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Exploitation Research of Tram's Head Lighting – Low Beam Lights

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Abstract

Appropriately shaped light beam conditions correct visibility from a tram driver's seat and makes it easier to assess properly road situations connected with behaviour of other road traffic participants. The article presents the current state of tram's front lighting. Projectors and reflectors have been tested together with the sources of light currently exploited in tram vehicles. The present photometric requirements as well as the legal state concerning exploitation of lighting in trams have been described. Qualitative analysis has been conducted of currently used light beams of low beam lights with the use of image analyzer of CCD camera for luminance measurement. A method of luminance measurement on photometric screen has been described. Comparative results have been presented of luminance measurement in measurement points and zones on the borderline of light and shade, and on the glare line of a tram driver coming from the opposite direction.

Keywords: tram's head lighting, low beam lights, CCD camera, luminance

1. Introduction

The factor influencing the safety of a moving track vehicle is the quality and condition of tram's head lighting. Proper distribution of a light beam within the area of a vehicle's foreground plays a decisive role in the perception of luminous sensations by the tram driver. Appropriately shaped light beam conditions proper visibility from the tram driver's seat and facilitates correct assessment of traffic situations connected with the behaviour of other road traffic participants.

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Review of Polish and worldwide literature within the field of foreground lighting of track vehicles indicates a scarce number of publications concerning systemic approach to this issue. Poland lacks legislative solutions dedicated to this field. Current requirements concerning technical parameters of lighting solutions used in tram vehicles are included in the Directive of Minister of Infrastructure [1], [2].

Requirements included in the abovementioned directives contain only general information, which can be used when drawing up a method of quality assessment of tram's lighting. What they are lacking in is detailed measurement guidelines taking into account the specificity of tram's foreground lighting in urban traffic conditions. Guidelines included in the abovementioned directives stipulate only borderline values of luminous flux density and ranges of particular light beams of a tram. There is a possibility of defining more detailed requirements, for example, by defining a photometric measurement screen for this group of vehicles. Therefore, it is justifiable to make an attempt at application of modern photometric tools in order to optimise the quality of light beams used in tram's front lighting.

It should be mentioned that according to the knowledge of the author of the present paper, there is no research being currently conducted on the head lighting of tram vehicles either in Poland or in Europe.

Lamps exploited in tram vehicles in most cases are obsolete constructions [9]. Traditional paraboloidal reflectors are mainly used with classic (R2 or BA20 bulb) (Fig. 5, Fig. 7, Fig. 9) or halogen (H4 bulb) (Fig. 11, Fig. 13 and Fig. 15) sources of light. In the latest constructions of optical-luminous lamps, more modern solutions for creating luminous flux are used by means of application of ellipsoidal reflectors (Fig. 3) with halogen H7 light bulbs.

The solutions for optical-luminous systems used in motor car vehicle technology are most often directly implemented in tram vehicles. Frequently, they fail to fulfill requirements [9] referring to light beam distribution and direction. Different observation conditions from the tram driver's cabin, the level of tram driver's eyes, the level at which tram's head lighting is installed as well as track features diametrically differ from the requirements for foreground observation in a motor vehicle.

ECE regulations and Polish Norms [5] stipulate lighting used in motor vehicles. In the case of tram light equipment, no detailed photometric requirements exist. The lack of such regulations clearly leads to negligence in head lighting exploitation. The most frequent cases of negligence refer to the following: wrong direction of a light beam, application of a light bulb with an underestimated light beam, usage of overexploited reflectors with partly damaged reflecting elements or lamp bowls.

Measurements presented in the paper are an introduction to an analysis of the quality of tram vehicle's foreground with the use of mathematical tools. Researches are underway on the possibility of application of uniform technical solution for tram vehicle's foreground lighting [7] and application of automatic light beam control system of a tram [8]. Detailed requirements for particular light beams used in tram vehicles are currently being prepared.

In Poland, researches on the quality of light beams are conducted for the needs of motor car vehicle lighting. Within the range of analysis of a light spot image of motor vehicle's head lights, a device was created at the Institute of Automotive Transport, which makes it possible to assess the quality of a light spot of the optical-luminous solution applied [6]. The analyser of motor car vehicle lighting assesses light beam emitted in terms of exploitation parameters. Borderline of light and shade and measurement points and areas are being assessed among others in accordance with normative requirements for particular kinds of light beams. The measurement is conducted by means of CCD converter, and the values are presented in luminous intensity units. It should be mentioned that the constructed analyser is a prototype dedicated to motor car lighting devices and as such cannot be directly applied to the analysis of tram head lighting quality.

To date, due to normative requirements [5], assessment of light beam quality has been conducted by means of direct measurement of luminous intensity on measurement screen [4]. Such an analysis can only answer the question referring to the value of luminous intensity in particular measurement points and areas. It does not, however, allow for assessment of a full light beam distribution. The solution applied by the author of the present paper consists in direct measurement of luminance on measurement screen, obtained for a measured light beam. In such a way a full picture of luminance of a measured light beam is obtained. This method, because of measuring equipment applied, is unique in Poland.

