ABSTRACT

The photometric requirements of today’s headlamps do not relate to the headlights as built into the vehicle, but to the individual headlamp before its installation. The aim of this survey is to demonstrate the relation between technical requirements of individual headlamps and the actual situation on the road. For that purpose headlamps were measured: on the one hand those of known vehicles (reference vehicles) with correctly adjusted and cleaned headlamps; on the other hand headlamps in everyday traffic, i.e. possibly incorrectly adjusted and soiled.

It could be shown that the glare of illuminance of the gas discharging headlamps in the measuring point of the human eyes of an on-coming car is lower than of normal traffic vehicles.

INTRODUCTION

The legal requirements of headlamps vary from country to country. These regulations relate to the place, levelling and photometry.

MEASURING

The measuring can be divided into the following items:

- Photometric measuring points (ECE and MVSS / SAE)
- Dynamic courses of the photometric measuring points
- Dry road
  - Situation:
    - Humid
    - Rain
- Wet road
  - Situation:
    - Humid
    - Rain
- Reference vehicles
- Normal traffic

All in all twelve combinations are possible. The measuring points are shown in Figure 1 and Table 1.

Table 1. Measuring Geometry.

<table>
<thead>
<tr>
<th>Measuring Point</th>
<th>Measuring Distance d / m</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>50L</td>
<td>50.4</td>
<td>left road side</td>
</tr>
<tr>
<td>VL</td>
<td>50.4</td>
<td>left shoulder 1 m left 2.50 m height</td>
</tr>
<tr>
<td>50R</td>
<td>50.1</td>
<td>right road side</td>
</tr>
<tr>
<td>VR</td>
<td>50.4</td>
<td>right shoulder 1 m right 2.50 m height</td>
</tr>
<tr>
<td>75R</td>
<td>75.1</td>
<td>right road side</td>
</tr>
<tr>
<td>R50L</td>
<td>75.1</td>
<td>Direction as defined by relevant regulations</td>
</tr>
<tr>
<td>HV</td>
<td>95.4</td>
<td>Direction as defined by relevant regulations</td>
</tr>
</tbody>
</table>

Street Geometry

The measuring equipment was set up on a “Bundesstraße” with a speed limit of 44 mph. The drivers were not informed about the measuring taking place.

Photometric Measuring

The photometric measurements were made by single \( V(\lambda) \)-adapted photoelements in the directions and distances as listed in Table 1. All values described later are recalculated for a distance of \( d = 25 \text{ m} \) and valid for a light distribution of a system with two superimposed headlamps. The possible forward reflection on the pavement into the direction of the photoelements was shielded. The whole measuring system was controlled by a system-timer of the computer used for the data collection.

Photometric Requirements

For the measurements a set of measuring directions as listed in Table 1 and shown in Figure 1 were selected. The new measuring points VR and VL describe the situation of the illumination at traffic signing. The photometric limiting values except those for VR and VL
can be taken from the relevant ECE-Regulation. The photometric requirements for headlamps are based on certain test voltages. These voltages can differ from those measured at the headlamp mounted on a car. There are many other effects influencing the photometric values of headlamps for example:

- ageing of headlamps and lenses
- ageing of filament lamps
- changing of the plugs’ resistance, etc.

Therefore, a large variety of measured values could be expected.

![Figure 1. Measuring Points in Street Geometry.](image)

**RESULTS**

The speed of the vehicles varied from 40 to 48 mph (reference vehicles) and from 44 to 68 mph (normal traffic).

The results are split into four items:

**Vehicles**

- in normal traffic
- with gas discharging headlamps
- with H4-Headlamps
- with modular build up illumination

**Situation on the road (normal traffic)**

In Figure 2 the illumination $E_{(HV)}$ of vehicles in normal traffic are shown. $E$ describes the arithmetic mean value.

![Figure 2. Illumination $E_{(HV)}$ for Normal Traffic.](image)

The figure illustrates the great variety of results in the HV-point. The mean value $E$ follows after measuring pairs of headlamps in normal traffic. The values’ scattering results from a high gradient in the HV-point, incorrectly adjusted and/or soiled headlamps. The single headlamp’s mean value exceeds the legal maximum value of the ECE regulation which amounts to $E = 0.7$ lx. Apart from the already mentioned reasons, the high voltage in the vehicle and its variation (mean value 13.5 V instead of the supposed 12 V) are responsible for this effect.

