Maintenance procedures for light points in roadway lighting

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1. Introduction

The correctly designed and executed road lighting provides the appropriate vision conditions for all road users by meeting the basic lighting requirements within the entire lighting equipment operation period. The progressing inevitable deterioration of the road lighting quality – when comparing with the initial value – results form progressing changes caused by pollution and ageing factors such as:

- decrease of the light sources luminous flux value and burnout of the light sources as a result of their operation,
- decrease of the light sources luminous flux values as a result of atmospheric pollutants,
- decrease of the luminaires efficiency as a result of ageing and atmospheric pollutants effecting luminaires optical parts.

For the purpose of the correct operation of the road lighting equipment and to provide the appropriate photometric parameters on the lit road, it is very important to perform regularly the maintenance operations of the equipment. When concerning the lighting points operation, these maintenance operations are connected mainly with performing light sources replacement and luminaires cleaning, including replacement with the new ones when ageing resulting from operation does not permit to provide the appropriate lighting parameters. The procedures for performing the maintenance operations should be determined on the basis of real photometric and usable parameters of produced lighting points applied in the road lighting. The appropriate maintenance schedule assumption assures obtaining the appropriate quantitative and qualitative lighting parameters as well as allows considering the optimum maintenance (reserve) coefficients for the designed road lighting.

2. Presently applied maintenance procedures and photometric parameters variations as a result of lighting points operation in the road lighting

The presently binding in Poland maintenance operation procedures considering the road lighting equipment and installations have been drawn up on the basis of The Ministry of Mining and Power Engineering Decree of 1987. In accordance with the regulations, maintenance operations connected with the lighting points operation exclusively should be

periodically performed in the form of visual inspection and survey. Visual inspections performed annually consist in estimation of not operating light sources and, impossible to explicitly determine with use of visual inspection, estimation of how dirty are lighting points. Whereas surveys consist in performing visual inspections and cleaning lighting points and should be performed at least once in two years on main roads within the city boundaries and at least once in three years on the other roads. Moreover, regulations determine the obligation of replacing burnout light sources when for every hundred successive luminaires of any lighting sequence of one or several roads within the city boundaries the number of burnout light sources amounts to: 5% for central and main city roads lighting, 10% for national roads and 15% for the other roads. Moreover, the number of admissible damaged light sources, for roads within the city boundaries with several and up to twenty lighting points installed, should not exceed 20% of successively installed luminaires, (calculated in relation to all luminaires).
Presently applied in Poland lighting points maintenance procedures in many cases are out-of-date or economically groundless when concerning frequency and range of work, (cleaning luminaries and light sources replacement).
The binding Ministry of Mining and Power Engineering Decree does not determine any relations between the light sources replacement method and luminaires cleaning. Moreover, the Decree has been drawn up for luminaires and light sources applied in the road lighting over fifteen years ago. Presently manufactured luminaires have been implemented improved constructional solutions and made with use of different technologies and materials. Considering the above mentioned, the maintenance frequency and work range should be specified on the basis of real photometric and usable parameters variations of presently manufactured and applied light points within the road lighting. The maintenance operations frequency depends on the variation intensity of luminous flux emitted by luminaires. Luminous flux variations result from luminaires photometric parameters variations and light sources variations within the operation period. Temporary relative variations of the road lighting luminaires luminous flux can be determined on the basis of the following dependence:

$$\frac{\Phi(t)}{\Phi(t=0)} = \frac{\eta(t)}{\eta(t=0)} * \frac{\Phi_{Źr}(t)}{\Phi_{Źr}(t=0)} \qquad (1)$$

Where:

$\Phi(t)$ – total luminaires luminous flux after t time of operation,
$\Phi(t=0)$ – initial luminaires luminous flux after light sources seasoning time,
$\eta(t)$ – luminaires efficiency after t time of operation,
$\eta(t=0)$ – initial luminaires efficiency,
$\Phi_{źr}(t)$ – total light source luminous flux after t time of operation,
$\Phi_{źr}(t=0)$ – initial light sources efficiency.

