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COMMISSION INTERNATIONALE DE L'ECLAIRAGE
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INTERNATIONALE BELEUCHTUNGSKOMMISSION

TECHNICAL REPORT

PERFORMANCE ASSESSMENT METHOD FOR VEHICLE HEADLIGHTING SYSTEMS

CIE 188:2010

UDC: 628.971.85
628.971.85:629.113.06

Descriptor: Lighting by lamps attached to the vehicle
Lighting by motor vehicle lamps

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This Technical Report has been prepared by CIE Technical Committee 4-45 of Division 4 "Lighting and Signalling for Transport" and has been approved by the Board of Administration of the Commission Internationale de l'Eclairage for study and application. The document reports on current knowledge and experience within the specific field of light and lighting described, and is intended to be used by the CIE membership and other interested parties. It should be noted, however, that the status of this document is advisory and not mandatory. The latest CIE proceedings or CIE NEWS should be consulted regarding possible subsequent amendments.

Ce rapport technique a été élaboré par le Comité Technique CIE 4-45 de la Division 4 "Eclairage et signalisation pour les transports" et a été approuvé par le Bureau de la Commission Internationale de l'Eclairage, pour étude et emploi. Le document expose les connaissances et l'expérience actuelles dans le domaine particulier de la lumière et de l'éclairage décrit ici. Il est destiné à être utilisé par les membres de la CIE et par tous les intéressés. Il faut cependant noter que ce document est indicatif et non obligatoire. Il faut consulter les plus récents comptes rendus de la CIE, ou le CIE NEWS, en ce qui concerne des amendements nouveaux éventuels.

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PERFORMANCE ASSESSMENT METHOD FOR VEHICLE HEADLIGHTING SYSTEMS

SUMMARY

This report has been produced to meet the need for a standardised, accurate and reliable method of assessing the photometric performance of vehicle headlights. It considers the requirements of headlight performance in terms of road scene illumination and limitation of glare, and the assessment of performance in terms of lane guidance and the detection of pedestrians and objects. The work undertaken to define the assessment method is summarised along with the results of the validation testing. A standardised photometric assessment method and calculation procedure for use by manufacturers and assessment organisations is provided.

METHODE POUR EVALUER L'EFFICACITE DES SYSTEMES D'ECLAIRAGE DES VEHICULES ROUTIERS

RESUME

Ce rapport a été rédigé dans le but de fournir une méthode standard, précise et fiable pour évaluer l'efficacité photométrique de l'éclairage des véhicules. Il tient compte de la nécessité d'illuminer l'environnement routier en limitant l'éblouissement et évalue la capacité à éclairer la voie et à aider à la détection de piétons et d'obstacles. Cette étude définit une méthode d'évaluation et comprend également les résultats des tests de validation. Elle fournit une méthode standard d'évaluation photométrique et une procédure de calcul à l'usage des fabricants et des organismes de contrôle.

LEISTUNGSBEWERTUNGSSYSTEM FÜR KRAFTFAHRZEUG-SCHINWERFER

ZUSAMMENFASSUNG

Dieser Bericht ist erstellt worden, um dem Bedarf für standardisierte, exakte und zuverlässige Methoden zur Bewertung der photometrischen Leistungsdaten von Kraftfahrzeug-Scheinwerfern gerecht zu werden. Dabei werden die Anforderungen an Scheinwerfer in Bezug auf die Ausleuchtung der Straße und die Begrenzung von Blendung sowie die Erkennbarkeit der Fahrspur, von Fußgängern und Objekten berücksichtigt. Die Relevanz der aufgestellten Bewertungskriterien ist durch diverse Tests validiert worden, so dass nun eine standardisierte photometrische Bewertungsmethode und eine Berechnungsvorschrift für die Nutzung durch Fahrzeug- und Fahrzeugteile-Hersteller sowie Test-Organisationen zur Verfügung steht.

1 INTRODUCTION

The joint CIE Technical Committee (TC 4-45) and GTB (Brussels Working Party on Vehicle Lighting) Front Lighting Working Group activity was established in August 2005 as a continuation of the GTB NCAP (New Car Assessment Programme) Taskforce that had been working for two years with the objective of developing a headlight performance rating system to be proposed to the European New Car Assessment Programme (Euro NCAP). When Euro NCAP decided not to continue to introduce a headlight rating system, the work undertaken by GTB was transferred into the CIE structure with a view to completing the study, publishing the conclusions and establishing a technical standard.

During the GTB NCAP taskforce activity a total of 48 organisations from the GTB global national delegations had contributed and 18 meetings had been held between August 2003 and April 2005. A week-long testing event had taken place in Spain in May 2005 with the successful validation of a number of the performance parameters but further work was indicated with regard to the algorithms for the assessment of range and glare.

The CIE TC 4-45 Technical Committee working in conjunction with GTB continued to work on the refinement of the assessment of range and glare. A second validation test event took place in Germany in March 2006 and this contributed to a revised algorithm for the calculation of passing beam and driving beam range. A test event to concentrate on the validation of the glare assessment algorithms took place in Belgium in February 2007 and a further event to validate the range calculations took place in Italy in May 2007.

This report is the result of a requirement from car manufacturers and headlighting manufacturers to develop a common approach toward the performance assessment of vehicle lighting systems. Although this has been a long-standing requirement, the intentions to introduce procedures to publish the results of headlighting system assessments (rating systems) by government agencies in Europe, Japan and North America provided an incentive for all the leading global manufacturers to work together to develop an industry standard.

During the work to develop this report contributions have been received from 52 manufacturers, institutions and testing services providing a unique global representation. In total 33 meetings have taken place with the discussions and conclusions being recorded in reports and minutes of meetings archived for reference of all TC members but no attempt has been made to include the detail in this report. Although some references to published papers are included, in general the report is the combination of the knowledge and technical expertise of specialists in the field of automotive lighting. The proposed standardised assessment method has been validated by experiments and practical "on-road" assessments to ensure that the results of any calculations are representative of what a vehicle user will actually experience.

A database with sets of test data for calibration of software tools can be downloaded from the CIE website at <http://www.cie.co.at/index.php/DOWNLOADS/TC4-45+database>.

2 PREFACE

2.1 Background

There have been numerous attempts to develop methods of headlight performance assessment. Most headlighting system manufacturers and car manufacturers have developed in-house procedures to provide a means of validating and benchmarking new products as early as possible in the design phase.

There has also been a steady increase in the number of consumer organisations and car magazines that publish results of their performance evaluations. Furthermore, a number of government organisations have studied the feasibility of introducing NCAP designed to promote improvements in road safety and performance. As a result of these various activities, there is duplication of effort for manufacturers working to develop new headlighting systems as each car manufacturer has its own assessment criteria. In the case of organisations producing reports intended to offer guidance to consumers, confusion is generated because there is no agreed standard method of assessment.

This report describes the work carried out by GTB and CIE since August 2003 to develop and validate a standard method of headlight performance assessment. Initially, the study was undertaken by the GTB NCAP Taskforce and then it was transferred to CIE TC 4-45 to finalise the study, publish the findings as a CIE Technical Report and to subsequently develop a CIE Standard.

