LIGHTING OF TRAM'S FOREGROUND WITH THE USE OF HEAD AND LOW BEAM LIGHTS – RESEARCH

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Abstract

Recent progress within the area of front lighting of motor vehicles makes it possible to implement some technical solutions in other types of vehicles. High quality of front lighting is a factor required not only in motor vehicles. The article shall present the current state of front lighting of trams and qualitative analysis shall be presented of currently used light beams.

The emphasis put on the quality of motor vehicle projectors, their constant development and application of new kinds of light sources, as well as application of advanced systems of automatic light beam direction does not translate into application of these solutions in tram vehicles. Safe movement of a track vehicle is conditioned by the quality and state of its main lighting. Appropriate distribution of a light beam plays a significant role in the perception of luminous sensations from a vehicle's foreground. It ensures a proper assessment of behaviour of other road traffic participants and conditions proper visibility from a tram driver's seat.

The analysis of tram line lighting shall be conducted on the basis of real photometric measurement data with the use of calculation programme having an advanced model of foreground lighting of the vehicle at its disposal. Lighting recommendations shall be presented taking into account the characteristics of light beams used in trams

Keywords: *transport, tram, simulation, lighting distribution, tram lighting, front lighting*

1. Introduction

Properly selected lighting for the prevailing atmospheric conditions as well as for the situation in the foreground of a track vehicle, may significantly contribute to the improvement of luminous sensations' perception from the vehicle's foreground by the tram driver. Urban traffic situations force the tram driver to be constantly alert and to take confident decisions taking into account all environmental factors and stimuli. A definite majority of recorded tram accidents and catastrophes are tragic in consequences because as a result of these incidents not only passengers die but also other participants of road traffic. On the Polish scale, this phenomenon was not considered as an essential issue. This is connected with the fact that tramline network exists only in several larger Polish cities and with the fact that this network has been recently substituted with bus services or transport system excluded from road traffic, for example, underground railway.

The greatest intensity of tram catastrophes and accidents can be seen mainly in large agglomerations and industrial areas. It concerns such cities as Warsaw, Katowice, Cracow, Poznan, Gdansk and Lodz. Some of these cities are characterised by a complex tram service system applied in very narrow streets (e.g. in the city centre). Also in the cities of extended network of communication (Katowice, Warsaw) which is situated within the area lacking sufficient stationary lighting infrastructure.

Stationary lighting installed within the lane of the road very often fails to illuminate the area of the tramline. Therefore, the lighting installed directly on the vehicle has a significant influence on the observation of the surrounding area and the foreground of the tram vehicle. Proper functioning of the main lighting of the vehicle is an essential factor ensuring the tram driver appropriate assessment of the situation in the foreground of the vehicle, especially at night time.

The present paper shows luminous properties of low beam and main lights applied in tram vehicles.

The external lights are designed to illuminate the road in front of the vehicle or its neighbourhood and they are also used to inform other participants of the traffic about the state of a given vehicle.

Tram's lights can be divided into two fundamental groups:

– external lights,
– internal lights.

External lights approved for usage in tram vehicles are:

– low beam lights,
– main lights,
– front, rear and side indicators,
– brake lights 'stop',
– front and rear position lights,
– rear reflectors other than triangular, front and rear,
– hazard lights,
– front and rear fog lights,
– reverse lights,
– daylight running lights.

Detailed requirements concerning lighting equipment in trams on the area of Poland are included in the Directive of the Minister of Infrastructure no. 2300 from 19th December 2003 on the range, conditions, terms and mode of conducting technical inspections of trams and trolleybuses, as well as the organizational units conducting these inspections" [1] and in the Directive of the Minister of Infrastructure no. 2301 from 22nd December 2003 "on the technical conditions of trams and trolleybuses and the range of their indispensable equipment" (Journal of Laws No. 230 item 2301 from 22nd December 2003) [2]. No separate provisions exist in the Polish law, regulating the range of requirements for the lighting installed on trams.