The luminaires luminous flux operational decrease in relation to the new luminaires luminous flux (for t=0), below the level of lighting maintenance coefficient assumed within the road lighting designing stage, is the starting point for taking decision concerning performing maintenance operations. Within the maintenance operations course the luminous flux emitted by luminaires increases every time. However, the luminous flux

value of luminiares subject to maintenance is smaller than the initial luminous flux value. The value can be determined on the basis of the following dependence:

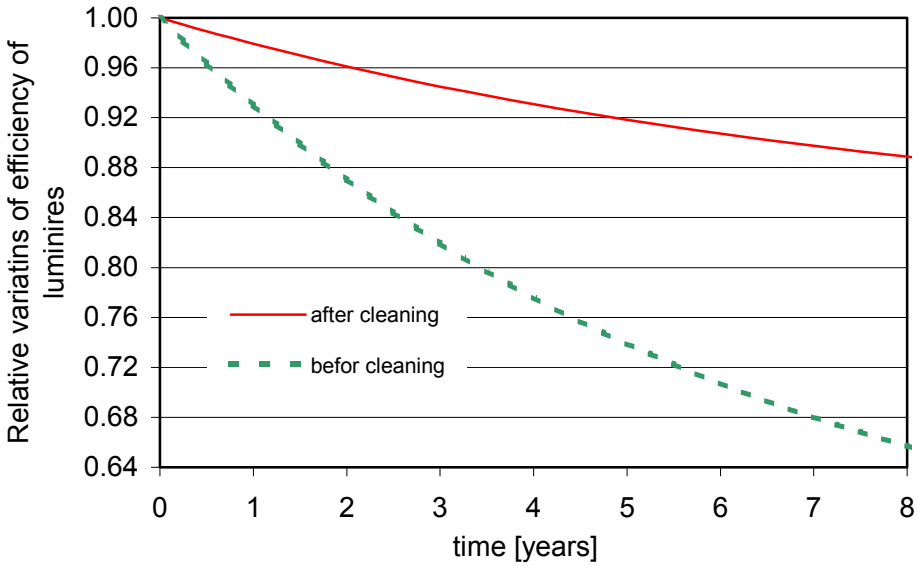
$$\frac{\Phi_{cz}(t)}{\Phi(t=0)} = \frac{\eta_{cz}(t)}{\eta(t=0)} * \frac{\Phi_{źr}(t)}{\Phi_{źr}(t=0)} \qquad (2)$$

Where:
Φ_{cz} (t) – total luminaires luminous flux after t time of operation,
H_{cz}(t) – luminaires efficiency after t time of operation.

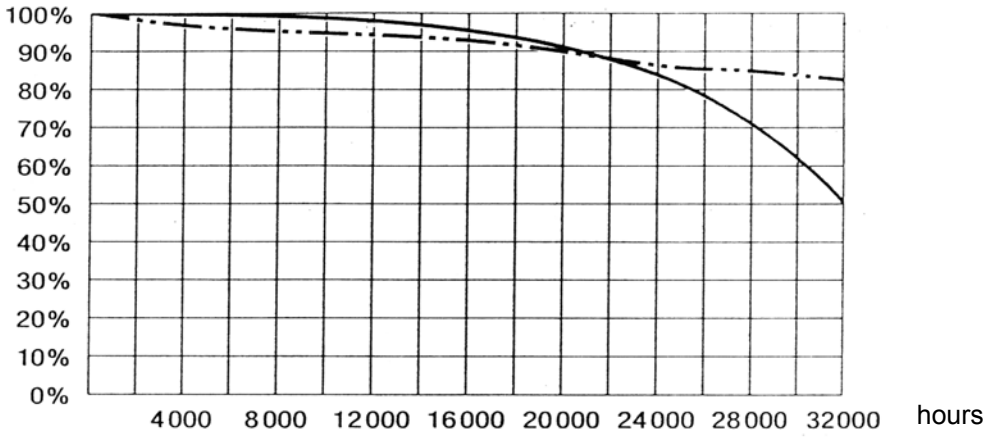
To determine luminous flux operational variations of luminaires applied in the road lighting, it is necessary to know: the luminaires efficiency variations when operating in the determined environmental conditions and applied light sources luminous flux variations.

The exemplary experimentally determined curves [4, 6] for luminaires type SGS 203 – 150 W, operating on a significant importance city traffic road, of average daily traffic > 34 000 vehicles and of average annual dustfall of approx. 92 g/m^2 have been presented on Drawing 1.