It should be noted that the validation of the calculation methods has been carried out using headlights designed according to the requirements of the United Nations Economic Commission for Europe (ECE) Regulations. This was done because the original motivation for the work came from Europe where the ECE beam patterns are a regulatory requirement. Although the validation work is based upon the ECE beam pattern, the assessment method is equally applicable to all geographic regions and allows comparisons of all beam pattern types to be carried out.

2.2 GTB Cooperation with Euro NCAP

Following the decision of the Euro NCAP organisation to extend its New Car Assessment Program to include active safety, the European Automobile Manufacturers Association (ACEA) and the GTB offered to work with Euro NCAP to develop a method of rating headlight performance based upon the following objectives:

- o To support the intention of Euro NCAP to introduce a rating system for vehicle lighting with the objective of encouraging improved safety through vehicle design and manufacture.
- o To provide an objective method of assessing vehicle lighting (initially front lighting)
- o To develop a system that will provide useful data for both Euro NCAP and the manufacturers by clearly identifying the areas where improvement is required.

The GTB Taskforce was established and started working in August 2003. Twenty meetings were held between August 2003 and June 2005. A four-day validation testing event took place in Spain in May 2005. Additionally, the taskforce chairman participated in the meetings of the Euro NCAP Visibility & Lighting Subcommittee and held parallel taskforce meetings in the USA with the Society of Automotive Engineers (SAE) Lighting Committee. Overall, between August 2003 and June 2005, more than 5000 man-hours had been dedicated to the activity to produce a draft procedure for consideration by Euro NCAP. There was an urgency to deliver the proposal to the Euro NCAP directorate due to its intention to reach a decision concerning the introduction of a headlight rating system in 2005.

2.3 The Rationale for the GTB Approach

Effective headlight design is a compromise between the need to provide good illumination of the road-scene whilst minimising the effects of glare toward the other road users. Although developments such as HID have resulted in improvements in the road illumination it is clear that there is a need to further improve the passing beam with particular regard to increasing its forward range, but this cannot be achieved unless increases in glare levels are accepted.

Emphasis upon maintaining strict control on glare has been a consistent feature of lighting regulations and this is particularly the case with the ECE Regulations. However, despite these strict controls, many complaints concerning discomfort glare are received by governments with the result that the perceived significance of glare outweighs the benefits of improved visibility. This has the effect of restricting further significant development of headlight beam patterns. Objective data relating headlight performance to accidents are extremely difficult to determine and whilst the pragmatic view has favoured strict glare control, many lighting experts argue a case for accepting increased glare to facilitate improvements in forward illumination. The major road safety issue concerns accidents with pedestrians and it is acknowledged that higher illumination levels projected further down the road are required to make significant improvements. These higher illumination levels, however, must be balanced with the requirement to avoid unacceptable glare levels to the oncoming driver. In general, regulators receive many more complaints from the public concerning glare than about insufficient forward illumination but there are no clear guidelines to define where the emphasis should be placed. In view of this it was agreed that the GTB method should provide a means of assessing glare and illumination separately. This would then allow individual organisations to evaluate the data and apply their particular emphasis when compiling their assessment reports.

An objective method based upon laboratory controlled measurements is necessary to provide data that could subsequently be analysed using specially developed algorithms. Many methods currently used to evaluate headlight performance are based upon subjective testing which is prone to errors due to differences in the test set-up and environmental conditions. Additionally, such tests are very time consuming and the results are not always repeatable. Other methods using camera techniques were discounted due to the difficulties of controlling the test conditions.

From a manufacturer's point of view it is important to be able to evaluate the performance of the headlight early in the development stage so that the design can be frozen before tool making commences. If computer simulation software is used to generate the illuminance data, that can then be used with the performance assessment software. The results of this assessment can then enable effective benchmarking and evaluations of compliance with customer requirements to be carried out in time to provide an opportunity for fine tuning of the design before the manufacture of definitive tooling and the start of production.

2.4 The Proposed NCAP Assessment Procedure

The GTB approach proposed to Euro NCAP was based upon the assessment of the headlighting system being undertaken by laboratories having a capability for photometric measurement and meeting the standards defined by the GTB Photometry Working Group. This was to ensure accuracy and consistency of results between laboratories.

The steps in the assessment procedure were determined as follows:

- a. A vehicle is selected by Euro NCAP and delivered to the chosen laboratory for testing
- b. Data relating to the lighting installation is recorded (mounting height, separation, beam aim, supply voltage)
- c. Headlights are removed from the vehicle and the photometric laboratory produces a matrix of data using a defined angular field and test point resolution. The test voltage to be used is determined by measurement on the vehicle under specified conditions and the headlight adjustment (passing beam aim) is set to the nominal value specified by the car manufacturer for the specific vehicle being assessed. Two sets of data are recorded; initially using the light source as supplied with the headlight and then using a calibrated standard light source.
- d. The laboratory uses software based upon the defined algorithms to transform the photometric data grid into specific performance criteria. This calculation takes account of the actual installation conditions concerning mounting height and separation.
- e. Calculate the performance rating following a standard procedure as shown in Figure 1.

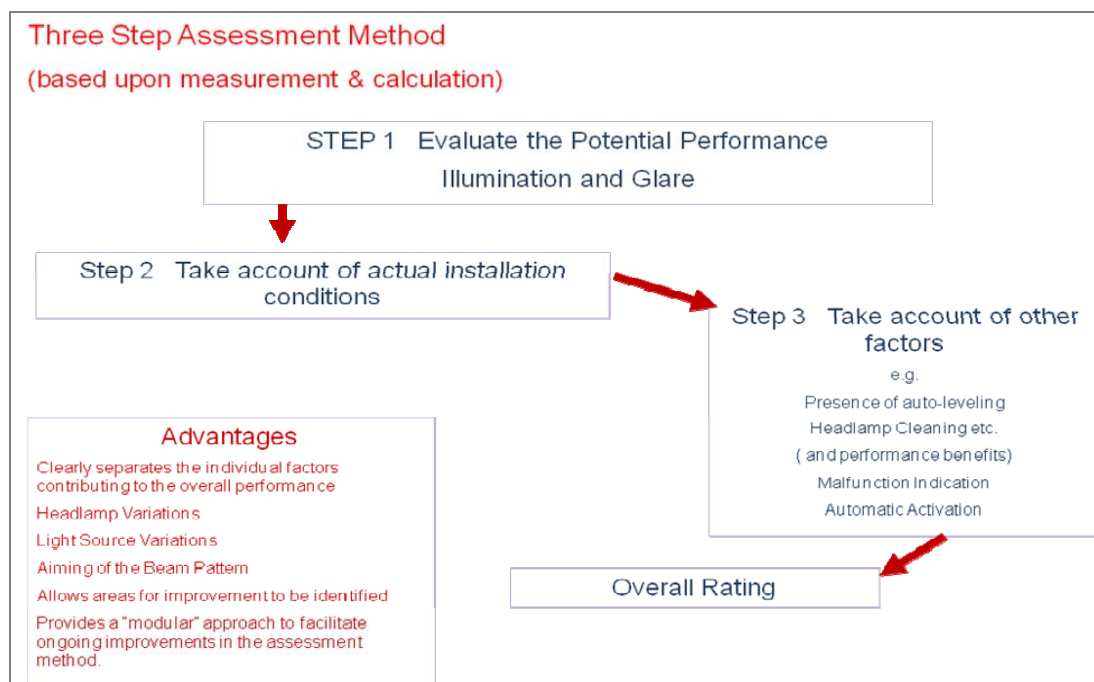


Figure 1. Proposed rating method – three step process.

