with discharge lamps if necessary [5]. This assumption is confirmed by our observation that the industrial lighting market, focused on the use of discharge lamps, for some reason is not completely declining; Chinese manufacturers are actively working on it, actively displacing Ukrainian products. Therefore, the relevance and practical component of this work is unconditional, the topic of the work is “hot”, and similar works, in our opinion, will be of scientific interest for quite a long time.

This paper aims to consider in more detail the essence of both approaches to the design of industrial luminaires, to impartially consider the positive and negative aspects of such approaches, and to draw certain conclusions regarding the feasibility of switching from traditional lighting to LED technology.

#### **THE FIRST APPROACH. DESIGN OF TRADITIONAL INDUSTRIAL LIGHTING USING DISCHARGE LAMPS**

In the traditional understanding of the lighting device as such [1, 19, 20] – it consists of two main components – a light source and lighting fixtures. The second component provides everything necessary to turn the light source into a device (power, protection from external influences, design capability for fixing

and mounting the light and, most importantly – the optics of the device). The reflector or diffuser in a traditional light plays one of the key roles – it forms the necessary light distribution of the light device together with the lamp [1]. Traditional lighting [1, 20] has for decades interpreted the unshakable truth – the light intensity of the lamp in any calculation direction is the sum of the light forces from the source (which is not shielded by additional fittings) and from additional optical elements (reflectors, diffusers).

A striking example of this approach is the design of industrial lights with discharge lamps.

When developing a new modification of the lighting device, the main task is to calculate the geometry of the reflector, which together with the lamp forms its light distribution. In the literature [20] the method of elementary reflections is given, the essence of which is to consider the light beam formed by the light device as a set of individual light beams – elementary reflections, the shape and size of which are determined by the characteristics of both light source and reflector. The algorithm for solving the problem is as follows. First, the required light curve of the reflector is calculated, which together with the light intensity of the selected light source forms the required light distribution of the light device. In fact, the light curve of the reflector is the difference between the light intensity of the light device, which is taken as the initial characteristic in its design, and the light intensity of the light source, which through conversion from theoretical curves in conventional units (for a lamp with a conventional luminous flux of 1000 lm) to actual units. for the flux of a real lamp, which is selected as the light source of the designed device). Having the necessary curve of light intensity of the reflector, we begin to perform the selection of its geometry, which would provide this light intensity. The reflector is divided into zones, each zone provides its contribution to the resulting curve. Zonal curves of light intensity are provided by a certain curvature of a zone and optical characteristics of reflector material. In [12] the algorithm of machine calculation of such problem is given. The authors of this work critically analyzed this literary method and we proposed [12] a modified variation of the classical method as a more accurate and effective. The disadvantage of the classical method is the long time of selection of the curvature of each reflector zone and the poor quality of the final description of the required light intensity curve of the reflector by the family of its zonal curves of light intensity. We have proposed a slightly different approach to solving the inverse problem. We did not set the required light intensity curve of the light, but zonal light intensity curves of the reflector, for which there was an exact solution

regarding the required geometry of the corresponding zone.

Our main relationships were as follows. The zone light intensity of the light device  $I_\alpha$  for the selected angle  $\alpha$  is determined by the formula:

$$I_\alpha = \rho \cdot L_{l,b} \cdot \kappa_\alpha \cdot A_z \cdot \cos \sigma_\alpha, \quad (1)$$

where  $A_z$  – is the area of the selected zone,

$L_{l,b}$  the brightness of the luminous body in the direction of  $\varphi_a$  zone,

$\kappa_\alpha$  – is the coefficient of filling the zone with the light part in the direction  $\alpha$ ,

$\sigma_\alpha$  – is the angle of projective reduction of the zone to the direction perpendicular to the direction  $\alpha$ .

