

PROPOSAL OF LIGHTING REQUIREMENTS FOR LIGHTING DEVICES IN ADAPTIVE FRONT LIGHTING SYSTEM OF TRAM'S HEAD LIGHTS

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Abstract

The factor influencing the safety of a moving track vehicle is the quality and state of tram's head lighting. Appropriate light distribution within the area of tram's foreground plays a decisive role in the perception of luminous sensations by the tram driver. A properly shaped light beam conditions appropriate visibility from the tram driver's seat and facilitates correct assessment of traffic situations connected with the behavior of other road traffic participants. The article proposes and discusses application of AFS system in trams particularly accounting for proposals of new lighting requirements for tram's head lighting devices.

The author of the present paper justifies the need for implementing new solutions for lighting of tram's foreground in order to improve the quality of lighting taking into account various road traffic situations. For this purpose, new normative guidelines have been proposed allowing for assessment of lighting devices installed on trams, which directly influence the quality of tram's foreground lighting. Proposal for AFS system components for tram, measurement screen for examining projectors of symmetrical low beam lights, for examining projectors of symmetrical main lights, for examining the right projector of curve light and for examining the left projector of curve light are presented in the paper.

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

1. Introduction

The development of tram's lighting in Poland was parallel with construction solutions for lighting devices used in motor car vehicles. The first lighting devices of a track vehicle were installed at the front of a car in the form of acetylene lamp with a small gas generator filled with carbide

When electrification of track vehicles developed and became common, electric lighting was introduced, with a classic monofilament light bulb, which from the point of view of construction was a light bulb used for illuminating apartments.

In 1970s and 1980s, construction development of vehicle front lighting devices took place. Construction solutions became common, in which double filament bulbs dedicated to motor car vehicles were used. This solution provided the possibility of using two types of light beams: long-distance main beam light and low beam light of symmetrical distribution of a light beam [3].

Throughout the following years, constructions of lighting devices were created (reflectors mainly) which eliminated the danger of glare effect on drivers of vehicles coming from the opposite direction, with asymmetrical low beam light [1, 2].

Such a solution for a light beam distribution and direction in which the right half of the tram's foreground is illuminated at a longer stretch than the left one is currently used. It should be clearly emphasized that construction solutions still applied in tram cars, are the same solutions borrowed directly from motor car vehicles.

Another solution for lighting devices construction of tram's head lighting was the introduction of halogen light bulb, which in comparison with a conventional light bulb is a source of higher luminous efficiency, bigger luminous flux, and first of all – of significantly higher durability [3]. This solution affects the quality of tram's foreground lighting – vehicle's foreground is illuminated more intensively.

2. Proposal for the system of automatic correction of light beam emission direction of tram's head lights

Within the field of automotive technology solutions are being implemented and more and more widely used, which make it possible to change automatically the position and kind of a light bundle, as well as its direction [3]. There are no contraindications, therefore, to implement these systems in track vehicles. A sample proposal and configuration of a system together with possible data sources to be used which are indispensable for lighting control in a tram has been presented in Fig. 1.