2. Luminance Measurement on Photometric Screen

The first stage of work on the subject was conducting laboratory measurements of tram reflectors and projectors. A series of measurements was conducted by means of classic goniometric method [4]. The results of these measurements were verified on the basis of luminance assessment method on photometric screen.

The advantage of luminance method is the possibility of assessment of light beam distribution regularity on the analysed image of a light spot.

In the present publication, the author presents only the results of luminance measurement of light spots of low beam lights exploited in tram vehicles.

The measurements of luminance were conducted by means of specialist portable camera LMK MOBILE ADVANCED made by the company Techno Team Bildverarbeitung GmbH [3] (Fig. 1).

The tool used allows taking a photo of a light spot image scaled in luminance units cd/m^2. Additionally, it is equipped with specialist software LMK 2000 making it possible to process and scale obtained luminance images for the purpose of assessment and comparison of obtained results.

Reflectors and projectors with dedicated sources of light underwent research. It is worth mentioning that real and not model sources of light were used. Such an

Fig. 1. The view of LMK camera for luminance measurement together with indispensable equipment [3]

approach made it possible to assess the current state of light beams exploited in tram vehicles.

The use of benchmark sources in the researches would be justifiable in relation to the assessment of reflectors and projectors only. However, it would affect the assessment of whole light optical systems exploited in tram vehicles. The researches were conducted on reflectors and projectors with dedicated sources of light which are used in everyday exploitation. Comparative researches on projectors and reflectors together with benchmark sources are being planned for the future.

The researches were conducted with the use of the reflectors and projectors presented in Figures 3,5,7,9,11,13,15.

Luminance measurements were conducted for seven light beams of low beam lights on measurement screen placed at a distance of 5 m perpendicularly to the tested lighting device (Fig. 2). The measurements of the screen equal 3.6 m within horizontal plane and 2m within vertical plane. Measurement photometric screen is produced from material characterized by Lambertian reflectance.

Luminance measurement results obtained are presented in Figures 4,6,8,10,12,14, 16 where logarithmic black-white scale was adopted ($\log_2$) calibrated from 0 to 75 cd/m^2.

Measurement points and zones were adopted in accordance with the guidelines of ECE R 112 regulations [5]. The above figures present a network of measurement points plotted on the image.

Normative guidelines stipulate luminous flux density values in particular measurement points and zones. The article proposes assessment of reflectors on the basis of luminance measurement making use of coordinates of measurement points and areas.

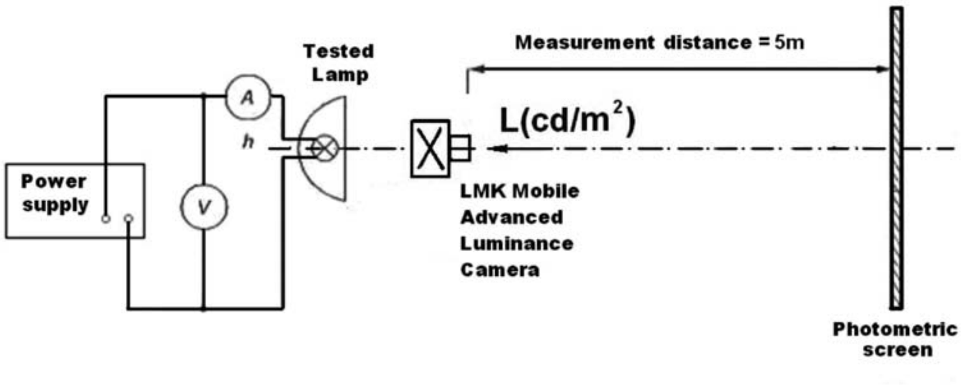

Fig. 2. Measurement station diagram

Fig. 3. Low beam light projector of 1BL-008 type with H7 light bulb

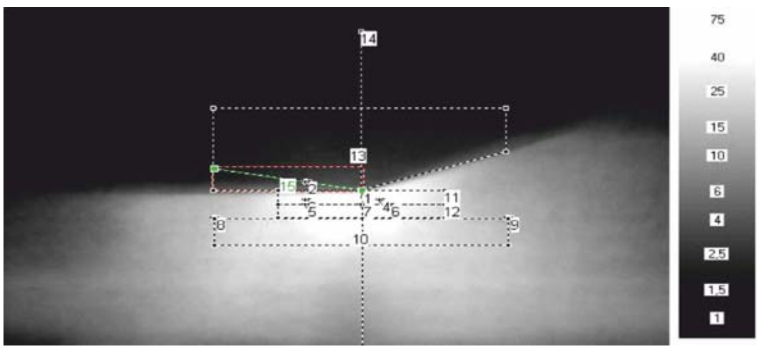

Fig. 4. The view of a light spot of low beam light projector 1BL-008 (H7) together with indicated places of luminance measurement

3. Laboratory Research Results

For measurement points, straight lines and areas presented in Table 1, luminance values for selected light beams of trams were registered. Table 1 presents overall results of luminance measurement in cd/m^2 of tested light beams of low beam lights.