Step 1 determines the potential performance of the system by removing the effects of the variability of the light source. To achieve this, the photometry of the headlight is carried out with a standard calibrated light source. The photometric data is then used in specially developed software that calculates a series of aspects of the illuminance of the road scene and takes account of the installation of the headlight into the vehicle in terms of the mounting height, separation, aiming angle and vehicle operating voltage. The details of the criteria chosen for the performance assessment are given in Clause 5 and 6 of this report.

Step 2 provides useful information about the effects of variability of the light sources, the headlight's optical system and the actual aiming of the headlight on the vehicle. During the initial collection of data concerning the installation on the vehicle the actual aim of the headlights is recorded and the effects of any discrepancy between the specified and actual aim can be determined using the evaluation software. Similarly, the effects of the light source tolerances can also be evaluated by repeating the photometry using the actual light source supplied with the headlight.

Step 3 was not defined because Euro NCAP decided not to continue to develop a headlight rating system but the intention of Euro NCAP was to take into account other influencing factors such as the presence of auto-levelling, headlight cleaning and their performance benefits, malfunction indication, automatic activation, etc.

Following the development of the proposed procedure by GTB, the Euro NCAP directorate decided to suspend its plans to introduce a headlight rating system until more accident data becomes available to enable a decision to be formulated concerning the relative importance of improved visibility and reduced glare. As mentioned earlier, the development of a good headlighting system requires a careful balance between the need to provide the best illumination of the road scene ahead and the need to ensure that other road users are not disadvantaged by high glare levels. The individual aspects of headlight performance in terms of illumination of the road scene ahead and in terms of glare toward the opposing driver can be determined, but the problem of how to balance the relative importance of these factors remains to be resolved if the final objective is to quote one overall rating for a headlighting system.

2.5 Joint CIE TC 4-45 / GTB Activity

Following the decision of Euro NCAP to suspend the introduction of a headlight rating system, the GTB taskforce decided that in view of the excellent progress made to develop a

standardised approach to performance assessment it was essential to complete the work and publish the results and ideally to establish an industry standard. Due to the close working relationship between the GTB and CIE it was decided to transform the taskforce into a CIE Technical Committee. The CIE TC 4-45 (Performance Assessment Method for Vehicle Headlights) was transformed into a joint activity with the GTB Forward Lighting Working Group.

The terms of reference agreed with Division 4 were as follows:

- o To produce a technical report with the objective of subsequently developing a standard that defines an objective procedure for the evaluation of forward-lighting system performance in terms of active safety. The work carried out by the former GTB Euro NCAP taskforce constitutes the basis for this development.

The expected outcomes were:

- o a global approach to headlight performance assessment to provide a basis for:
 - o NCAP applications,
 - o appraisals by the motoring press and consumer organisations,
 - o evaluation and promotion of new headlight technologies;
- o a tool providing value for industry that is:
 - o easy to understand,
 - o easy to apply by many / varied users,
 - o applicable at the concept stage for new headlight designs.

Following the transformation of the GTB taskforce into the CIE TC 4-45, a further 12 meetings were held between December 2005 and February 2008 and multi-day validation testing events took place in Germany, Belgium and Italy.

3 DEFINITIONS

The terms used in this report are as defined in the International Lighting Vocabulary (CIE DS 017.2/E:2009, ILV: International Lighting Vocabulary, 2009), together with the following additional definitions:

headlighting system

a full set of headlights as fixed to a vehicle

nearside

for traffic on the right side of the road, the right side of the vehicle

offside

for traffic on the right side of the road, the left side of the vehicle

NOTE The text of this report uses the term 'headlight', whereas some of the figures use the term 'headlamp'. As indicated by the ILV, the meaning is identical.

With regard to the performance of the passing beam it is necessary to define whether the traffic flow is for right-hand or left-hand rule of the road. For the purposes of this report it is assumed that the traffic is moving on the right-hand side of the road (as in continental Europe and USA for example) and all reference to features of the beam pattern and photometric performance is related to this. In the case of traffic moving on the left side of the road (as in Japan and the UK for example) a reference to a feature on the right should be transformed to refer to an identical feature translated to the left side.

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4 HEADLIGHT PERFORMANCE CONSIDERATIONS

4.1 Performance Evaluation Method

An ideal beam pattern (light distribution) is difficult to define. There is a basic level of safety that is defined in the various lighting regulations and this is a careful balance between the needs to adequately illuminate the road scene ahead and to avoid causing undue discomfort to the opposing traffic.

Figures 2 and 3 show the passing and driving beam distributions produced by the 16 typical headlighting systems used throughout this report. These have been calculated taking account of the installation height, separation and aim of each of the headlight beam distributions constituting the headlighting system and show the vertical illuminance¹ distribution plotted on the road surface.

The detailed lamp and installation data are given in Table 1, and Appendix A provides a summary of the photometric data. All of these fully comply with the photometric requirements of the regulations and were used throughout all of the evaluations and testing described in this report. Whilst all exceed the minimum safety levels as defined in the photometric requirements of ECE Regulations it can clearly be seen that a wide range of performances are provided by modern vehicle headlighting systems.

The task of developing an assessment method is one of providing a means of comparing performance levels using techniques that produce repeatable results corresponding also with the subjective impressions of the driver.

Table 1. Lamp and installation data for the 16 headlighting systems used in this report.

Sample No.	Light Sources - Halogen		Light Sources - HID		Vehicle Data						
	Optical System				Initial Aim / %	Voltage / V		Mounting Height / mm		Separation / mm	
	Reflector	Projector	Reflector	Projector		Passing	Driving	Passing	Driving	Passing	Driving
1	X				1	12,9	12,9	670		1 129	
2	X				1	13,2	13,2	630	626	1 340	1 090
3				X	1	13,2	13,2	665	645	1 240	1 060
4	X				1,2	13,2	13,2	679	679	1 010	1 010
5				X	1	13,2	13,2	715	695	1 265	1 035
6				X	1	13	12,9	745	650	1 440	1 390
7				X	1,30	13,7	13,7	661	649	1 301	966
8	X				1,20	12,94	12,94	900,5	824,7	1 297	1 066
9	X				1	13,2	13,2	889	889	1 156	1 156
10				X	1	13,2	13,2	670	670	1 310	1 046
11				X	1	13,1	13,1	717	639,3	1 285	1 285
12				X	1	13,7	13,7	695		1 215	
13	X				1	13,4	13,8	700	787,7	1 244	1 244
14	X				1	13,2	13,2	824	824	1 212	1 212
15			X		1	13,2	13,2	637	637	1 196	953
16	X				1	13,2	13,2	711	690	1 292	992

¹ In the following, if not indicated elsewhere, vertical illuminances are meant when speaking of illuminances.