Analysing the requirements included in the above directives, one can state that there exists an important reference to photometric requirements imposed on motor cars [5]. The requirements in particular concerning the levels of directional luminous intensity of main lights, asymmetry of a light bundle and the border between light and shade of low beam lights. Another requirement is the range of chromaticity – white colour or selective yellow.

For the group of tram vehicles photometric requirements have not been specified taking into account different road and vehicle geometry, or traffic conditions in the urban environment. In consequence, there is no photometric screen dedicated to trams or detailed illuminance values in measurement points and zones. For vehicles of this group reflectors and projectors are used with geometry of a light bundle coming from a motor car. This is a result of no solutions dedicated to this group of vehicles.

Within the infrastructure of the capital city of Warsaw there are about 875 tram vehicles in function [4]. The majority of which has been in use for several or even several dozen years. The tendency of exchanging the tram stock is connected with the implementation of modern solutions from the point of view of passenger use as well as taking into account safety requirements and driving comfort for the tram driver.

Within the field of tram lighting few construction innovations are being implemented.

In trams produced during post-war years, lighting produced by the firm ZELMOT was mainly used. Currently, lamps of other firms are being interchangeably installed. Initially, light bulbs of R2 type were used, then, halogen source H4. Sample solutions, often interchangeably used in trams 13N (Fig. 1) and 105N (Fig. 2.) are presented in Fig. 4 and 5. The latest constructions of trams are equipped with projectors of lenticular type – for low beam lights and reflectors of FF type – for main lights. The example of the use of these lamps is tram 120N (Fig. 3) where Hella lamps have been used (Fig. 6). Reflecting elements of these lamps are made of highly efficient magnesium materials. In the case of low beam light lamp, projector DE has been used. Both constructions are equipped with a smooth pane having the function of a shield and in both solutions modern, halogen source of light H7 light bulb has been used.

2. Researches of tram's main lighting

In Fig. 1, 2 and 3 below, we have presented the pictures of trams with a marked geometry of the position of tram driver's eyes as well as the location of lamps installed on the vehicles. This data is indispensable for conducting photometric analysis on the basis of simulation program.

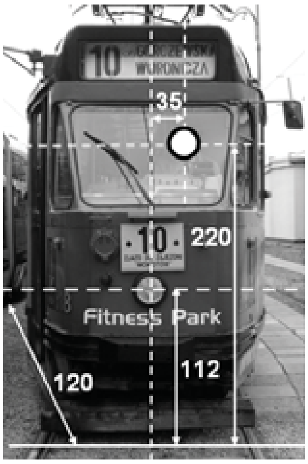

Fig. 1. Tram 13N with a single reflector 0215.8.10.8.0 produced by Zelmot (with a H4 light bulb)

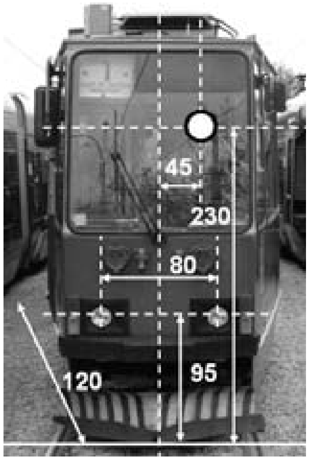

Fig. 2. Tram 105N with two reflectors 0245.2008.1 produced by Zelmot (with a R2 light bulb)

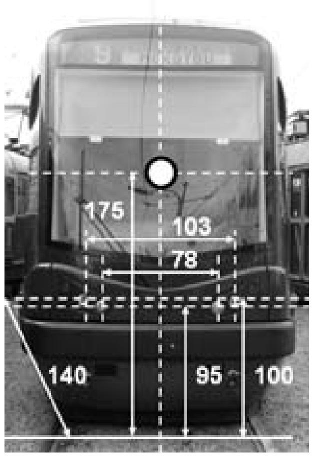

Fig. 3. Tram 120N with two low beam light projectors 1BL 008 193-01 (with a H7 light bulb) and two main light reflectors 1KO 008 191-02 (with a H7 Hella light bulb)

