Operational changes of photometric parameters of road lighting luminaires.

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1. Introduction

Road lighting is an extremely important factor determining the comfort and safety of road traffic. On the basis of tests carried out in numerous countries it has been shown that proper road lighting may contribute to lesser number of accidents AT night by some 30%, as compared with the condition when stationary road lighting does not exist, is switched off or is improperly designed and the traffic operating costs of lighting equipment are reimbursed in the form of possible savings that the society may gain due to lesser number of accidents. Correctly designed and executed lighting should ensure proper vision for all its users by meeting basic requirements as regards lighting during the entire period of operation. All road users, i.e. drivers, pedestrians and cyclists should have proper vision conditions in order to perform their visual tasks. The entire road along with its vicinity should be clearly seen so that a driver could be quick enough to see the pedestrians and cyclists as well as all other objects within the traffic lane, while the pedestrians and cyclists could see approaching vehicles. One of the elements guarantying correct road lighting is maintaining the photometric parameters of luminaires on a proper level. As far as the quantitative changes of road lighting parameters are concerned, the most crucial factor affecting such changes during the period of lighting operation is the drop of efficiency of luminaires caused by dust and dirt accumulation on optically active parts of the luminaires. The process of such dirt accumulation on particular elements of the luminaire is of continuous nature, irrespective of whether the device is under operation or not. This process is partially reversible due to maintenance procedures carried out (after cleaning the luminaires, the luminous flux value increases but will never resume the original state). The degree and intensity of dirt accumulation depend on the luminaire design (mainly on the level of IP protection) as well as on the atmospheric conditions prevailing in the location of luminaires (amount of industrial pollution, traffic density, rust exposure around the road).

In order to establish the operational changes of the luminous flux of road lighting luminaires, laboratory tests of luminaires operating under real conditions have been carried out.

2. Laboratory tests

For laboratory tests SGS 203 luminaires have been chosen, which operate with high pressure sodium lamps with the power of 150W. These luminaires are most commonly used on main roads of the Wielkopolska Province and therefore it seemed expedient to determine first of all the operational changes for this type of luminaires. According to the data provided by the manufacturer, the luminaires are characterized by high mechanical strength and tight design with the level of protection IP 65 for optical part and IP 43 for electrical part. Reflectors of luminaires are made of aluminum sheets of superb purity, while the globes are made of UV resistant polycarbonate. Furthermore, the luminaires are characterized by easy and fast service.

All luminaires which underwent photometric measurements had been operated in the city of Poznań in locations of various environment pollution illustrated by means of average annual dust fall and of various average daily traffic density. According to the data provided by the road lighting services, none of the luminaires had undergone previous maintenance procedures. The working environment of luminaires is presented in Table 1.

For each laboratory test five luminaires from a given street have been chosen on a random basis and the operational changes of their efficiency before and after maintenance procedureshave been determined in relation to the efficiency of new luminaires. The maintenance procedures consisted in washing the globes and cleaning the reflectors.

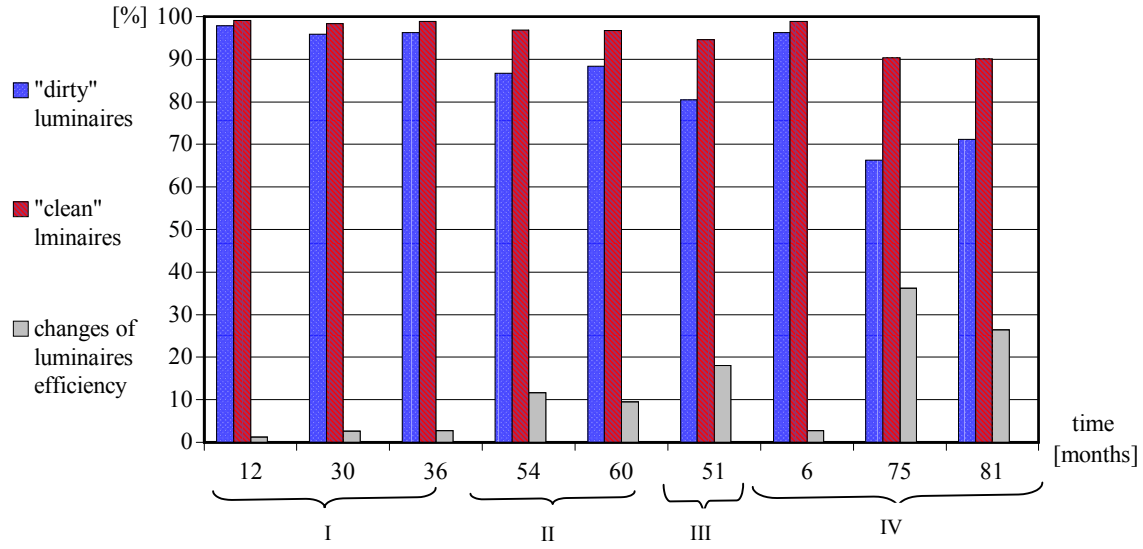
The results of conducted measurements are presented in Table 2 and on Drawing 1.