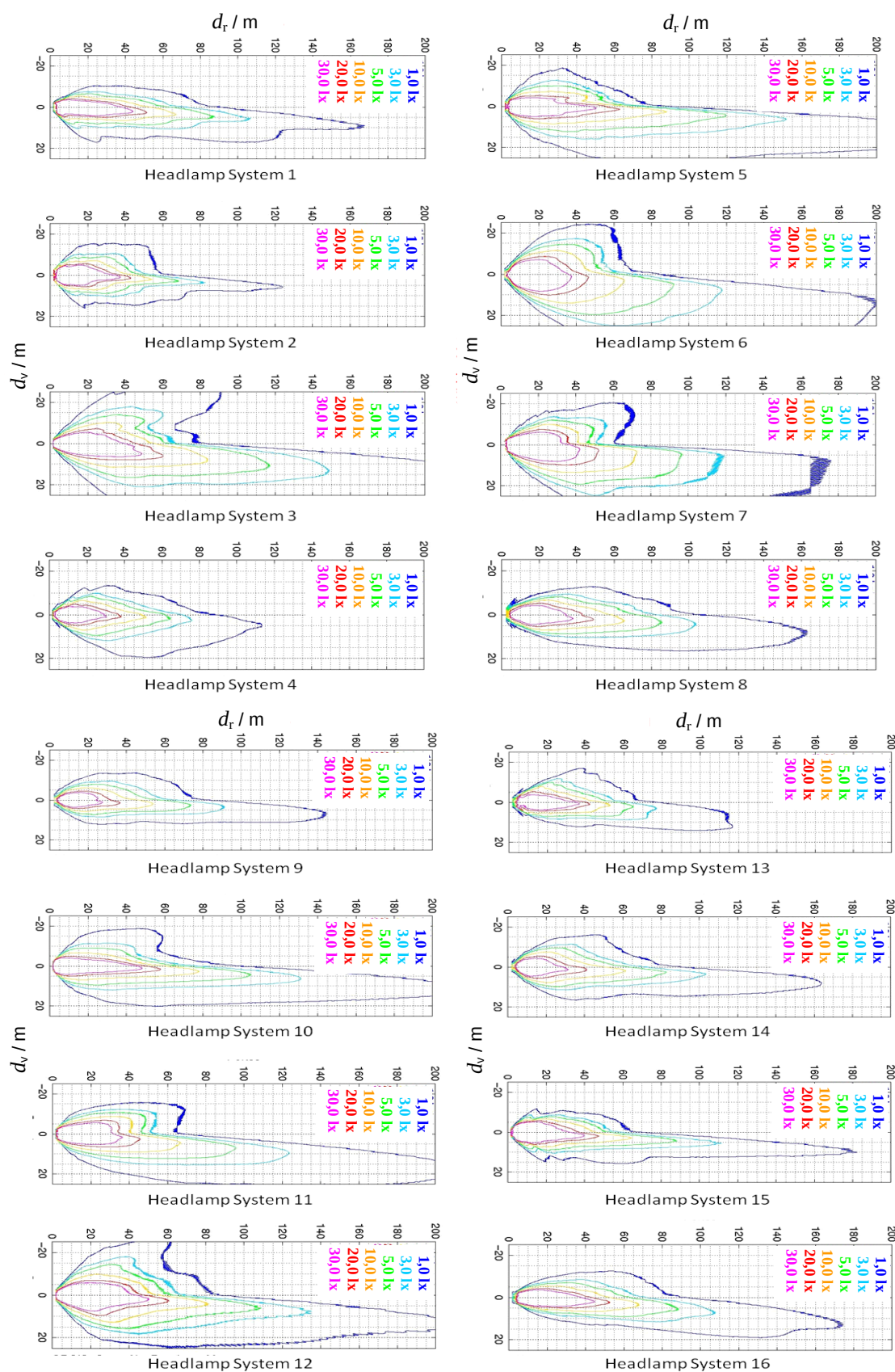


Figure 2. Typical passing beam distributions plotted as vertical illuminance at the road surface (d_r : distance along the road, d_v : distance from vehicle longitudinal axis).