Fig. 4. Lamp 0215.8.10.8.0 produced by Zelmot with a H4light bulb installed on tram 13N

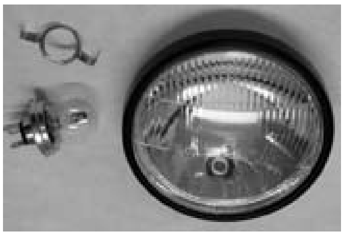

Fig. 5. Lamp 0245.2008.1 produced by Zelmot with a R2 light bulb installed on tram 105N

Fig. 6. Low beam light projector (left) 1BL 008 193-01 and reflector FF of main lights (right) 1KO 008 191-02 produced by Hella with H7light bulbs installed on tram 120N

For the purpose of conducting photometric analysis it was indispensable to obtain solid of directional luminous intensity of each of the lamps presented above. Photometric data was measured at a goniometric station for automatic measurements of motor vehicle lamps and for research on light distribution of other lamps and reflectors. Figures from 7 to 12 present results of laboratory measurements.

Within the framework of research on horizontal distribution of a light bundle, light analysis of target observation on the tram's foreground in good atmospheric conditions with the use of head lights has been conducted by means of simulation program TARVIP [6]. Good atmospheric conditions adopted for calculations result from guidelines concerning lighting equipment in trams [1, 2]. Unfortunately, the abovementioned requirements are lacking in definition of the notion of ‘good atmospheric conditions’. For calculations, the values were adopted from the classification of weather conditions (clear, T_{atm} = 0.86 km^{-1}) [6].

Low Beam Light

Main Beam Light

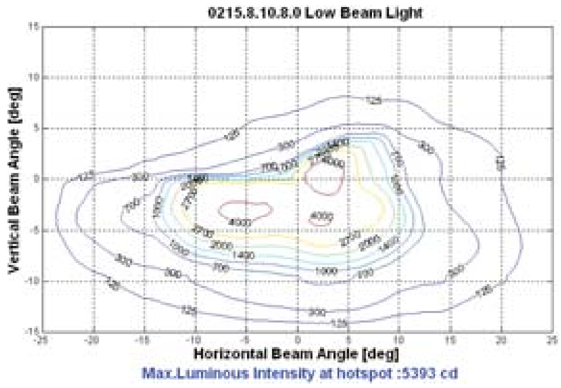

Fig. 7. Iso-candela plot of low beam light lamp 0215.8.10.8.0 (H4) on measurement screen installed on tram13N implemented for TARVIP [6]program

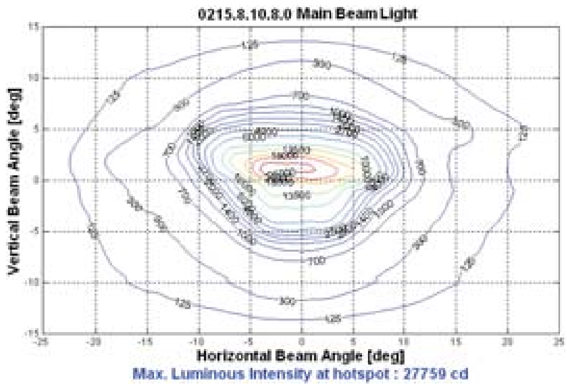

Fig. 8. Iso-candela plot of main beam light lamp 0215.8.10.8.0 (H4) on measurement screen installed on tram 13N implemented for TARVIP [6]program