Table 1
WORKING ENVIRONMENTS OF LUMINAIRES

Number of working environments of luminaires	General characteristics of the working environments of luminaires
I	Streets of small traffic significance for the city, small average daily traffic density (> 6000 vehicles), area characterized by average annual dust fall (approximately 92 g/m^2)
II	Streets of fundamental traffic significance for the city, medium average daily traffic density (> 16000 vehicles), area characterized by average annual dust fall (approximately 78 g/m^2)
III	Streets of fundamental traffic significance for the city, high average daily traffic density (> 22000 vehicles), area characterized by average annual dust fall (approximately 86 g/m^2)
IV	Streets of fundamental traffic significance for the city, very high average daily traffic density (> 34000 vehicles), area characterized by average annual dust fall (approximately 92 g/m^2)

Table 2
RELATIVE OPERATIONAL CHANGES OF LUMINAIRES EFFICIENCY

The working environments of luminaires	The operational time [months]	Luminaires		Increase of luminaires efficiency
		Befor maintenance procedures	After maintenance procedures	
		$\eta(t)/\eta(t=0)$ [%]	$\eta_{cz}(t)/\eta(t=0)$ [%]	[%]
I	12	97,9	99,1	1,2
	30	95,9	98,4	2,6
	36	96,2	98,9	2,8
II	54	86,7	96,9	11,7
	60	88,3	96,7	9,5
III	51	80,4	94,9	18,0
IV	6	96,3	98,9	2,7
	75 (at the crossroads)	66,3	90,3	36,2
	81	71,2	90,1	26,5

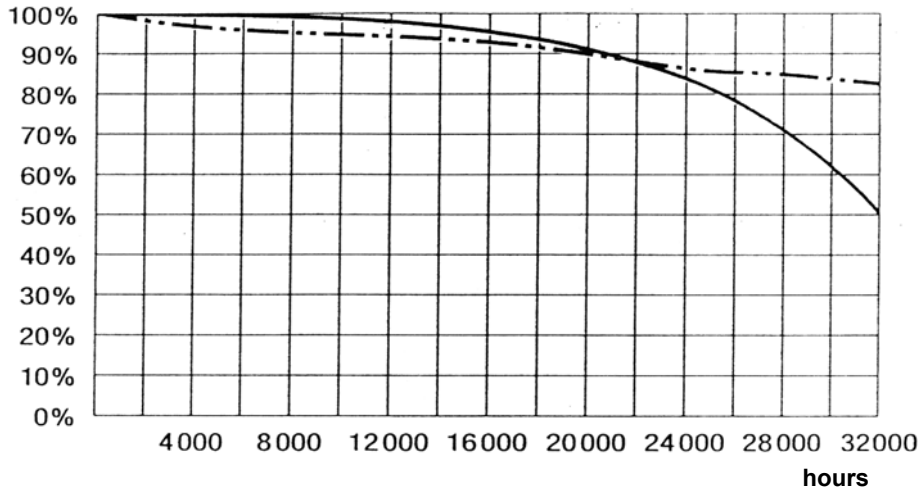


Drawing 1. Operational changes of efficiency of the tested type of road lighting luminaires in various working environments