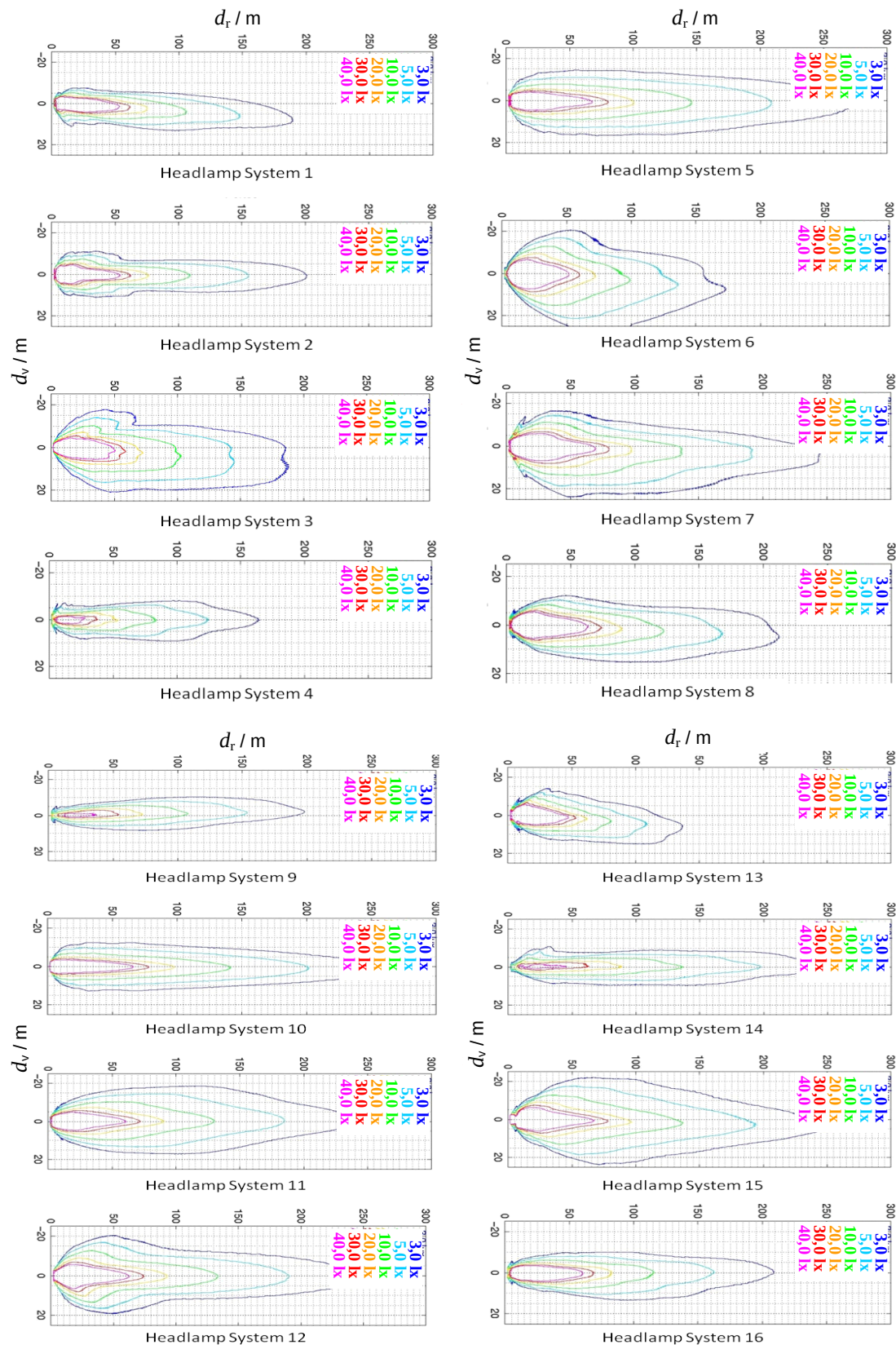


Figure 3. Typical driving beam distributions plotted as vertical illuminance at the road surface (d_r : distance along the road, d_v : distance from vehicle longitudinal axis).

When assessing the compliance of a headlighting system to safety regulations or standards it is solely the photometry of the passing beam and driving beam that is evaluated using calibrated equipment in the photometric laboratory. In service, the photometric potential of the headlight is influenced by a number of factors that will cause the actual performance to differ from that defined in regulations or standards. These include mounting height, supply voltage / operating current, beam alignment, variations in light source geometry, the headlight optical system, luminous flux etc. A beam distribution that will provide a good performance under a particular combination of installation conditions may therefore present a less satisfactory result both in terms of road scene illumination or opposing glare under less favourable installation conditions. The basic task is therefore one of defining an assessment method that will evaluate the performance at a number of critical areas of the road scene taking account of the actual installation parameters.

4.2 Road Scene Illumination

Vehicle headlights have the task of illuminating the road scene ahead of the vehicle in order to provide guidance for the driver to retain control of the vehicle through adequate illumination of road markings, the edges of the road and features such as verges, trees and road signs. Additionally, the driver requires early warning of the presence of obstacles including pedestrians and other road users.

In order to ensure that the headlight performance assessment adequately takes account of these differing requirements it was concluded that the vertical illuminance provided by the headlighting system must be assessed both at the road surface and at a horizontal plane located 0,25 m above the road surface that corresponds to the mid-point of the leg of an average pedestrian.

Based upon existing research [1], an illuminance of 3,0 lx has been taken as the threshold to ensure recognition of road features, pedestrians and obstacles. This assumes a grey target having a 4 % reflectance.

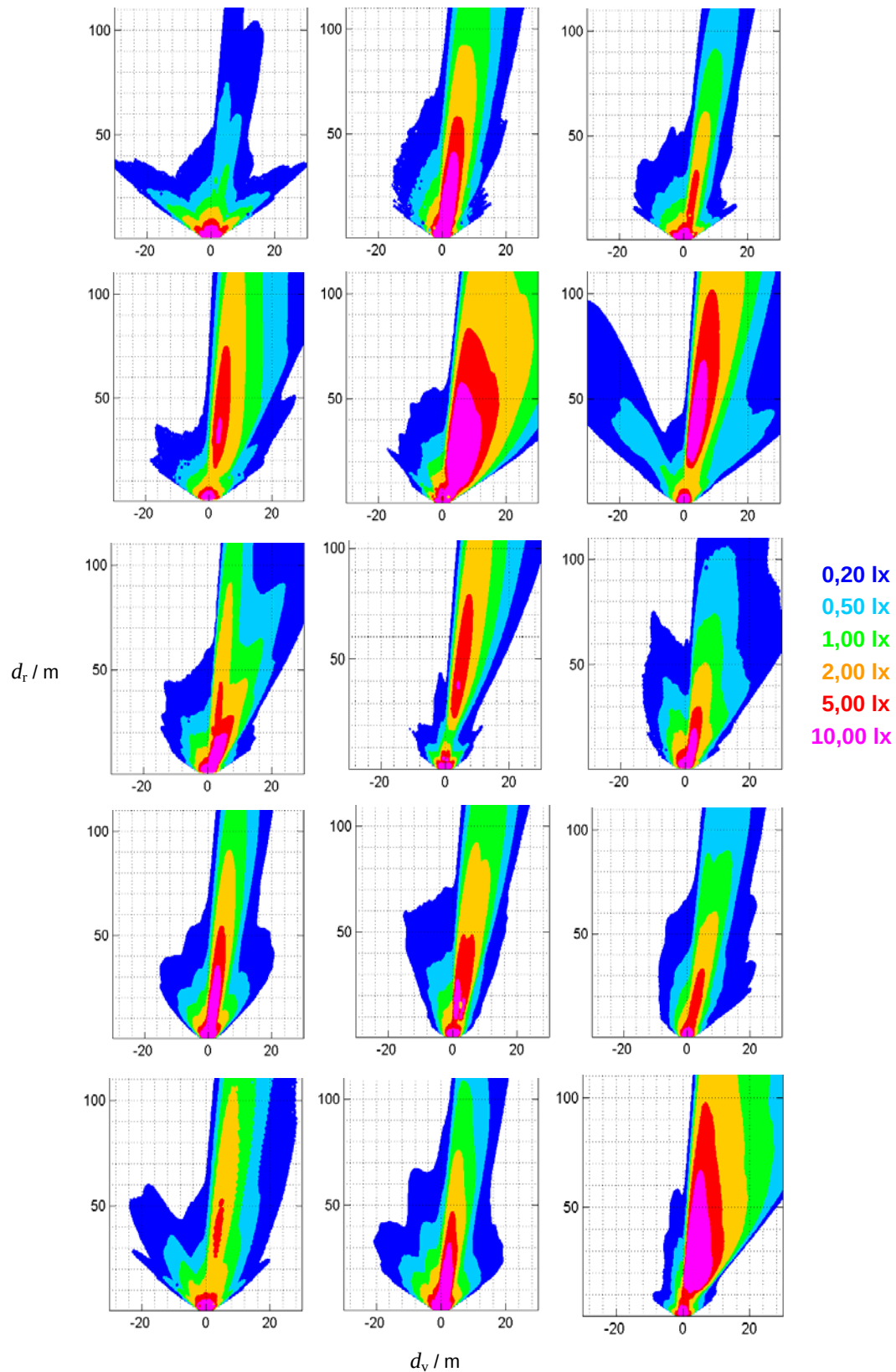
Although vehicle headlighting plays an essential role in the illumination of many traffic signs, it was decided to exclude this from the assessment. The interaction of traffic signs and vehicle lighting is a complex issue where the overall effectiveness of the complete system depends upon road geometry, sign positioning, sign materials and condition as well as the arrangement of the headlights on the vehicle [2]. TC 4-45 concluded that, as the lighting regulations already include minimum photometric requirements for luminous intensities at angles above the horizontal that provide the basis upon which the traffic signs are designed, it is not practicable to include this factor into the performance assessment method.