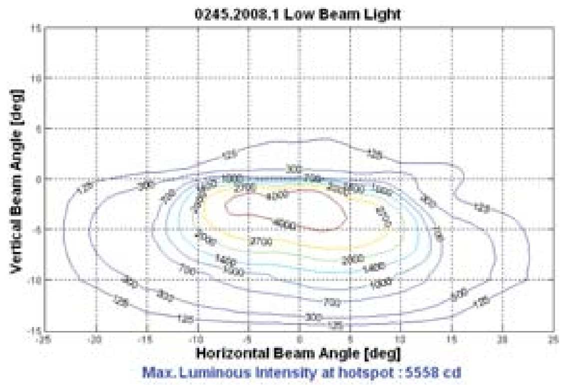

Fig. 9. Iso-candela plot of low beam light lamp 0245.2008.1 (R2) on measurement screen installed on tram 105N implemented for TARVIP [6]program

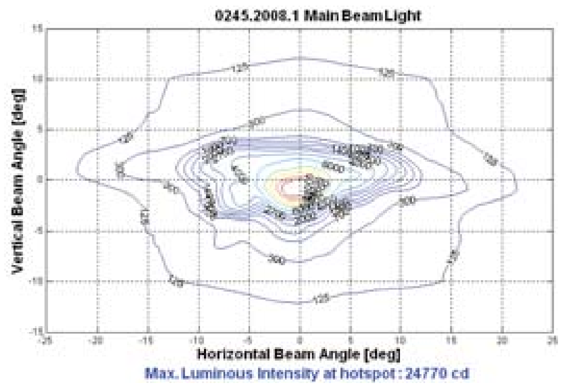

Fig. 10. Iso-candela plot of main beam light lamp 0245.2008.1 (R2) on measurement screen installed on tram 105N implemented for TARVIP [6]program

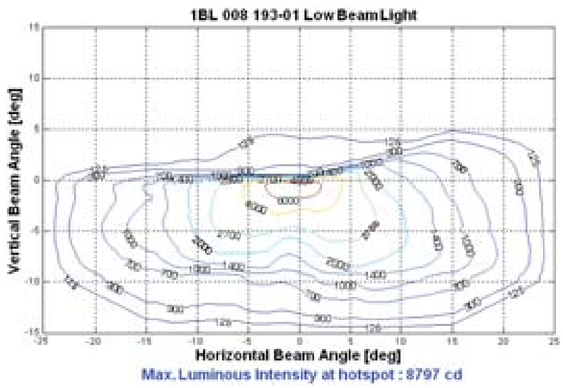

Fig. 11. Iso-candela plot of low beam light projector 1BL 008 193-01 with a H7 light bulb produced by Hella on measurement screen installed on tram 120N implemented for TARVIP [6]program

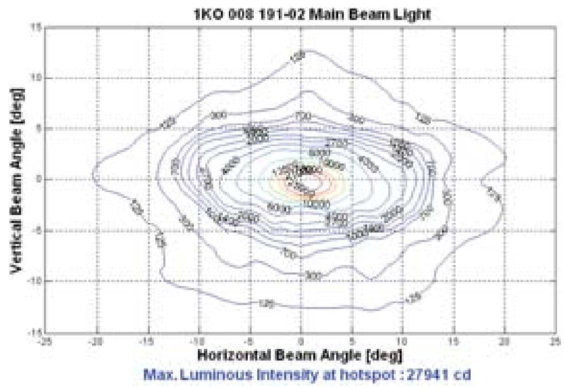

Fig. 12. Iso-candela plot of main beam light reflector 1KO 008 191-02 with a H7 light bulb produced by Hella on measurement screen installed on tram 120N implemented for TARVIP [6]program

The basic target being analysed was a human figure (Fig. 1) of the following parameters: height 1.7[m], width 0.52[m], surface 0.884[m^2], position in relation to centreline of the road 3.91[m], target reflection coefficient adopted at the level of $\rho = 0.2$, whereas the character of reflection is that of Lambert's. The target was being observed from the tram driver's seat, and the tram was moving at the sped of 50 [km/h]. Transparency of the vehicle's windscreen was adopted at the level of 78 [%].

Fig. 13. Position of the target on the tram's foreground
(the lines indicate the limiting outline of tramline and the axis of tram's trajectory)

For the sake of calculations, a straight fragment of a two-way tramline was chosen of the width of each lane - 3.6m. Luminance of road metal was adopted at the level of 0.05 cd/m^2 [6]. The present author deliberately adopted such a low level of luminance threshold, assuming lack of any stationary lighting or other sources of light in night time driving conditions.