Fig. 5. Main light and low beam light reflector of 0-300-181-003 type with BA20D light bulb

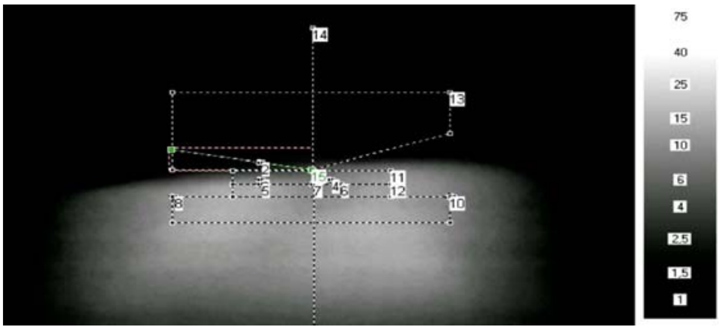

Fig. 6. The view of a light spot of low beam light reflector 0 -300-181-003 (BA20D) together with indicated places of luminance measurement

Fig. 7. Main light and low beam light reflector of RE09237 type with R2 light bulb

Measurement data of tested low beam light beams constituted a basis for conducting comparative analysis, the result of which is presented in a graphic form in Figures 17 and 18.

ECE regulations define the values required within the units of luminous flux density, stipulating the minimum and maximum level in a certain point and area. Some points and areas have the values of luminous flux density limited from the upper level so that a light beam does not cause the glare of the drivers coming from the opposite direction (B50L). In the abovementioned researches, the measurement

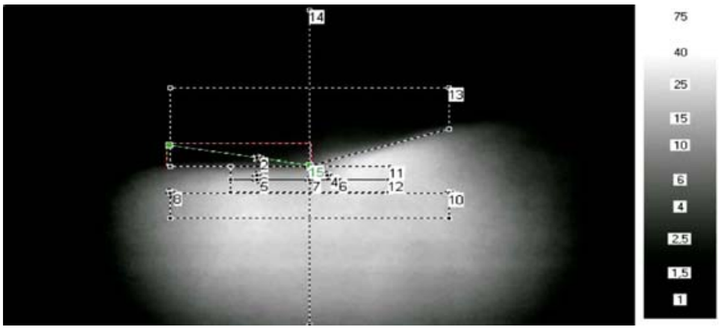

Fig. 8. The view of a light spot of low beam light reflector RE09237 (R2) together with indicated places of luminance measurement

Fig. 9. Main light and low beam light reflector of RE03210 (019469) type with R2 light bulb

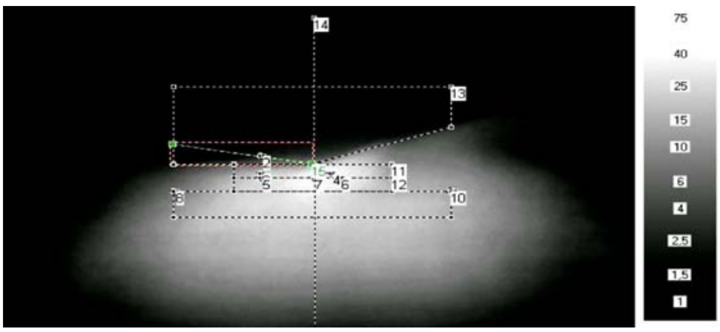

Fig. 10. The view of a light spot of low beam light reflector RE03210 (R2) together with indicated places of luminance measurement

of luminance has been used interchangeably, which made it possible to fully assess light beam distribution. It should also be mentioned that it is possible to calculate the value of luminous flux density into the value of luminance, however, it requires the knowledge of the value of measurement screen reflection coefficient. Making use of luminance results obtained, it has been decided to compare these values with the

Fig. 11. Main light and low beam light reflector of RE22879 type with H4 light bulb

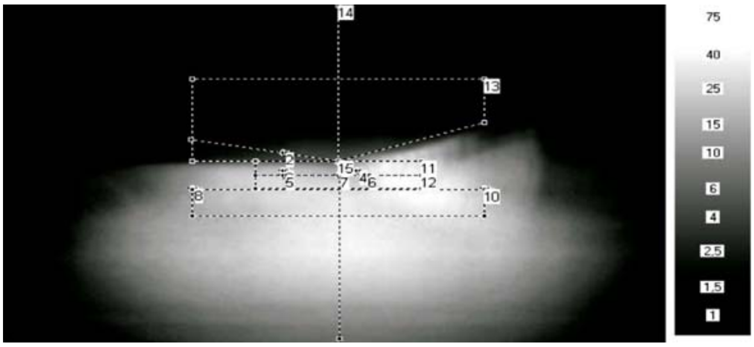

Fig. 12. The view of a light spot of low beam light reflector RE22879 (H4) together with indicated places of luminance measurement