If we proceed from the known zonal light intensity curves, then, in fact, the value of  $I_\alpha$  is known. In the right part of relation (1) the product  $\rho \cdot L_{l,b}$  is a constant value (of course, within the selected zone). Namely, for lamps whose shape is approximately cylindrical:

$$\rho \cdot L_{l,b} = \frac{\rho \cdot I_{\varphi_m}}{A \cdot \cos \phi_m}, \quad (2)$$

where  $A$  is the area of the luminous body (the geometry of the light source is known to us),

$I_{\varphi_m}$  – is the value of the light intensity of the lamp in the direction of the middle of the zone (also the value is known)

$$\begin{aligned} \frac{I_\alpha}{\rho \cdot L_{c,m}} &= A \cdot \cos \sigma_\alpha \cdot \kappa_\alpha = \\ &= \frac{\pi^2 \cdot \Delta\phi \cdot \sin \phi_m \cdot r_m^2}{90 \cdot \cos i_m} \cdot \cos \sigma_\alpha \cdot \kappa_\alpha \end{aligned} \quad (3)$$

where  $\Delta\phi$  is the actual angular width of the zone,

$r_m$  – is the average value of the radius-vector that determines the geometric shape of the zone,

$i_m = \varphi_m - \delta_m$  is the angle of incidence of the axial beam to the midpoint of the zone ( $\delta_m = \frac{(\phi_0 + \alpha_0) + (\phi_1 + \alpha_1)}{4}$ ), де  $\varphi_i$  and  $\alpha_i$  are the angles constituting incident and reflected rays at the boundary points of the reflector zone with the axis, transferring to the left side of the equation all the parameters that can be considered known in the framework of the problem, and taking the notation:

$$A = \frac{I_\alpha}{\rho \cdot L_{l,b}} \cdot \left( \frac{90}{\pi^2 \cdot \Delta\phi \cdot \sin \phi_m} \right) \quad (4)$$

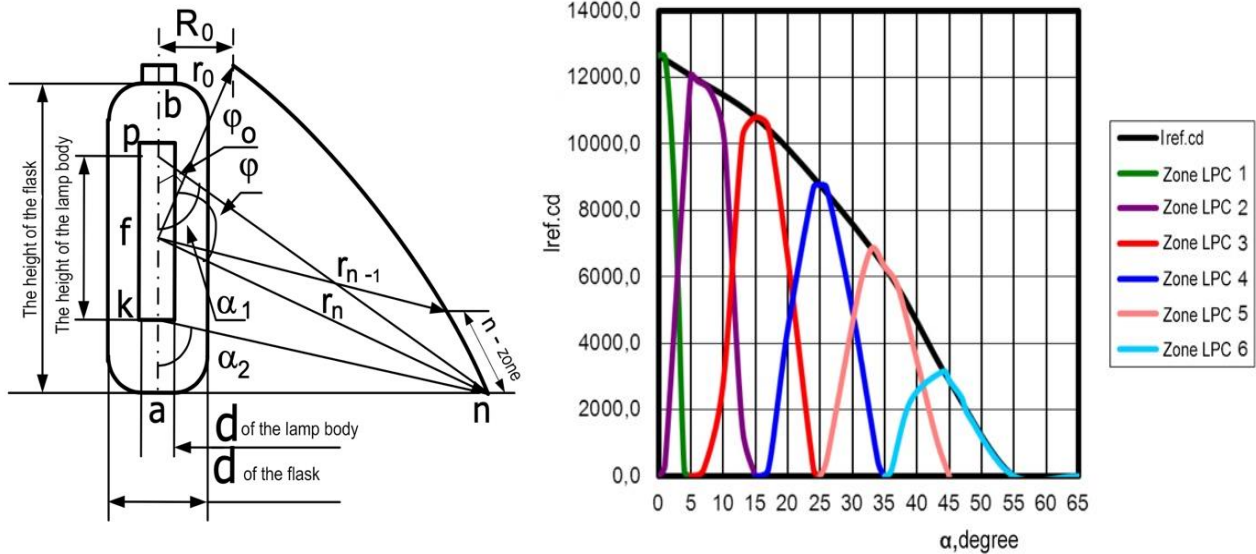
we obtain the following simple expression:

$$A = r_m^2 \cdot \kappa_\alpha \frac{\cos \sigma_\alpha}{\cos i_m} = r_m^2 \cdot \kappa_\alpha \cdot \frac{\cos(\phi_m - \delta_m)}{\cos(\delta_m - \alpha)} \quad (5)$$

The latter expression (5) is key in our proposed method [12]. It allows a threefold relationship – between the required value of  $I_\alpha$ , the function of the required path of the rays (which are given in the literature and which, in fact, determine the parameter  $I_\alpha$ ) and the shape of the reflector  $r_m$ . Due to this expression, these parameters can be selected in a consistent,

single array, which is impossible when using the direct method [1]. In [12] we demonstrated the application of the method for a specific engineering calculation, so there is no need to dwell in detail on all its

features. In Figure 1, we will only illustrate schematically and graphically the principle of division of the reflector into zones and the formation of a family of zonal light intensity curves, which corresponded to individual zones.