First, a series of simulations were conducted consisting in determining optimal directions of a light bundle emission in a vertical plane. After determining these values, calculations were made of changes of direction of a light bundle emission in a horizontal plane.

The purpose of the analysis conducted was determining lighting parameters of a vehicle's foreground at the change of direction of a light bundle emission in a horizontal plane. For the calculations, the change of direction of a light bundle emission was adopted within the range of ±10º and its influence on the following lighting parameters:

– the range of vision from the tram driver's position,
– the level of contrast on the border of the range of sight,
– haze luminance – being at the same time backward luminance coming from the reflection of a luminous flux on fog particles.

The figures below present the results of simulation analysis. Particular parameters of road lighting and the target placed on it (human figure) illuminated by light bundles of projectors and reflectors of low beam lights and main lights installed on trams. In the present considerations, the names of tram models are used and not the names of particular lamp types. Indications of lamps ascribed to particular trams can be found in descriptions of figures 4, 5 and 6. Such an approach is connected with making calculations for a particular geometry of a vehicle and a lamp installed on it.

As it follows from laboratory measurements conducted, directional luminance distributions of particular lamps are significantly different from one another. Classic reflectors used in trams 13N and 105N may ensure minimum, in accordance with the norm, levels of directional luminance, but they do not guarantee maintenance of light parameters in changeable atmospheric conditions. Emitted light bundles of main lights in a vertical plane are wide, which has a negative influence on glare of other participants of road traffic. This factor also contributes to increasing backward luminance ('white wall of fog' effect) during bad atmospheric conditions, fog or snow. Low beam lights used in trams differ in the shape of a low beam light bundle e.g. a low beam light bundle of lamp 0245 (Fig.9.) used in tram 105N does not have asymmetry features. This type of solution is allowed to be used in track vehicles.

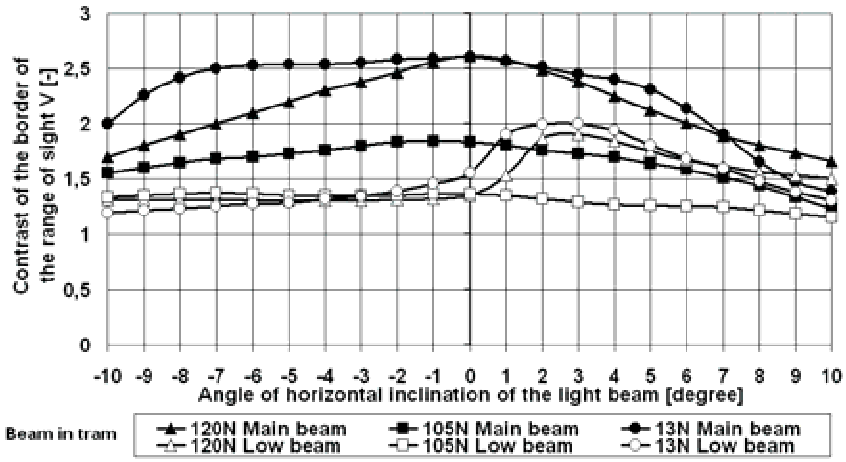

Fig. 14. Contrast on border of the range of sight (for visibilities V = 1) at constant maximum transmissivity coefficients (Tatm= 0.86km^{-1}) which characterize atmosphere in front of the vehicle