4.3 Glare

The evaluation of glare (opposing glare / mirror glare / veiling glare) was strongly debated and it was concluded that this must be an important part of the assessment method. It can be argued that glare levels are adequately controlled by regulations and standards. Indeed it was found in early experiments that if the headlights are viewed from a static position corresponding to the normal location of the oncoming driver's eye at a distance of 50 m the conclusion is that all headlights produce acceptable levels of glare. However, it is clear that glare cannot be assessed in a static condition and that in a dynamic situation, where the relative position of the headlight beam pattern and the opposing driver's eye is constantly changing; some passing beam patterns will have the potential to create more discomfort than others.

Figure 4 shows the glare illuminance performance of a range of headlights and Figure 5 compares two headlighting systems exhibiting very different potential glare characteristics. The findings of Damasky [3] relating to the incidence of the oncoming driver's eye position have been used to define the critical glare zone shown in Figure 15. The diagrams have been plotted as isolux lines on a vertical plane 940 mm above the road surface relating to the minimum opposing driver's eye height and it can clearly be seen that headlight "A" in Figure 5 will present less glare in the nearside right-hand corner of the glare zone than headlight "B" but it can also be seen that headlight "B" will produce a greater illuminance to the right of the car axis contributing in improved forward visibility of the road scene for the driver. The challenge is to determine how to balance these two conditions (glare and visibility) when attempting to rate the overall headlight performance.

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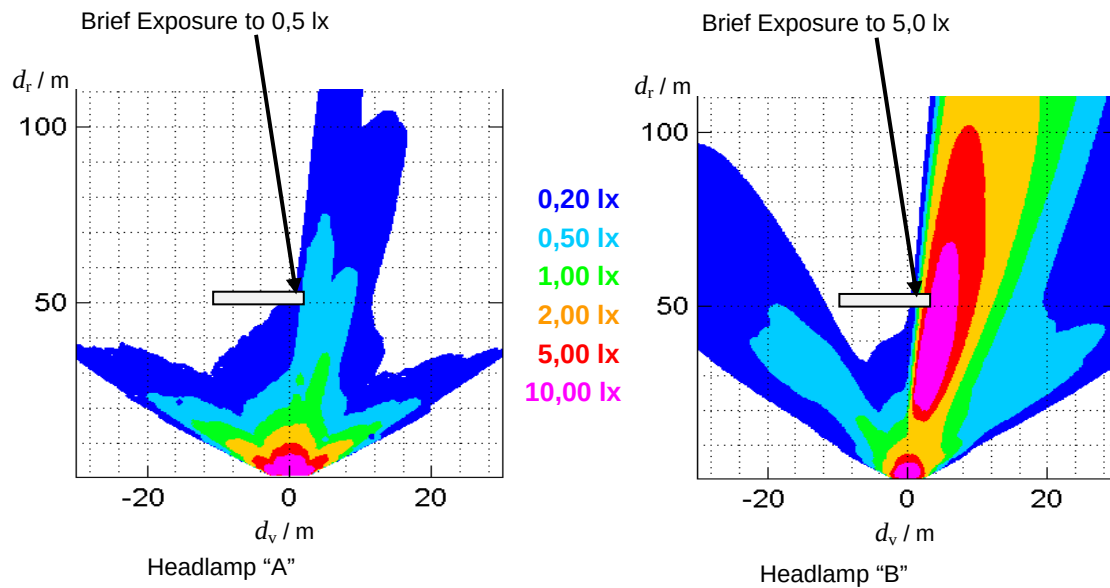


Key

d_r distance along the road

d_v distance from vehicle longitudinal axis

Figure 4. Potential glare illuminance of headlighting systems.
(Plotted on a horizontal plane at 940 mm above the road surface.)



Indicates the zone where the opposing driver's eyes will occur on normal two-lane roads [3]

Key

d_r distance along the road

d_v distance from vehicle longitudinal axis

Figure 5. Comparison of potential glare illuminance from 2 different headlighting systems. (Plotted on a horizontal plane at 940 mm above the road surface.)

Having concluded that the evaluation of glare must be a factor in the assessment method it was decided to only consider the effects of opposing glare. Mirror glare was considered but the internal mirror was dismissed as it is already provided with a means of reducing the effects of glare from the following vehicle. The external side mirror is positioned so that it is located directly in the same zone where it is important to provide a good illumination of the road scene (Figure 6). This means that to add the external mirror glare as a factor will act as an impediment to improve the seeing distances of the passing beam in order to obtain good overall headlight ratings. It was considered that glare in the external mirror can be justifiably discounted because technologies exist to reduce the reflectivity of the mirror.

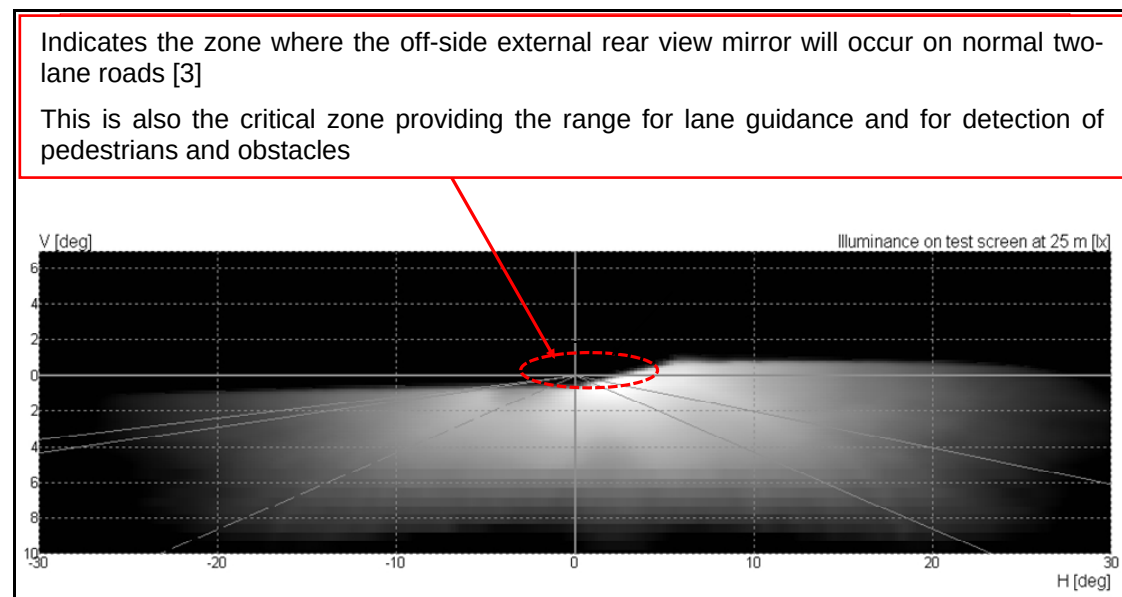


Figure 6. Position of the external rear-view mirror relative to the passing beam.

5 PASSING BEAM ASSESSMENT PARAMETERS

5.1 Range for Lane Guidance

The range of the passing beam is the most significant characteristic providing satisfactory guidance for the driver to be able to safely follow the course of the road and identify possible hazards.