**Figure 1.** Illustration of the zonal calculation of the required profile of the reflector of the light with a discharge lamp

Note only that by selecting the value of  $r_i$  for each zone (such that the reflector has a smooth, and, moreover, the shape we need), and selecting the value of the parameter  $\delta_{cp}$  (according to the schemes given in [1, 20] reciprocating incident and reflected rays), we can determine the values of  $\kappa_{\alpha}$ , at which the compound equation holds. Thus, for each zone, the geometry of the reflector is quickly and accurately calculated, which provides the required light intensity curve of the light.

Our calculation algorithm is well automated. As part of the software calculation, the parameters of the light source are set as initial data – power, luminous flux, geometry of its structural units (burner, outer bulb), regulated light distribution of the designed lamp and an array of other data. coating with a protective film, the required lower limit of the efficiency of the designed device and its gain, as well as the size of the gap – the blind hole of the reflector – the value of which is the greater the greater the lamp power). At the output, the program automatically calculates the curvature of the reflector, as well as displays data on its coefficient of efficiency and gain.

## THE SECOND APPROACH. DESIGN OF INDUSTRIAL EQUIPMENT FOR LED LIGHTING

If for the design of lights with discharge lamps the main task was to calculate the profile of the reflector (which, in fact, was responsible for the formation of the required light distribution of the light as a whole),

then when designing LED lighting – the main thing to choose LEDs.

The fact is that LED-technology has become so advanced that it is the light source (LED-module) which determines the light distribution of the light. Reflectors for LED devices cease to play the function of optical elements. Manufacturers of LEDs, offering their products, provide the buyer with data from photometric tests [6] of LEDs, performed on modern equipment – goniophotometers. The tests provide information on the conditions of modules certification – used equipment, experimental conditions, provide detailed information on lighting and technical characteristics of LED modules, provide, in fact, data of its thermal tests [2, 3, 18], which is very important for choosing LED products to solve specific problems. In addition, it is extremely important that, along with photometric tests, manufacturers of LED modules sometimes provide ies-files, which allow using DIALux to conduct a model test of this LED-source for specific rooms or spaces. Analysis of such a test by the manufacturer of lights is the basis for the design of the lights as a whole.

In our opinion, the main stages of designing LED lights are as follows. Below, as an illustration of the ground for our judgments, we will demonstrate as an example the photometric test data for one of the LED elements [6-7].

1. Choice of light source and manufacturer on the basis of price / quality / required characteristics (flux, power, type of light power curve, light distribution, etc.).

The main characteristics [6-7] for the selection of the LED module at the beginning of the design are shown in Tables 1-3.

Table 1 – Light Source Model [6-7]

Parameter	Symbol	Value	Unit
Lens/Reflector Model	-	PL50SIL	-
Materials	-	SILICONE	-
Dimensions	-	See Fig. 1	-
Source Model	-	OSRAM SOL-ERIQ S13	-
Number of Sources	N	1	-
Power Supply Type	-	ISO TECH ISP3303	-
Driver Type	-	-	-
Driving Voltage	$V_F$	-	V
Driving Current	$I_F$	-	mA
Nominal Flux	$\Phi$	1600x1	lm

Table 2 – Measurement Setup [6-7]

Parameter	Symbol	Value	Unit
Operator	-	Simone Bassi	-
Goniophotometer Type	-	KLX12M	-
Measurement Distance	-	5	m
Room Temperature	T	25	$^{\circ}\text{C}$
Date	-	2014-Feb-20	-

Table 3 – Results [6-7]

Parameter	Symbol	Value	Unit
Total Flux	$\Phi$	1500	lm
Max Intensity	$I_{\text{max}}$	5066	cd
Max Illuminance at 5 m	$E_{\text{max}}$	203	lx
C-Viewing Angle at 50 % $I_{\text{max}}$	$2\varphi_c$	26	-
$\gamma$ -Viewing Angle at 50 % $I_{\text{max}}$	$2\varphi_\gamma$	26	-
C-Viewing Angle at 10 % $I_{\text{max}}$	$2\varphi_{c10\%}$	52	-
$\gamma$ -Viewing Angle at 10 % $I_{\text{max}}$	$2\varphi_{\gamma10\%}$	53	-
General Optical Measurement Tolerance	-	$\pm 10\%$	-

At this stage, let us choose a manufacturer – for example, the company Osram (reasonable value for money), we need a luminous flux of 1600 lm, maximum light output, radiation angle.