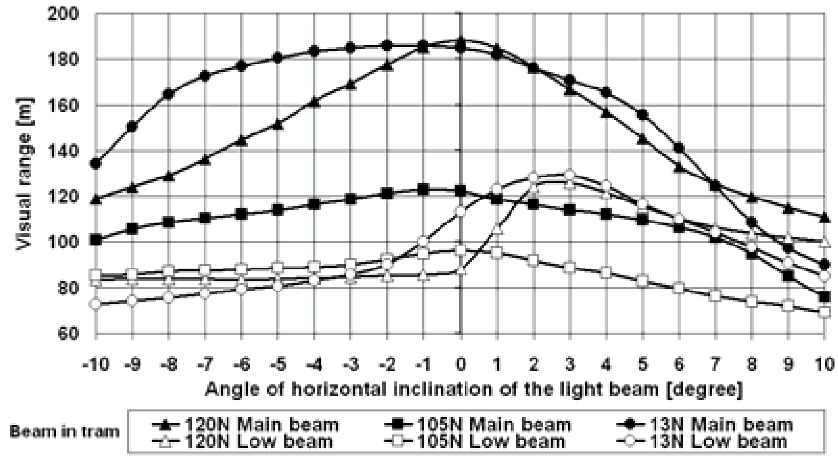

Fig. 15. The visual range in function of angle of inclination of light beam projector at constant maximum transmissivity coefficients (Tatm= 0.86 km^{-1})

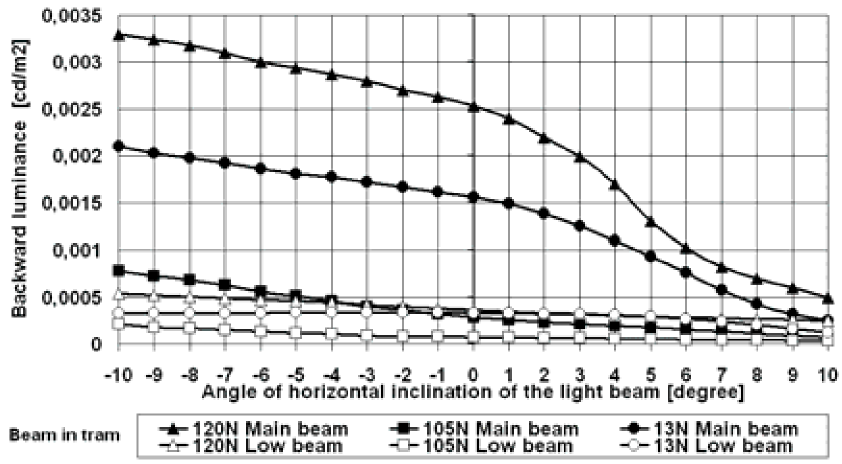

Fig.16. Haze Luminance in function projector light beam angle inclination at constant maximum transmissivity coefficients (Tatm= 0.86 km^{-1})

Analysing the contrast of observation target with the background on the border of the range of sight of tram's reflectors, (Fig. 14) it can be stated that the highest levels of contrast for road light bundles occur within the range of light bundle emission equalling 0º. For a light bundle of trams 120N and 13N, the value of contrast equals about 2.5, whereas for a bundle of main lights of a reflector used in tram 105N, it takes the value of about 2. A lower value of contrast for this bundle is a result of lower by about 15% directional luminance of a reflector equipped with a light bulb R2 in comparison with reflectors equipped with halogen sources. Inclination of light bundles from the optimal direction influences the contrast in a negative way. For low beam light bundles of asymmetrical character, maximum contrast equals about 2. The contrast of observation target with the background on the border of the range of sight of a low beam light projector installed on trams 13N and 120N, is the highest within the range from -1º to 5º.

The values of target visibility range by the tram driver (Fig. 15) should be considered sufficient for all types of lamps used. The lamps used in trams 13N and 120N ensure significantly wider (by about 60 m in comparison with the lamps used in tram 105N) range of visibility of objects on the road. Despite the fact that two lamps are installed on tram 13N, the value of emitted directional luminous intensity fails to ensure comfort of perception of luminous sensations from the vehicle's foreground. This results from the use of R2 light bulb of low efficiency.