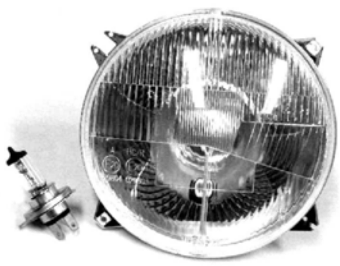

Fig. 13. Main light and low beam light reflector of RE03411 (029804) type with H4 light bulb

average value of luminance. The values have been calculated for each measurement point and area used in the research.

The results obtained have been presented by means of a line with a dot on graphs in Figures 19 – 31. All luminance values given in the radar graphs have the unit of (cd/m^2).

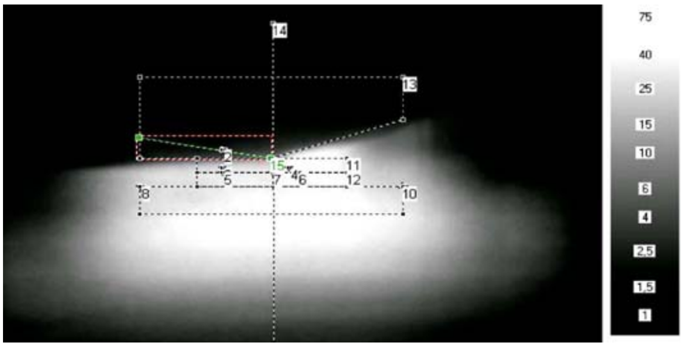

Fig. 14. The view of a light spot of low beam light reflector RE03411 (H4) together with indicated places of luminance measurement

Fig. 15. Main light and low beam light reflector of RE03210 (029939) type with H4 light bulb

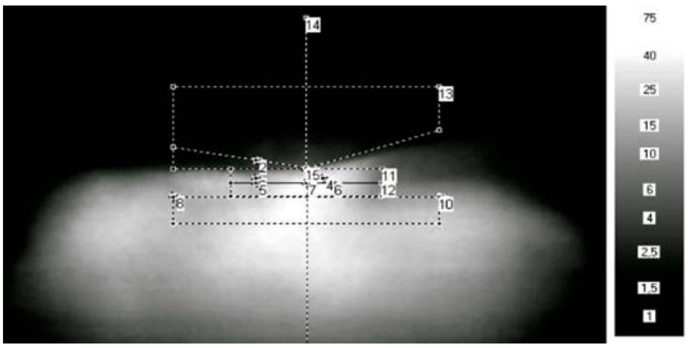

Fig. 16. The view of a light spot of main light reflector RE03210 (H4) together with indicated places of luminance measurement

Table 1

Average luminance values of low beam light reflectors and projectors in characteristic points and areas

Low beam	HV	B50L	75L	75R	50L	50R	50V	25L	25R	Area 1	Area 2	Area 3	Area 4
RE 22879 H4	7.44	3.49	20.94	23.54	24.82	24.30	20.60	12.69	19.24	29.92	22.17	1.37	30.82
RE 09237 R2	7.00	2.06	14.76	19.52	18.59	26.97	17.31	9.57	17.60	23.19	18.68	1.62	24.34
RE 03411 H4	13.12	2.69	26.4	46.13	30.86	52.79	31.40	22.73	22.60	37.37	34.10	1.64	37.82
RE 03210 R2	13.2	2.40	20.97	42.82	24.7	39.59	42.65	7.22	14.00	22.49	23.94	1.37	29.89
RE 03210 H4	10.18	2.85	14.41	43.35	19.09	41.46	51.10	15.44	12.29	26.84	20.92	1.66	30.73
1BL – 008	16.37	3.49	51.99	57.53	54.61	51.90	65.37	18.02	14.13	31.17	42.27	2.20	48.17
0 300 181 003	4.95	1.74	8.32	8.11	12.3	9.51	9.19	10.85	8.40	13.14	8.0	0.71	12.25
Average	**10.32**	**2.67**	**22.54**	**34.42**	**26.42**	**35.21**	**33.94**	**13.78**	**15.46**	**26.30**	**24.30**	**1.51**	**30.57**
Min.	**4.958**	**1.74**	**8.32**	**8.113**	**12.30**	**9.514**	**9.191**	**7.22**	**8.40**	**13.14**	**8.06**	**0.71**	**12.25**
Max.	**16.37**	**3.49**	**51.99**	**57.53**	**54.61**	**52.79**	**65.37**	**22.73**	**22.60**	**37.37**	**42.27**	**2.20**	**48.17**