2. Let us analyze the light power curve (Fig. 2) of the future LED-source of the light device. In fact, this is the future light power curve of the light device.

In this case, both the diagram in polar coordinates and in the rectangular coordinate system shows that the light distribution is appropriate for industrial lighting problems.

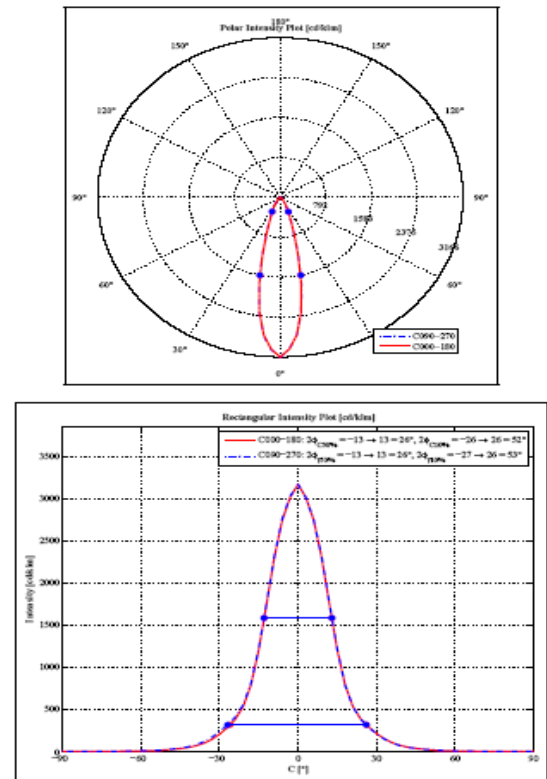
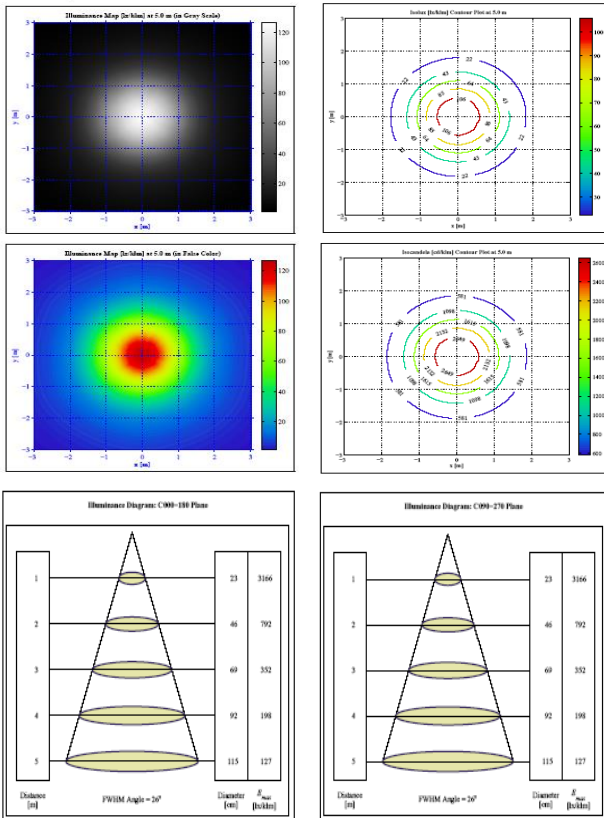


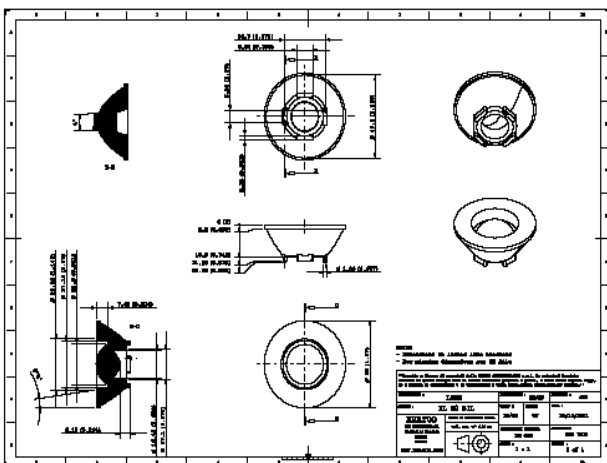
Figure 2. Analysis of the photometric test. Coordination of the light intensity curve for the required light distribution of the designed lights