Satisfactory levels of visibility range obtained for main beam lights of lamps used in trams 120N and 13N result from the use of halogen sources of light characterising of significantly higher luminous flux than a classic R2 type light bulb. The value of visibility range (Fig. 15) a low beam light installed on tram 105N on the level of about 120m may prove to be insufficient for performing a visual task by a tram driver in particular at higher speed levels. Maximum visibility range for low beam lights in good weather conditions is between 90m and 120m, when the norm requires the level of 45m.

Increase of backward luminance (Fig. 16) for negative angles is caused by luminous flux diffusion in the atmosphere before the vehicle, where the object appears. For the assumed value of proper atmosphere transparency equalling $0.86km^{-1}$, backward luminance obtained for all analysed light bundles takes low values and has no influence on the perception of luminous sensations from the vehicle's foreground. It can, however, be a factor determining the use of such a kind of lamps in the case of difficult weather conditions.

Change of direction of light bundle emission of head light projectors, change of the height at which the projectors are suspended as well as the location of an obstacle on the road essentially influence perception features of luminous sensations from the vehicle's foreground [7], which determines the way of proper use of tram's projectors in urban traffic.

3. Conclusions

Realization of fundamental and minimum photometric criteria for the lights of main lighting installed on trams results from lack of research and detailed guidelines for this particular type of vehicles. Specificity of tram traffic in urban environment requires detailed analyses and establishing optimal directions of emission for light bundles and values of directional luminance. Such an approach will enable the choice of the most advantageous kinds of light bundles from the point of view of lighting functions realization. The final effect of such research should be ensuring the tram driver optimal observation conditions of the vehicle's foreground by creating detailed photometric requirements, research and operation procedures.

Because of the specificity of public transport and a relatively small number of tram vehicles in relation to an overall number of vehicles participating in urban traffic, it should be stated that the subject of improving lighting quality in this means of transport is possible to realise and implement in newly produced and implemented constructions.

Introduction of uniform construction solutions in all types and models of trams would contribute to improvement of lighting quality also in older types of vehicles, lighting subassemblies of which do not conform to the requirements of current legal regulations and operation guidelines.

In the opinion of the author of the present publication, the requirements concerning front lighting lamps of tram vehicles should be standardised and precisely defined. Moreover, within the framework of improvement proposal of the current situation, the author suggests introduction of automatic regulation of a light bundle system [3], [8], the introduction of which would contribute to improvement of lighting quality. These systems could also be applied to older types of vehicles.

To summarise, it should be emphasized how significant in development process of lighting equipment of public transport vehicles is the safety of all participants of road traffic.

It goes without saying that further research in the field of tram's lighting is indispensable and research results may contribute to standardisation of regulations and requirements concerning all types of front lamps used in urban track vehicles.

References

[1] *W sprawie zakresu, warunków, terminów i sposobu przeprowadzania badań technicznych tramwajów i trolejbusów oraz jednostek wykonujących te badania*, Dz.U.Nr.230 poz.2300, 2003.

[2] *W sprawie warunków technicznych tramwajów i trolejbusów oraz zakresu ich niezbędnego wyposażenia*, Dz.U.Nr.230 poz.2301, 2003.

[3] *AFS – Advanced Frontlighting Systems*, EUREKA Project No. 1404, Phase 1 Feasibility Study, Final Report, 1996.

[4] *Informacje statystyczne ze strony internetowej Tramwajów Warszawskich* http://www.tw.waw.pl/

[5] Mazur, J.W., Żagan, W., *Samochodowa Technika Świetlna*, Oficyna Wydawnicza PW, Warszawa 1997.

[6] Schnell, T., Aktan, F., *Dokumentacja programu TARVIP*, University of Iowa, USA

[7] Tomczuk, P., *Wpływ dynamiki ruchu pojazdu samochodowego na kierunek wiązki świetlnej projektorów przeciwmgłowych*, Rozprawa doktorska, Wydział Elektryczny, PW, 2005.

[8] Tomczuk, P., Stypułkowski, K., *Light beam control system of tram's head lights*,Journal of KONES Powertrain and Transport, Vol. 15, nr 2, pp. 475-482, KONES 2008.