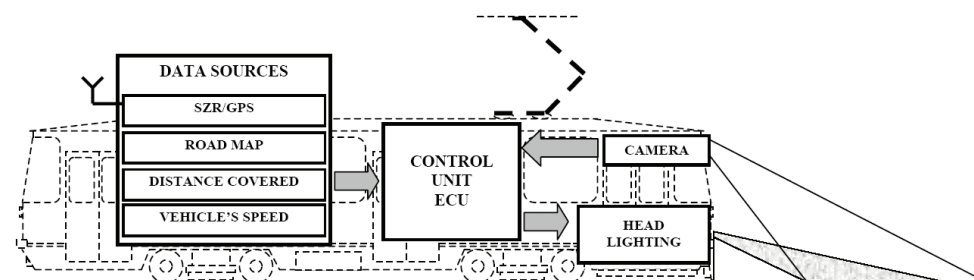


Fig. 1. Proposal for AFS system components for tram

The proposed method of controlling light beam emission direction is based on a visual signal from a camera placed in a tram. For this purpose, the use of a passive infrared camera operating at luminous flux density of 0 lx has been proposed. A signal from a camera is transmitted to the control unit, whose task it is to analyze the image from the point of view of detection of characteristic features of tram's foreground. Control algorithm applied is supposed to facilitate predictive determination of light beam direction. In the proposed system it is also possible to control light beam emission direction by using information from speed detectors and information about current location on the route with the use of digital road map of the route or a GPS signal.

In order to improve the current condition of lighting quality of tram's foreground, three variants of light beam control system of tram's head lights possible to be implemented are being proposed [4-6].

The third configuration of the system consists in exchanging currently used reflectors and projectors for new ones with dedicated light beams (of main, low beam and curve lights) [4, 5]. Lighting system is based on the model of head light reflector moved horizontally and vertically by the engine. In this module, the light beam directed at the road is shaped by electromagnetically moved diaphragm, placed between the source of light and the lens.

3. Proposal of luminous requirements for tram vehicles

Being modeled after photometric requirements for motor car vehicles, the present author proposes creating approximate requirements for tram vehicles.

After conducting a lighting analysis of currently exploited light beams it has been established that justification exists for using symmetrical light beams in the case of head, main and low beam lights.

Introduction of three kinds of lights of dedicated light beams for low beam, main and curve lights is proposed.

The presented requirements refer to the distribution of light beam obtained from a single reflector with the use of model halogen type light bulb. The projectors can at the same time be the source of light for low beam and main lights or just for one of them. The luminous requirements for the projectors are stipulated in the form of restrictions of the upper and lower level of luminous flux density, assessed on a special measurement screen imitating the space in front of a tram car. The measurement screen is placed at the distance of 25 m from the examined projector.

General requirements concerning chromaticity of lights are identical to those described in [3]. Quantitative luminous flux density levels are assessed on the measurement screen at zones and points accounting for geometry of the track. Fig. 2 presents a sketch of this screen for low beam light.

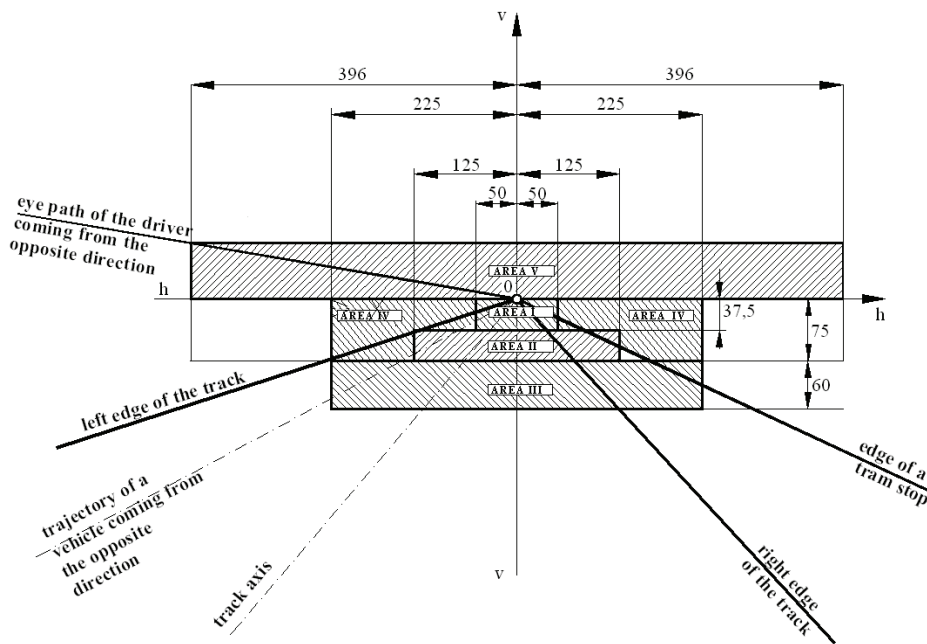


Fig. 2. Measurement screen for examining projectors of symmetrical low beam lights