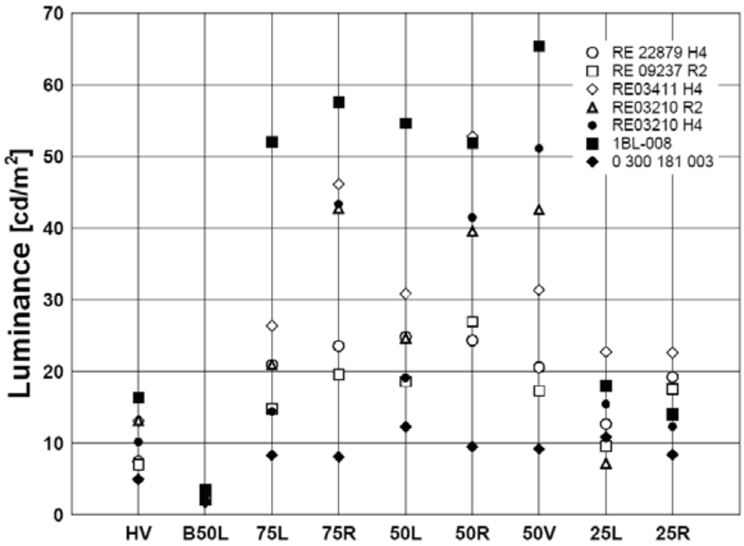

Fig. 17. Luminance measurement results in measurement points of low beam light beams

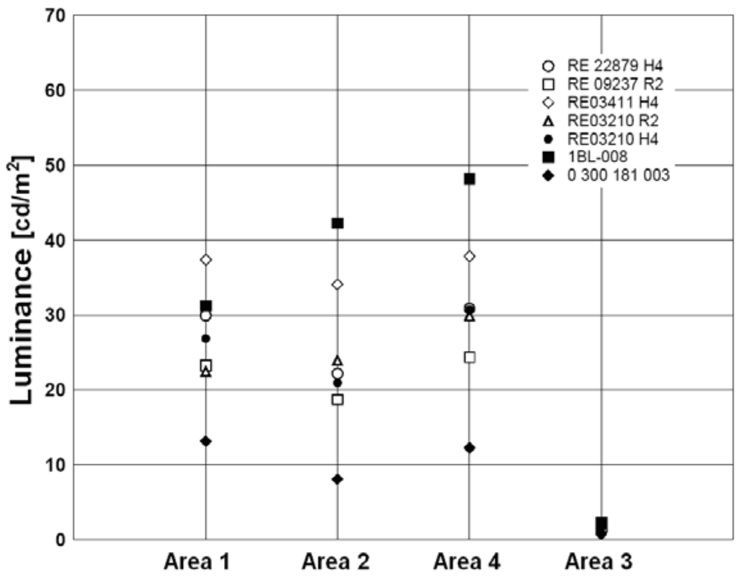

Fig. 18. Luminance measurement results in measurement areas of low beam light beams

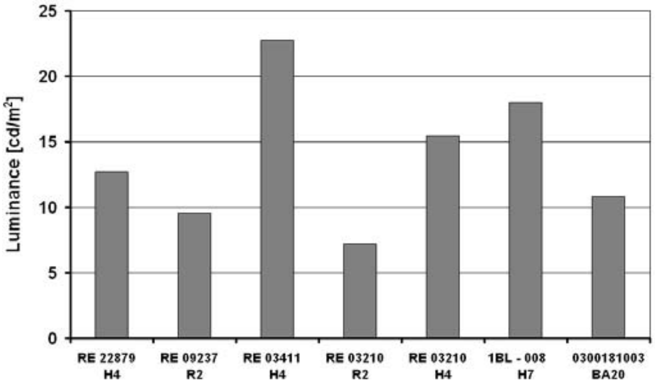

Fig. 19. Luminance values at the point 25L for the examined reflectors and projector

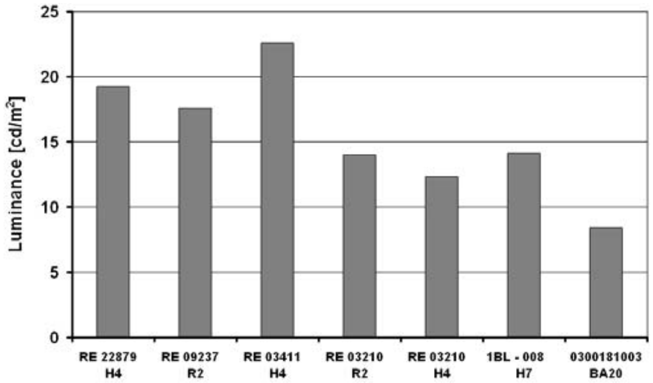

Fig. 20. Luminance values at the point 25R for the examined reflectors and projector