Figures 7 and 8 show the arrangement of the zones for calculating the range, which is assessed by evaluating the distance where an illuminance of 3,0 lx is achieved on the bottom of a vertical plane at right angles to the longitudinal centre line of the vehicle and in contact with the road surface. To adequately account for the effects of normal road geometry it is necessary to assess the range of the passing beam on a straight road and also around left and right curves. In the latter case a curve of 500 m radius is taken as the basis for the calculation. This radius was chosen as an example of a curve encountered on a two lane country road.

5.2 Range for Pedestrian Detection

Research carried out on USA roads [4] shows that the critical area with the highest risk of collisions with pedestrians is to the left side of the road. More night-time collisions occur with the pedestrian crossing from the offside to the nearside than vice versa.

To take this important question of pedestrian visibility in the left side of the passing beam into account, the range is assessed as shown in Figure 9 by calculating the distance where an illuminance of 3,0 lx is achieved at a horizontal plane located 250 mm above the road surface.

5.3 Width for Lane Guidance and Visibility on Curves

The width of the passing beam to the offside and nearside of the lane centre-line is determined in a Zone D as shown in Figure 12, extending from 30 m to 50 m in front of the vehicle. This zone is considered to be important in terms of providing the driver with the ability to follow the road around bends and to detect obstacles. The beam width is assessed by evaluating the distance where an illuminance of 3,0 lx is achieved on the bottom of a vertical plane in contact with and perpendicular to the road surface.

5.4 Width for Pedestrian Detection at Intersections

The width of the passing beam at intersections is determined in Zone E extending from 10 m to 20 m from the vehicle as shown in Figure 12. This zone is considered to be important in terms of providing the driver with the ability to detect pedestrians when turning at intersections. This follows the work of Sullivan and Flannagan [4] who identified the problem of pedestrian fatalities at night-time during such manoeuvres. The beam width is assessed by evaluating the distance where an illuminance of 3,0 lx is achieved at a point on the pedestrian's leg located 250 mm above the road surface.

5.5 Total Luminous Flux

Experience has shown that the evaluation of the total luminous flux projected in the road scene is not a reliable measure of the performance potential of a passing beam because this does not take account of the light distribution. For example, a passing beam having a high flux value may perform very badly because much of the luminous flux is projected onto the road surface close to the vehicle and the visibility straight-ahead and at wide angles may be inadequate. However, in combination with other parameters, the calculation of the total luminous flux projected by the passing beam, as detailed in Table 2, provides a valuable factor in the performance assessment to provide an indication of the optical efficiency of the system.

5.6 Opposing Glare

The assessment of opposing glare considers the dynamic situation as discussed in 4.3. It was established during the second validation tests that static assessment of glare does not result in meaningful comparisons and that it is necessary to consider the statistical probability of the presence of the opposing driver's eyes relative to the passing beam pattern. This approach was proposed by Targosinski [5].

Referring to the work of Damasky [3] a rectangular zone located at 50 m from the headlight is defined. The glare illuminance at each point in this zone is calculated and then weighted according to the statistical probability of the location of the opposing driver's eye as shown in Figures 13 to 15. An overall integrated figure is used to indicate the glare performance of the headlight as described in 7.2.5 and Table 3.

6 DRIVING BEAM ASSESSMENT PARAMETERS

6.1 Range for Pedestrian Detection, Lane Guidance and Visibility

The experience gained during the validation testing in Spain (test 2 – see Appendix B), Germany (test 3 – see Appendix B), and Italy (test 6 – see Appendix B), lead to the conclusion that a simple assessment of the central luminous intensity will not provide a meaningful evaluation of the performance of the driving beam with regard to range. Further, a high intensity projected along the vehicle longitudinal axis will have little effect on a long straight and featureless road. Lighting engineers are fully aware, based upon experience, that a well performing driving beam will exhibit a good central distribution to provide adequate illumination of the road scene on straight, bending and undulating roads.

Assuming a requirement to detect obstacles at a minimum stopping distance of 150 m from the vehicle along a curved road of 500 m radius to the left and the right, the driving beam must be capable of providing an illuminance of 3,0 lx at a lateral angle of 11°. To take account of vertical undulations of the road it is also necessary to consider the appropriate vertical angles, and for this it was decided to place the emphasis upon the case of the vehicle driving into a dip with an incline of 10 %. In order to provide the 150 m stopping distance this translates to a requirement of 3,0 lx in a direction of 5° upward. Although the case of a vehicle driving over a crest in the road is less critical, an angle of 1° downward is also specified. Figure 18 shows the points to be assessed.

6.2 Width for Pedestrian Detection at Intersections

The procedure is the same as that described for the passing beam in 5.4. The zone to be considered is shown in Figure 17.

6.3 Total Luminous Flux

The considerations are the same as those described for the passing beam in 5.5.

7 ASSESSMENT PROCEDURE

7.1 Basis of the Procedure

The procedure is based upon laboratory measurements of headlights under controlled conditions (calibrated light source, vehicle voltage, vehicle aim) using a defined format for the data including the angular increments of the measurement points. Using these data, aspects of the headlight performance are evaluated as detailed in 7.2 and 7.3. In all cases, the illuminance and luminous intensity values being assessed are derived from a combination of the individual photometric data measured for each component of the headlighting system. These values are combined taking account of the mounting height, separation and aim specified for the particular vehicle to which the system is installed. The method of combining the data is described in Clause 8.

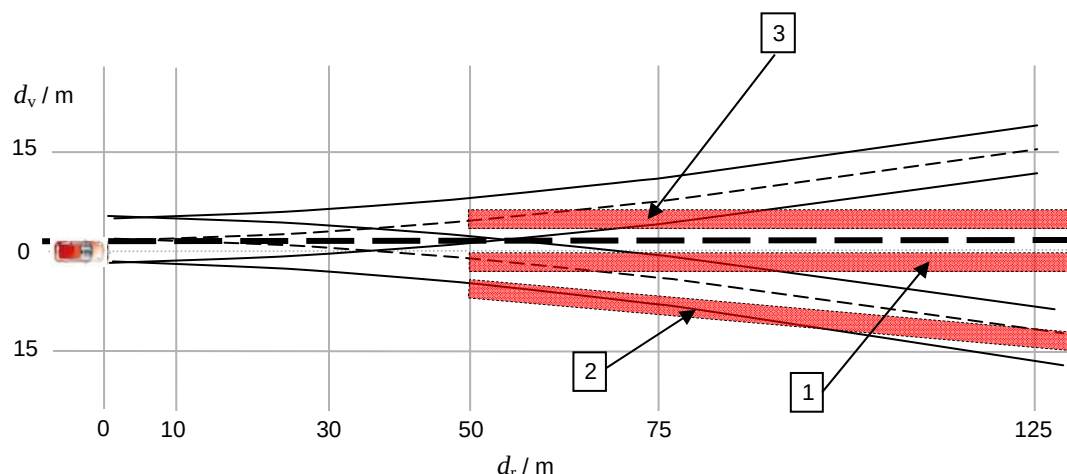
7.2 Passing Beam Illumination

Illumination of the road scene by the passing beam is assessed by evaluating the performance of the headlighting system as summarised in Table 2. The zones shown in this report are for right-hand driving.