Tab. 1. Luminous flux density requirements for low beam lights

| Zones | Luminous flux density E [lx] |
|----------|--------------------------------|
| Area I | $E \geq 12$ |
| Area II | $12 \geq E \geq 6$ |
| Area III | $6 \geq E \geq 3$ |
| Area IV | $3 \geq E \geq 0,5$ |
| Area V | $E \leq 0.5$ |

In the case of low beam light, the borderline between high and low level of luminous flux density (called the borderline of light and darkness) should create a distinct dividing line which is symmetrical and running within the h-h axis on the measurement screen .

The levels of luminous flux density predicted for this type of projectors of low beam lights should fulfill requirements included in Tab. 1. It should be stated that these are basic requirements, which fail to provide full analysis of light beam distribution of a projector. For measurement areas, an average value of luminous flux density from minimum 10 measurements should be adopted.

In the case of main beam lights, it has been established that there is a need for increasing the range and narrowing the beam in relation to the ones currently used in trams. It is recommended that the beam should be symmetrical around the v-v axis. Isoluxes of the maximum values should include the point of maximum luminous flux density ($h=0, v=0$) and should be within area I.

Chromaticity range of main lights is analogous to that of low beam lights. At zero point (intersection of h-h and v-v axes) Fig. 3, the value of luminous flux density should be maximum and should be included within the range of $240 \geq E \geq 48$ [lx]. In contrast with currently exploited beams of main lights, it is recommended to introduce areas restricting the disadvantageous emissions into zones not connected with direct trajectory of tram's motion (area IV). Upper level restriction is also introduced (area V) in order to restrict glare effect of tram drivers of trams coming from the opposite direction.

Luminous flux density levels predicted for projectors or reflectors of main lights should fulfill requirements included in tab. 2. These requirements fail to provide full analysis of light beam distribution of a lighting device.

In the case of measurement areas, an average value of luminous flux density from minimum 10 measurements should be adopted.