Changes in the luminous flux result from changes of both photometric parameters of luminaires and light sources during the period of operation. (Changes in the luminous flux of the light sources during operation may be determined experimentally or data provided by the manufacturer may be used for this purpose. Representative curves of changes of high pressure sodium lamps' luminous flux are presented in Drawing 2). Temporary relative changes of the luminous flux of road lighting luminaires may be determined on the basis of the following relation:

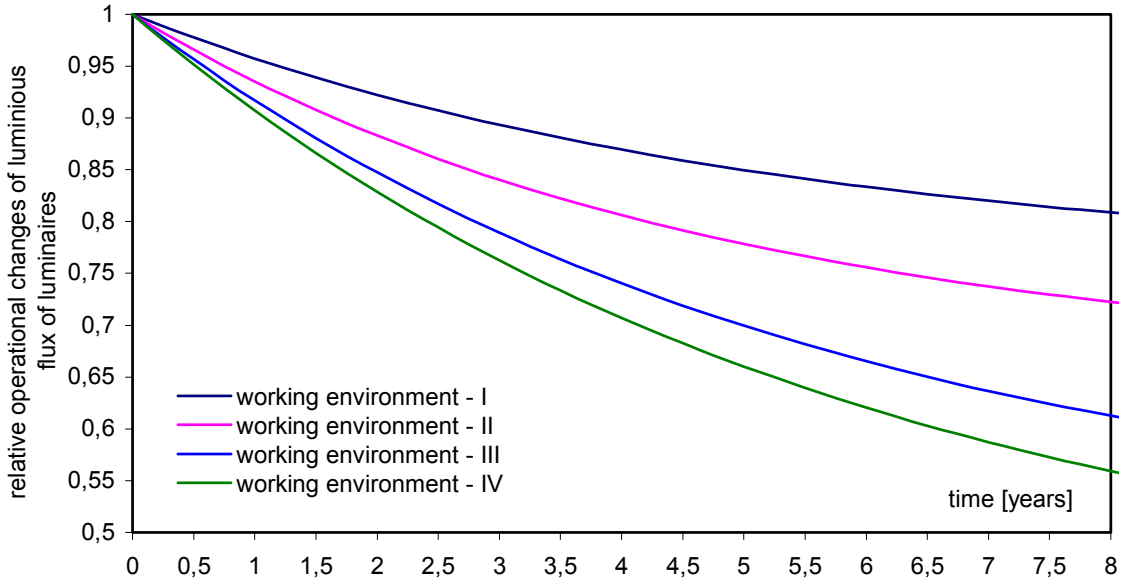
$$\frac{\Phi(t)}{\Phi(t=0)} = \frac{\eta(t)}{\eta(t=0)} * \frac{\Phi_S(t)}{\Phi s(t=0)} \qquad (1)$$

$\Phi(t)$ – luminous flux of luminaires,
$\Phi_s(t)$ - luminous flux of light sources,
$\eta(t)$ – luminaires efficiency.