Table 2. Aspects to be assessed - passing beam road scene illumination.

Zone See figures 7 to 12	Purpose	Assessment Method
A, B	Range for lane guidance	See explanation in 7.2.1 and Figures 7, 8, 9 and 10
C	Range along the offside verge for pedestrian detection	See explanation in 7.2.2 and Figure 11
D	Width for lane guidance and visibility on curves	See 7.2.4 and Figure 12 Evaluate arithmetic mean value of the width of the 3,0 lx line at 30 m, 40 m and 50 m in front of the vehicle at the road surface. Individual width values are calculated from the lane centre line to the offside and nearside of the vehicle
E	Width for pedestrian detection at intersections	See 7.2.4 and Figure 12 Evaluate arithmetic mean value of the width of the 3,0 lx line at 10 m and 20 m from the car on a plane located at 250 mm above the road surface. Individual width values are calculated from the lane centre line to the offside and nearside of the vehicle
Whole beam	Luminous flux	See 7.2.3 Total luminous flux (lm) within a vertical zone 5° up to 15° down, 45° left to 45° right

The general arrangement of the zones defined for the assessment of the passing beam range is shown in Figure 7. Zones A and C are aligned with the longitudinal axis of the vehicle, Zone B is inclined at an angle of 5° from the vehicle axis as shown.



Key

- d_r distance along the road
 d_v distance from vehicle longitudinal axis
- 1 Zone A range assessment – straight road
 - 2 Zone B range assessment – curved road
 - 3 Zone C range assessment – pedestrian visibility

NOTE 1 Zones A, B and C originate at $d_r=0$ as shown in figures 8, 9 and 10, but for clarity have been shortened in this diagram.

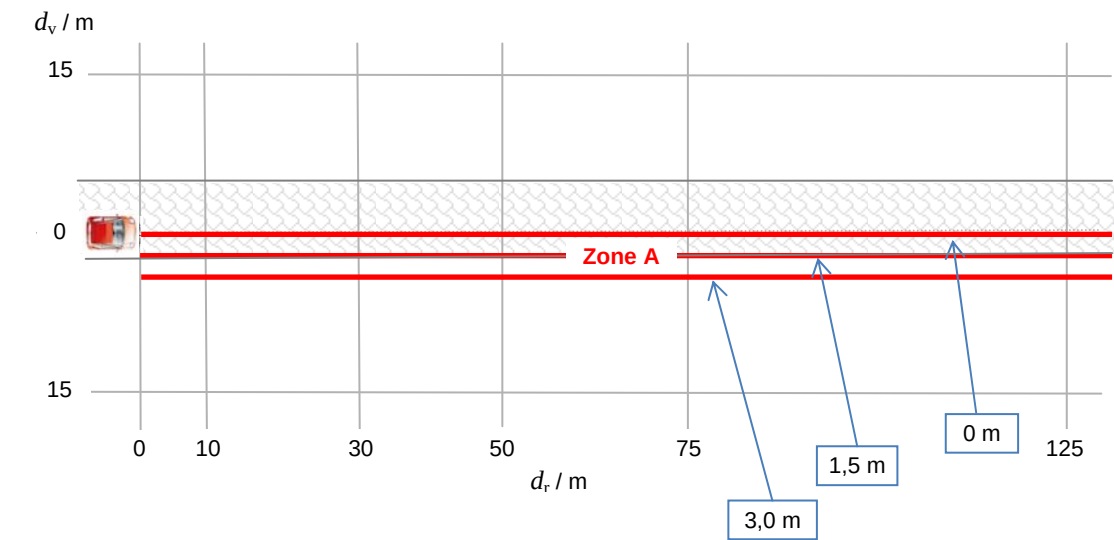
NOTE 2 Road width = 6 m (3 m per lane), 500 m radius curve.

Figure 7. Zones for assessment of passing beam range.

7.2.1 Passing Beam Range Assessment Procedure – Zones A and B

Referring to Table 2 and Figures 8 and 9 calculate the position of the intersection of the 1,0 lx, 3,0 lx and 5,0 lx isolux lines with each of the three longitudinal lines in Zone A. The range (in m) is the average of the values determined for the 1,0 lx, 3,0 lx and 5,0 lx intersection points with the three lines. The isolux lines are plotted on the road surface as vertical illuminance values. An example calculation is shown in Figure 9 where the determination of the intersection points for the 3,0 lx line is shown. Similar calculations to determine the average range value are carried out for the 1,0 lx and 5,0 lx lines.

A similar procedure is followed to calculate the range on the curved road shown in Figure 10. In this case the intersection points are determined along the lines inclined at $5,0^\circ$ in Zone B.

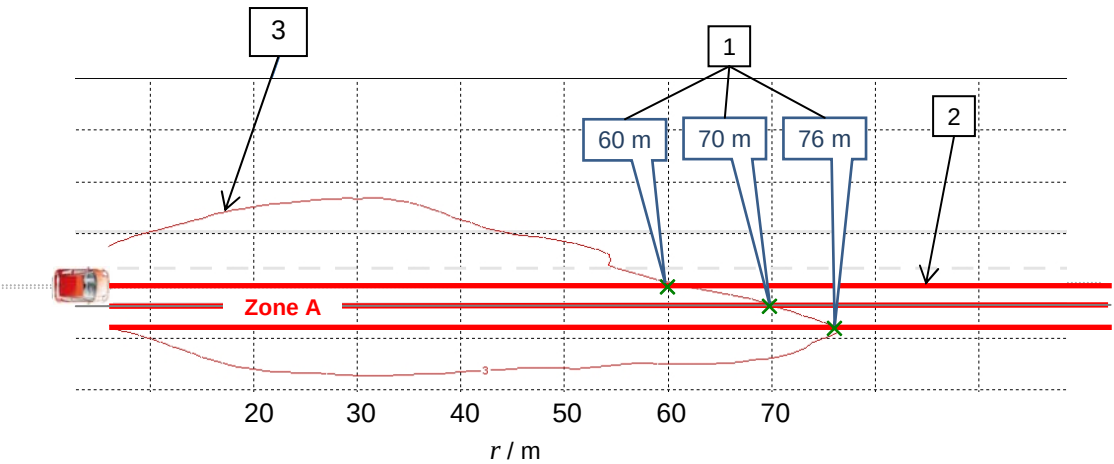


Key

d_r distance along the road
 d_v distance from vehicle longitudinal axis

NOTE The longitudinal lines in Zone A are situated at 0 m, 1,5 m and 3,0 m to the nearside of the longitudinal axis of the vehicle.

Figure 8. Zone A – range assessment for straight road.



Line at	0,0 m			1,5 m			3,0 m			Average range
Isolux line	1,0	3,0	5,0	1,0	3,0	5,0	1,0	3,0	5,0	
r / m		60			70			76		68,6

Key

r range
1 intersection points with the three lines in Zone A
2 vehicle longitudinal axis
3 3,0 lx line

Figure 9. Example of the calculation of range assessment for Zone A.