3. Matching the light distribution (Fig. 3) and the spectral composition of the source – the manufacturer of the lens / module provides a complete report, including photometric data in the form of an ies-file for testing in DIALux.



**Figure 3.** Analysis of the photometric test. Study of temperature distribution on the photometric body of the module glow and light distribution of the light

4. The geometry of the lens / module is agreed (Fig. 4). The manufacturer checks the availability of accessible and cheap capacities for the production of the housing and the radiator for such a light source.



**Figure 4.** Analysis of the photometric test. Analysis of a special appendix to the photometric test - specifications with the dimensions and dimensions of the led-module

5. The allowable temperature regime is taken into account [6-7] (Table 4), which withstands this led-module when designing a light for a specific task.

**Table 4 – Temperature regime [6-7]**

Material	T <sub>op</sub>	T <sub>stg</sub>
PMMA	-40°...85° C	-40°...85° C
PC	-40°...120° C	-40°...120° C
PC+Aluminium Coating with Protective Clear Coat	-40°...120° C	-40°...120° C
APEC+Aluminium Coating with Protective Clear Coat	-40°...180° C	-40°...180° C
ABC	-35°...70° C	-35°...70° C
SILICONE	-45°...150° C	-45°...150° C

6. The final stage is the design of the simplest and cheapest cost of the light housing. Our analysis of technologies used by different manufacturers shows that manufacturers are trying to minimize the cost of additional elements manufactured by them to obtain a more or less tangible profit for the sale of their products on the market. In particular, as we see, extrusion methods have developed strongly, while the use of a variety of other technologies is significantly limited. The case of the LED light performs several functions – it is a possibility of fastening and installation of the light on a light point and a basis for fastening of a radiator and the driver of the LED light.

**RESULTS AND DISCUSSION**

**DISADVANTAGES AND ADVANTAGES OF DESIGNING LIGHTS WITH DISCHARGE LAMPS**

The positive features of using such a design, in our opinion, are as follows. The light designed in this way is a complete “turnkey” design. Its design solved a complex problem that includes the entire cycle of intermediate tasks – obtaining the necessary light distribution, the design construction that provides this light distribution and depends on the results of lighting calculation and manufacturing technology, which, in turn, directly depends on the design solution. It should also be noted that the light designed in this way, in principle, is designed for a high-pressure discharge lamp with fairly good lighting and performance characteristics [5] – light output ~ 150 lm / W, a significant luminous flux of the device, and a fairly serious service life ~ 25 thousand hours. There are no difficulties in replacing the light source in such a light – Osram, Phillips, Belligt, Iskra and others do not remove them from production [5].

The disadvantages of a traditional industrial light for a discharge lamp are as follows. Nowadays, the value of development is largely determined by its cost of electricity consumption. Here it is necessary to admit frankly – the lighting installation is expensive. Our analysis of the site of Vatra's products [5] showed that their LED lamps with a power of 160 W,

for example, modification DSP67V-160-031, - 032, are a completely adequate replacement for similar discharge lamps with a power of 400 W. That is, electricity costs are reduced by 2.5 times. In the sense of ecology – a lighting installation with a discharge lamp is problematic – such light sources need further utilization, and this is again a cost. There are other operational shortcomings – there is no flexible change in the intensity and spectral composition of the glow, remote control is difficult compared to LED-analogues, the weight of the product is twice as much as LED devices, which increases the reliability of mounting elements, inertia in ignition and re-ignition, flicker (greater sensitivity to voltage fluctuations in the network), noise.

### DISADVANTAGES AND ADVANTAGES OF DESIGNING LED LAMPS

The advantages of such design are a modern light source, 60-70 % reduction of electricity costs, the ability to use dimmers. Next – the low weight of the light, ability to keep the temperature no worse than a discharge lamp, the resource of the source is two to three times greater. The luminous distribution of the light determines the light source, and, in fact, the deviation from the normalized luminous distribution will also be the responsibility of the source manufacturer (LED module). The design of the light is reduced to the design of the body and radiator. (In principle, solutions for radiators are also provided by the source manufacturer with the consent [6-7]).