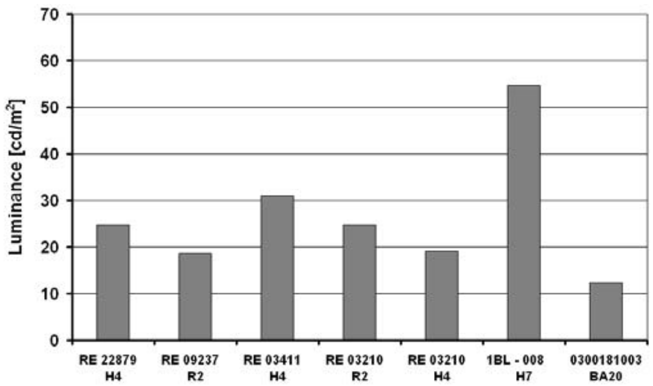

Fig. 21. Luminance values at the point 50L for the examined reflectors and projector

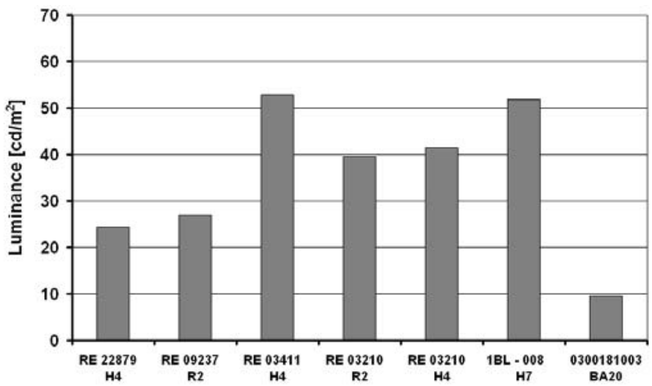

Fig. 22. Luminance values at the point 50R for the examined reflectors and projector

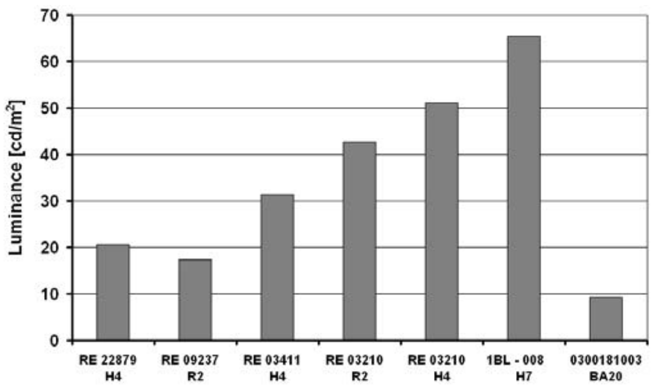

Fig. 23. Luminance values at the point 50V for the examined reflectors and projector

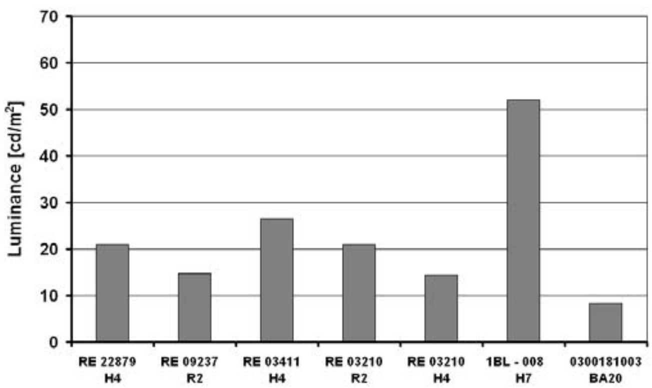

Fig. 24. Luminance values at the point 75L for the examined reflectors and projector

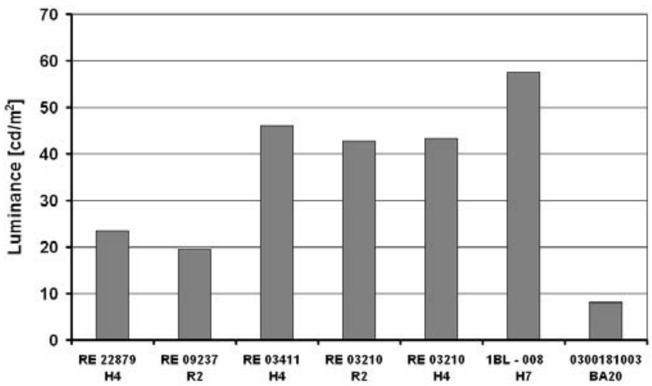

Fig. 25. Luminance values at the point 75R for the examined reflectors and projector