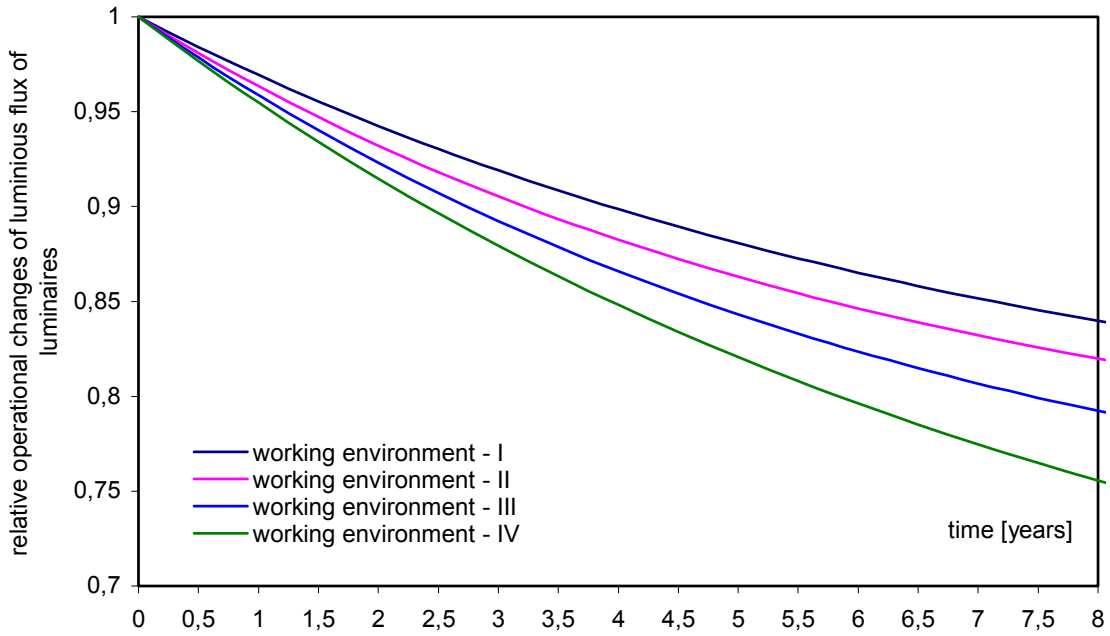


Drawing 2. Operational curves of changes of the luminous flux of high pressure sodium lamps with the power of 150 W, type NAV 4Y
broken line – curve of foot of the luminous flux of light source
solid line – curve of luminous flux quenching

As a result of conducted maintenance procedures, in each case an increased luminous flux radiating from the luminaires have been obtained. The value of the luminous flux of luminaires subjected to maintenance procedures is however always smaller than the initial value of the luminous flux. On the basis of the relation (1) and true curves of changes of the efficiency of luminaires and luminous flux of light sources during operation, it is possible to draw relevant curves of changes of the luminous flux of luminaires before and after maintenance procedures. Thereby drawn curves may constitute basis for determining the maintenance procedures for lighting points in road lighting systems.
The curves of luminous flux changes are presented on Drawings 3 and 4.



Drawing 3. Curves showing luminous flux changes in luminaires operating with high pressure sodium lamps, type NAV 4Y before maintenance procedures for various working environments.



Drawing 4. . Curves showing luminous flux changes in luminaires operating with high pressure sodium lamps, type NAV 4Y after maintenance procedures for various working environments

3. Summary

All lighting points operating in the road lighting system change their photometric and operational parameters thereby worsening the drivers' visual reliability. Conducted measurements made it possible to determine the operational changes of the luminous flux of selected type of road lighting luminaires operating under real conditions. They also enabled to determine how the maintenance procedures affect the value of changes of the measured parameter. On the basis of the measurements results it may be concluded that the most fundamental changes of efficiency are caused by the globes becoming dirty from the outside. Biggest operational changes in the luminaires' efficiency have been obtained in case of luminaires installed on cross-roads located within areas of high atmospheric pollution (working environment designated as IV) and characterized by high traffic density. The efficiency drop of such luminaires during the period of operation was sevenfold bigger than in case of luminaires installed within the same region, operating during similar time period but under lower traffic density. So it seems apparent that in order to determine the intensity and rate of operational changes of the relative efficiency of road lighting luminaires (both for designing road lighting and its operation) it is necessary to make allowances for the level of industrial air pollution and the traffic density along a given road section.

In all cases, the maintenance procedures improved the efficiency. The most considerable improvement of some 26 ÷ 36% has been obtained in case of the luminaires characterized by highest dirt accumulation on the globe (biggest efficiency drop during operation). However, due to irreversible wear and tear processes in the globes, the conducted maintenance procedures have not restored the original

efficiency values and, depending on the location of luminaires, the irreversible efficiency changes amounted to1 ÷ 10 %.

The laboratory tests confirm the necessity to carry out regular maintenance procedures at intervals determined on the basis of real changes of photometric parameters of road lighting luminaires. As a result of planned maintenance, it is possible to improve the parameters of road lighting during the entire period of lighting system operation, thereby ensuring better vision conditions for all road users.

4. Literature:

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