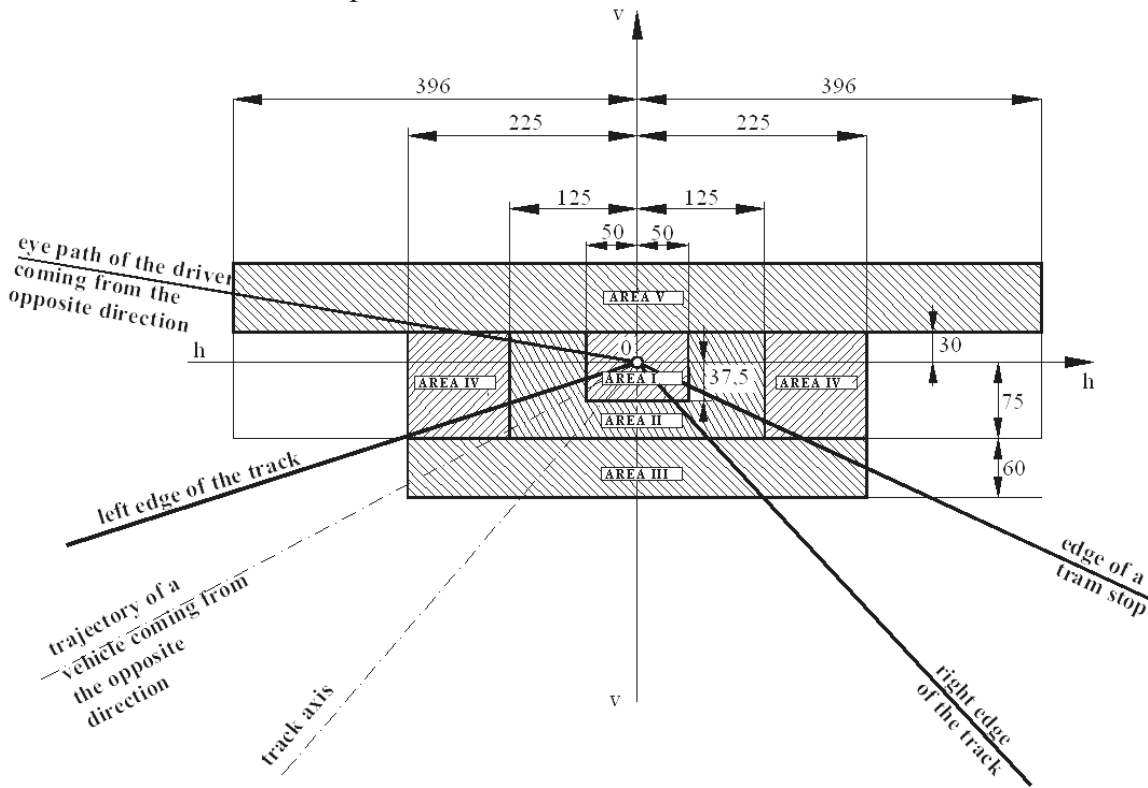


Fig. 3. Measurement screen for examining projectors of symmetrical main lights

Tab. 2. Luminous flux density requirements for main lights

| Zones and points on measurement screen | Luminous flux density E [lx] |
|--|--------------------------------|
| $h=0, v=0$ | $240 \geq E \geq 48$ |
| Area I | $E \geq 24$ |
| Area II | $E \geq 12$ |
| Area III | $E \geq 3$ |
| Area IV | $E \leq 1$ |
| Area V | $E \leq 1$ |

Introduction is proposed of a light beam of additional lights called curve lights. The aim of these projectors is additional lighting of crossroads areas, pedestrian crossings, tram stop areas and other particularly dangerous places. The requirements concerning luminous flux density of curve lights at three measurement areas have been presented in Fig. 4 and 5. Characteristic for these reflectors is symmetrical isolux distribution around the v-v axis on the measurement screen.

Luminous flux density requirements for projectors of curve lights are presented in Tab. 3.

Because of the specific lighting function, two measurement screens have been defined for the left and right projector of curve lights. These lights can operate only with low beam lights. Simultaneous operation of curve light beams is also possible in the case of additional lighting of crossroads and pedestrian crossings. In the conditions of driving on a bend, apart from low beam lights one curve light beam is also activated, which is responsible for additional lighting of appropriate area of tram's foreground resulting from driving direction.