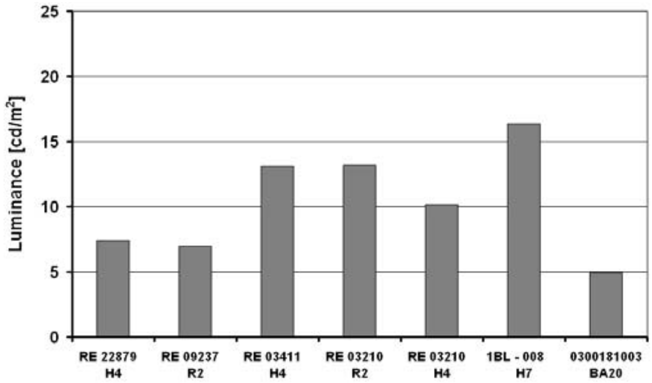

Fig. 26. Luminance values at the point HV for the examined reflectors and projector

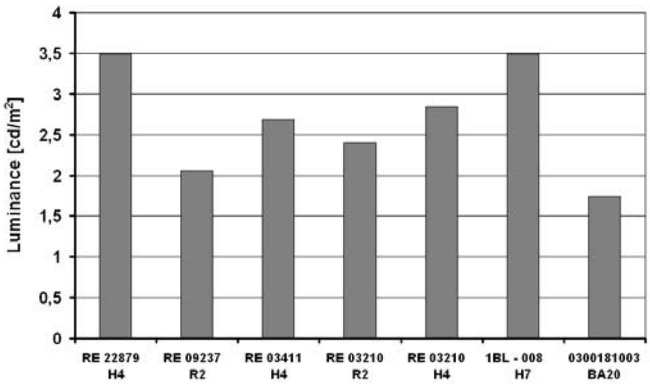

Fig. 27. Luminance values at the point B50L for the examined reflectors and projector

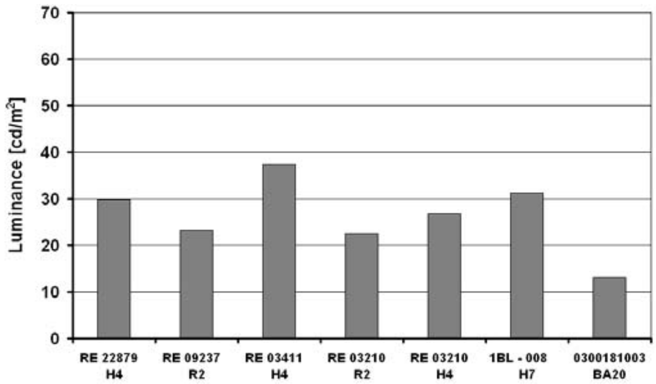

Fig. 28. Luminance values within Area 1 for the examined reflectors and projector

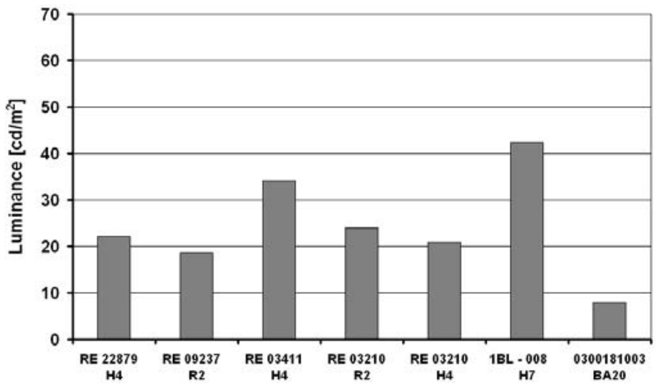

Fig. 29. Luminance values within Area 2 for the examined reflectors and projector

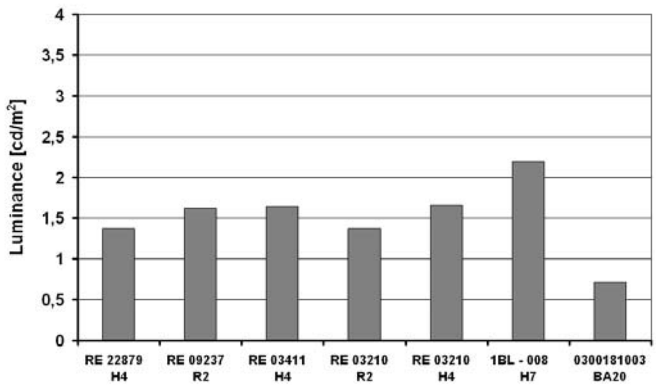

Fig. 30. Luminance values within Area 3 for the examined reflectors and projector

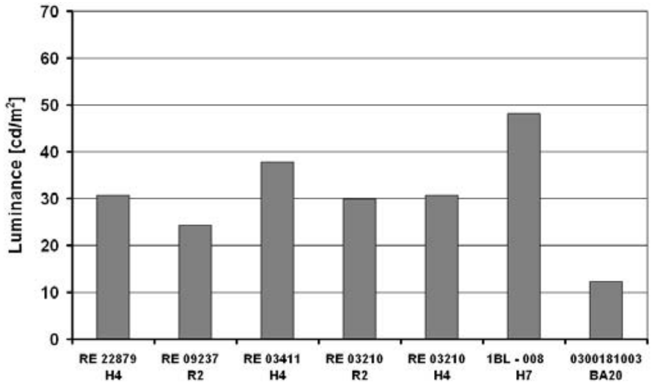

Fig. 31. Luminance values within Area 4 for the examined reflectors and projector

From the point of view of the quality of obtained light spot in the vehicle's foreground. An essential parameter of a light beam is the shape of borderline of light and shade observed from above and below the horizontal axis of photometric screen (H-H). Figure 32 presents the shapes of borderlines of particular projectors and reflectors by means of cross sections of light beams within axis V-V.