Lighting sources luminous flux variations during operation can be determined experimentally or relevant data can be taken from the manufacturer. The exemplary luminous flux variations curves have been presented on Drawing 2.

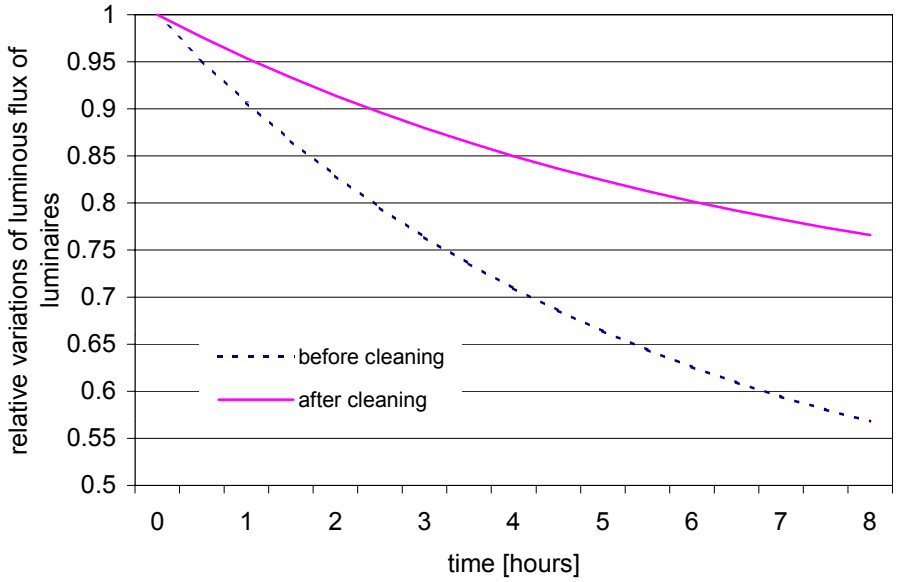


Drawing 1. Efficiency variations curves of luminaires operating in the exemplary working environment [4, 6]



Drawing 2. Experimental luminous flux variations curves in time of the high pressure sodium lamps 150 W type NAV 4Y [2]
Broken line – light source luminous flux decrease curve
Full line – light sources burnout curve

On the basis of dependence (1) and (2) as well as real curves of luminaires efficiency variations as well as light sources luminous flux variations during operation, it is possible to draw relevant luminous flux variations curves for the road lighting luminaires.
The luminaires luminous flux variations during operation curve and the luminous flux maximum variation values after cleaning luminaires curve, determine the maximum interval between performing successive maintenance operations.
The exemplary luminous flux variations curves have been presented on Drawing 3.



Drawing 3. Luminous flux variations curves of luminaires operating in the exemplary working environment [4, 6]

3. Operation of lighting points in the road lighting

In accordance with the binding in Poland luminaires maintenance procedures, luminaires that have been determined the operational efficiency variations (Drawing 1), should be cleaned once in two years without requiring light sources replacement within this period. These maintenance operations performed on luminaires exclusively allow luminous flux increase, in relation to the initial luminous flux value of the luminaires, up to the value resulting from the product of efficiency variations after luminaires cleaning and light sources luminous flux variations.

$$\frac{\Phi_{cz}(t_{cz})}{\Phi(t=0)} = \frac{\eta_{cz}(t_{cz})}{\eta(t=0)} * \frac{\Phi_{źr}(t_{cz})}{\Phi_{źr}(t=0)} \qquad (3)$$

Where:
t_{cz} – maintenance operations performance time

In case of luminaires operating for t_{max}~~22,5 year (4,5% of annual depreciation charge) and operated in accordance with the above mentioned procedures and when light sources are replaced after burnout, after approx.$1,4_{tśr}$ the maintenance coefficient value determined on the basis of the dependence:

$$u(t_{max}) = \frac{\Phi(t_{cz})}{\Phi(t=0)} - \frac{\Phi_{cz}(t_{cz})}{\Phi(t=0)} + \frac{\eta_{cz}(t=1.4\cdot\tau_{śr})}{\eta(t=0)} + \frac{\Phi_{cz}(t_{max}-t_{cz})}{\Phi(t=0)} - 1 \qquad (4)$$

and curves presented on Drawing 3, amounts to $u(t_{max})$=0,51 . It means that during lighting designing stage, to provide the appropriate parameters on the lit road, it is necessary to consider the luminaires luminous flux variation up to 49%.