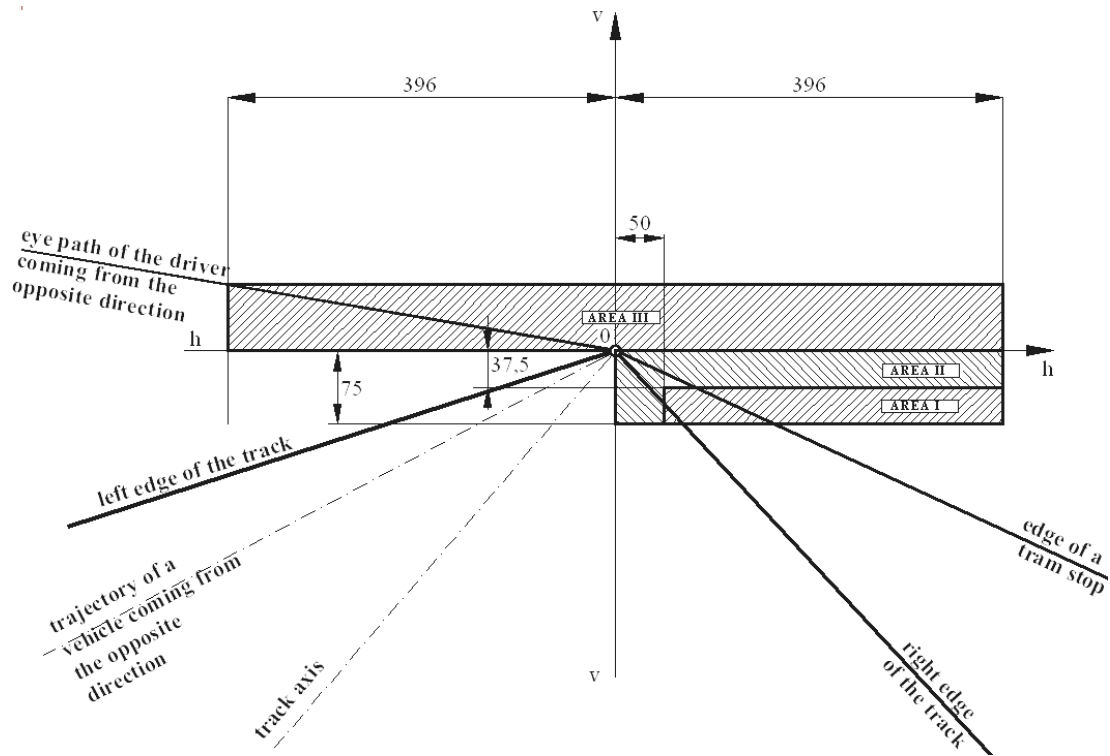


Fig. 4. Measurement screen for examining the right projector of curve light

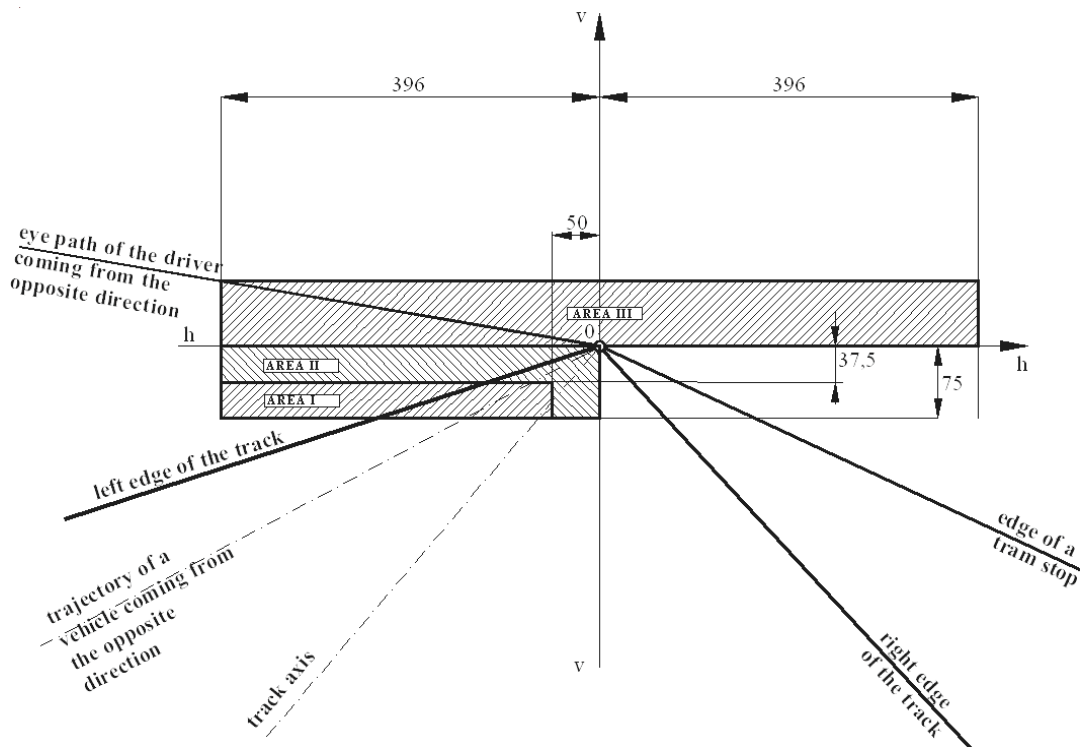


Fig. 5. Measurement screen for examining the left projector of curve light

Tab. 3. Luminous flux density requirements for curve lights

| Zones | Luminous flux density E [lx] |
|----------|--------------------------------|
| Area I | $E \geq 6$ |
| Area II | $E \geq 1,5$ |
| Area III | $E \leq 0,5$ |

Outside built-up area there is a possibility of cooperation between curve and main lights. For this type of lights, the zone of maximum luminous flux density is within area I. Introduction of restriction of luminous flux density within area III is proposed in order to avoid glare effect.

4. Summary

Laboratory and simulation researches conducted on head lighting devices of trams have unambiguously indicated huge and disadvantageous differentiation of lighting parameters of these devices. [5]. Lighting parameters of the examined lighting devices affect the quality of vehicle's foreground lighting at the same time influencing the safety of road traffic participants

Reflectors and projectors used in tram vehicles can be considered as a special type of tram's head lighting devices. From the functional point of view, they should ensure good observation conditions from the tram driver's seat with the same good visibility of the tram by other road traffic participants, including pedestrians. These devices play an important role in relation to other participants of road traffic, informing them of the presence or approaching tram.

Luminance measurements on the tramline preceded by laboratory tests and simulation of luminous parameters of tram reflectors and projectors have indicated failure in adapting light beam distribution of the examined lighting devices to the function they are supposed to have [5]. In the case of all examined tram's head lighting devices, light beam distribution was too wide and the luminous flux was shaped in such a way that caused very disadvantageous glare effect on other road traffic participants.