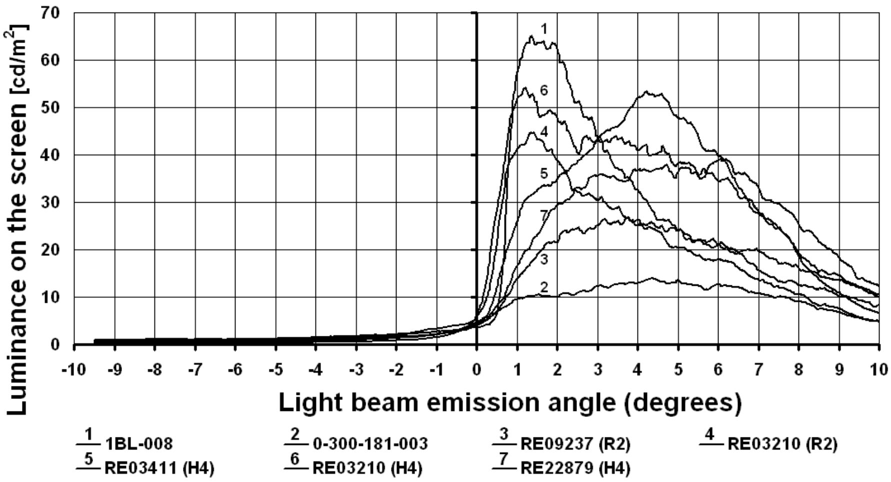

Fig. 32. Section within vertical axis V-V of light beam – borderline of light and shade

4. Conclusions

Analysing obtained measurement results it was established that a modern projector of low beam lights of 1BL-008 type has the most advantageous parameters of a light beam. What was used as a source of light was a halogen light bulb

H7, which ensures a high luminous flux. The projector 1BL-008 of low beam lights makes use of a projector system of creating a light spot. Such a construction exceeds by several percent lighting efficiency of classic paraboloidal reflectors (Fig. 21,22 and 23). Luminance results obtained reflect a more advantageous light beam of these constructions.

Paraboloidal reflectors of low beam lights with a classic source of light – R2 type light bulb, obtain the lowest values of luminance in points where its high level is required, that is, 75R (Fig. 25), 50V (Fig. 23). It is definitely more advantageous to use lighting equipment with halogen light source of H4 type. Comparable results were obtained in measurement areas 1 (Fig. 28), 2 (Fig. 29), and 4 (Fig. 31). These areas are responsible for good observation results directly in front of a vehicle. In area 3 (Fig. 30) – above the borderline of light and shade luminance value is rather small. The ratio of average area luminance 2 and 3 indicated a high level of contrast – close to the value of 16.

Lighting equipment of disadvantageous lighting parameters is reflector of 0-300-181-003 type with BA20D light bulb. This reflector in all measurement points and areas presents significantly understated luminance values.

The analysis of borderline of light and shade confirms the results obtained in measurement points and areas. Projector 1BL-008 (Fig. 32) has borderline of the highest luminance contrast. Whereas, in the case of the light beam of 0-300-181-003 reflector it is difficult to talk about the existence of clear borderline. In reflectors RE 03411 H4 (Fig. 14), RE 22879 H4 (Fig. 11), RE 09237 R2 (Fig. 8), luminance maximum is significantly deflected (for about -5^o) form the horizontal axis H-H of measurement screen. These reflectors are characterized by blurred borderline of light and shade, which is advantageous from the point of view of jump luminance changes created on the surface of eyes as a result of sudden changes of direction of light beam emission within vertical plane.

Conclusions from the conducted measurements confirm the need of performing further analysis of foreground lighting of a tram vehicle as well as searching optimal optical-luminous and construction solutions improving observation conditions from the tram driver's cabin.

As a result of researches conducted, it should be stated that it is possible to conduct an analysis of light beam distribution with the use of CCD camera for luminance measurement. The results presented in the article do not cover the whole spectrum of measurement possibilities. Thanks to the use of image converter it is possible to conduct more detailed analyses as well as to assess a tested lighting device with regard to measurement results obtained from the use of a classic method [4]. Moreover, a luminance method can be extended by conducting measurements in real working conditions of lighting equipment, for example, from the observer's or tram driver's seat.

Researches on the quality of tram lighting conducted by the author of the present publication indicate the need of implementing uniform and detailed photometric requirements for this group of vehicles.

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