In case the luminaires maintenance operations would have been performed twice a year, including the light sources replacement then the luminaires luminous flux would increase up to the value resulting from the efficiency variation as a result of cleaning.

$$\frac{\Phi_{cz}(t_{cz})}{\Phi(t=0)} = \frac{\eta_{cz}(t_{cz})}{\eta(t=0)} \qquad (5)$$

Because:

$$\frac{\Phi_{źr}(t=cz)}{\Phi_{źr}(t=0)} = 1$$

In this case, considering the light sources replacement, there will occur smaller luminaires luminous flux variations between successive maintenance operations and the maintenance coefficient determined on the basis of the dependence:

$$u(t_{\max}) = \frac{\Phi(t_{cz})}{\Phi(t=0)} - \frac{\eta_{cz}(t_{cz})}{\eta(t=0)} + \frac{\eta_{cz}(t_{\max})}{\eta(t=0)} \qquad (6)$$

shall increase up to the value $u(t_{max})=0,70$. So the maximum luminous flux variations amount to 30% when comparing with the initial value.

Considering high costs of light sources, their group replacement after two years of operation, (after approximately 8000 lighting hours), has no economic grounds. However, when assuming that economic replacement interval of high pressure sodium (vapour) lamps type NAV 4Y is approximately 0,5 $\tau_{śr}$, (16000 hours ~ approximately 4 years of operation), then the maintenance coefficient value determined on the basis of the dependence (6), for 4 years maintenance periods, will be: $u(t_{max})=0,61$.

So it is easy to notice that performing lighting points maintenance consisting in luminaires cleaning including the light sources replacement allows increasing intervals between successive maintenance operations. Increasing intervals even twice does not produce the luminaires luminous flux variations increase when comparing with presently binding procedures and as a result it does not produce the maintenance coefficient value decrease either.

4. Conclusions

All lighting points operating in the road lighting system change their photometric and usable parameters in course of operation and as a result influence (deteriorate) the drivers vision reliability. Assuming the determined reserve coefficient value at the stage of designing should result from lighting points photometric parameters variations and from the planned light sources and luminaires maintenance method and operations frequency. For appropriate estimation of the maintenance coefficient it is necessary to assume the appropriate maintenance procedures of the lighting points applied in the road lighting. On the basis of calculations and analysis, the author considers that the most appropriate maintenance method for lighting points in the road lighting is combining luminaires cleaning with the light sources group replacement.
Taking into consideration the necessity to provide the appropriate vision reliability to all road users, it is required to perform individual replacement of burnout light sources between cleaning sessions. This method is technically and economically grounded. The complex performance of maintenance operations within the determined period of time allows limiting expenses related with these operations and decreasing the necessary frequency of luminaires opening, (that reduces the luminaires possible leak). Moreover it allows applying lower maintenance (reserve) coefficient values within the lighting equipment designing stage and maintaining at the same time the appropriate lighting parameters on the road within the entire lighting equipment operation period.

Literature:

[1] IES: Lighting handbook, New York, III: Eng. Society 1981.
[2] Osram. Natrium-Xenon-Lampen. Technischen information
[3] Philips Lighting B.V.1993: Lighting manual.
[4] Zalesińska M.: Techniczno – ekonomiczna analiza kosztów eksploatacji punktów świetlnych oświetlenia drogowego. Rozprawa doktorska. Politechnika Poznańska, Poznań 2003
[5] Zalesińska M, Gandecki A.: Operational changes of road lighting luminaires. Lux junior'01, 5. Internationales Forum fur den lichttechnischen Nachwuchs, Ilmenau 21-23.09.2001.
[6] Zalesińska M, Hauser J., Gawroński M.: Operational changes of photometric parameters of road lighting luminaires. Lux junior'03, 6. Internationales Forum fur den lichttechnischen Nachwuchs, Ilmenau 19-21.09.2003.