The current condition of tram's foreground lighting disadvantageous in the present author's opinion, which is proved by measurements on the tramline as well as laboratory researches, constitutes the basis for proposing new hardware solutions, which will contribute to the improvement of quality of this lighting.

Uniform luminous requirements proposed here will allow for assessment of particular construction solutions for these devices. Giving requirements concerning the values of luminous parameters at measurement zones and areas will eliminate from exploitation such construction solutions for lighting devices that are disadvantageous from the point of view of the function they are supposed to have.

These requirements constitute the basis for further assessment of tram's foreground lighting.

Introduction of uniform construction solution of automatic control system of light beam emission direction in trams will improve the quality of vehicle's foreground lighting and will influence the traffic safety of all its participants.

References

- [1] Bullough, J. D., *Physiology of glare*. TRB Washington 2003.
- [2] Gibbons, R. B., *Glare modeling formule*, Virginia Tech Transportation Institute USA 2003.
- [3] Mazur, J. W., Żagan, W., *Samochodowa Technika Świetlna*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 1997.
- [4] Stypułkowski, K., *Adaptive Control System of Light Beam Position of Tram's Head Lights*, Journal of KONES Powertrain and Transport, Vol. 16, No. 2, pp. 433-439, Warsaw 2009.
- [5] Tomczuk, P., Stypułkowski, K., *Selected issues of tram's front lighting exploitation*. PAN Monografie Zespołu Systemów Eksploatacji Komitetu Budowy Maszyn, Problems Of Maintenance Of Sustainable Technological Systems, Polskie Naukowo-Techniczne Towarzystwo Eksploatacyjne, T. I, s. 152-169, Warszawa 2010.
- [6] Tomczuk, P., Stypułkowski, K., *Light beam control system of tram's head lights*, Journal of KONES Powertrain and Transport, Vol. 15, No. 2, pp. 475-482, Warsaw 2008.