The disadvantages, in our opinion, is the fact that the manufacturer of LED-lights, in fact, is removed from the process of designing the light distribution of the light. It begins to depend on the "ready-made" solutions that are on the market. In addition, the manufacturer of LED lights can not guarantee adequate replacement of the light source after depletion of its resources (after 75-100 thousand hours). When the module fails, it is almost guaranteed that it will be impossible to find a completely similar one. In addition, if before the light source was 10 % of the price of the light fixture, now the manufacturer will have to accept that the manufacturer of the LED-module will receive 70 % of the profit. We should also not forget that the technology of the finished LED-lights is simplified, which will gradually lead to the collapse of a number of technologies for the manufacture of optoelectronic equipment in Ukraine.

### CONCLUSIONS

The work provides the first thorough and unbiased analysis of two fundamentally different approaches to the design of industrial lighting fixtures.

The first approach involves the use of high-pressure discharge lamps in lighting devices. A step-by-step algorithm for designing luminaires of this type is presented, using the author's methodology for calculating the required reflector profile in the task of developing industrial lighting luminaires with regulated light distribution. The advantages and disadvantages of such a design are considered in detail, the main disadvantage of a lamp designed in this way is its low energy efficiency.

The second approach is based on the use of ready-made certified LED modules for the design of lighting devices. It is indicated that the main advantage of such a design is significant energy savings. It is noted for the first time that the main disadvantage of such a design is the inability to replace a light source (module) that has exhausted its resource, unlike lamps with traditional discharge lamps. It is also indicated that for the manufacturer, using ready-made LED modules in design is not very profitable because most of the profit goes to the purchase of expensive components of foreign origin.

It is shown for the first time that the task of completely transitioning industrial lighting to the use of LED modules is quite ambiguous and, to a certain extent, doubtful, given the aforementioned shortcomings of ready-made LED modules, which cannot be ignored in the near future.

It is predicted that over time the concept of industrial LED lighting may be revised in some way with a turn towards designing luminaires with high-pressure discharge lamps.

### DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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## Аналіз двох різних підходів щодо проектування промислового освітлювального обладнання

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**Анотація.** У даній роботі розглядаються два підходи, що актуальні на сьогодні при проектуванні світильників промислового освітлення. Перший стосується розробки нових модифікацій традиційних світильників з розрядними лампами. Розглянуто запропоновану авторами методику розрахунку профілю дзеркального відбивача, що утворює разом із обраним джерелом світла фіксованого типу і потужності оптичну систему приладу, що забезпечує регламентований світлорозподіл світильника у цілому. Методика дозволяє швидко і ефективно виходити на необхідні прості і технологічно орієнтовані конструкції дзеркальних відбивачів світильників, піддається автоматизації і є гнучкою при переходах від одних типів розрядних ламп на інші з урахуванням різних типів їх потужностей. Другий підхід орієнтований на використанні світлодіодних модулів, які створено спеціально для задач промислового освітлення і є у виробництві і продажу. Особливістю проектування світлодіодного приладу є те, що він потребує відбивача як такого, тобто джерело світла є повноцінною оптичною системою проектного приладу, що цілком забезпечує регламентований світлорозподіл світильника. Метою даної роботи є неупереджене порівняльне дослідження застосовності вказаних інженерних підходів в розробці сучасних світлових приладів, що матиме практичну цінність для розробників систем освітлення. Виконано неупереджений і ґрунтовний аналіз застосування цих підходів у проектуванні оптико-електронних приладів, послідовно розглянуто переваги і недоліки такого проектування як для виробника, так і для споживача. Головною перевагою проектування світильників з

розрядними лампами є комплексна розробка приладів, зберігання власних технологій і інженерно-конструкторських наробок та незалежність від іноземних постачальників комплектуючих, а основними перевагами приладів на світлодіодній основі є відповідність нових розробок сучасними вимогам енергоефективності і екологічності.

**Ключові слова:** крива сили світла, відбивач, промислове освітлення, світлодіодні модулі, розрядні лампи, енергоефективність, світлова віддача.

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