Figures 3 and 4 show the frequency distribution $f$ of the $E_{(B50L)}$ and $E_{(75R)}$. A normal distribution ensues from both diagrams. The mean values amount to

$E_{(B50L)} \approx 1.04$ lx and

$E_{(75R)} \approx 10.3$ lx.

While the glare point of B50L surpasses the legal standard of 0.4 lx (per individual headlamp) only slightly, the minimum value of 12 lx in 75R is not achieved by far. Consequently, the distance of recognition is shortened and this results in a decrease of safety in traffic.

The measurings were repeated on several days during like weather conditions. Figure 5 plots the mean values of four sensors during six/seven different measurings in normal traffic. Every sketched value is based on a minimum of 33 and a maximum of 406 different vehicles. The discrepancies, which become particularly visible in the HV-value, again refer to insufficiently adjusted and soiled headlamps.
Figure 3. Frequency Distribution $f$ of the Illumination $E(B50L)$ for Normal Traffic.
Number of Measurings: $n = 78$

Figure 4. Frequency Distribution $f$ of the Illumination $E(75R)$ for Normal Traffic.
Number of Measurings: $n = 78$

Figure 5. Mean Values of the Illumination $E$ for Different Measurement Series $n$.

- HV, B50L: Illumination in the Measuring Direction HV, B50L
- VR, VL: Illumination in the Measuring Direction of Shoulder Mounted Traffic Signs (R: Right Shoulder, L: Left Shoulder)

$E(HV)$, $E(B50L)$: Calculated Mean Values

The relation between $E(B50L)$ and $E(75R)$ is shown in figure 6. The mean values of the glare-point and the range amount to $1.06 \text{ lx}$ and $12.3 \text{ lx}$ respectively. As a conclusion follows:

$$\frac{E(B50L)}{E(75R)} = 10$$

Figure 6. Illumination $E(B50L)$ and $E(75R)$ for Normal Traffic.

$E(HV)$, $E(B50L)$: Calculated Mean Values
Number of Measurings: $n = 78$
Gas Discharge Headlamps (GDL)

During the last years the glare of headlights with GDLs has been discussed. The road users' subjective judgements usually declare them as being more glaring than those headlamps common up to now. Because of that, vehicles with these light sources were separately analysed so that an objective conclusion could be drawn. Figures 7 and 8 depict the luminous flux of a vehicle with correctly adjusted headlights in the points of 50L and 75R. The mean values amount to E = 1.1 lx and E ≈ 38 lx respectively and fulfill the legal requirements. The glare values do not exceed those in normal traffic, that is to say, those of vehicles with conventional halogen headlamps.

The GDL's relation of glare and range, however, comes up to about 1:30 and reaches a value three times as high as the one measured during normal traffic. An intensified use of GD-Headlamps would therefore contribute to the enhancement of vehicle safety.

For reference measurements and the comparison of knowingly correctly adjusted and clean headlamps with those of normal traffic, eleven different vehicles were employed and taken into account. 10 to 87 times each of these were driven along the measuring range, which resulted in 358 individual measurements. In Figure 9 the measuring point 50L of correctly adjusted and clean headlamps as well as the values gained during normal traffic are plotted. It shows that the glare values in the second survey of identified headlamps are in most cases lower.

A comparison of glare and range in Figure 10 reveals that its relation comes up to 1:50 in the case of correctly adjusted and clean headlamps. Due to these results, enhanced vehicle and traffic safety could be achieved by further use of headlamp washers as well as by ensuring that headlights will correctly be adjusted.
Comparison of Various Tests

The comparison of various headlamps in different measuring points on dry road is plotted in Figures 11 and 12. The following categories of vehicles are shown:
- normal traffic (n=363)
- individual vehicles with GDLs (n=82)
- individual vehicles with H4-headlamps (n=97)

The mean values are plotted logarithmically.

Adverse Weather Condition

The tests on dry road excluded the measuring of the forward reflection. On humid or wet road that kind of reflection accounts for a significant share in the measuring points – especially in the glare-point B50L. Due to this fact, the set-up was modified for these tests. The changes of the measured values can be seen in the Figures 13 and 14.

The periods of rain are divided into three phases:

<table>
<thead>
<tr>
<th>Table 2: Comparison of E(B50L) on Dry and Wet Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>from n</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>19</td>
</tr>
<tr>
<td>51</td>
</tr>
</tbody>
</table>

*dry road conditions*
During the different intensities of rain, varying degrees of increased luminous flux in the glare-point can be observed (cf. Table 2). By contrast, the luminous flux in 75R are similarly high as the values on dry road.

The results gained of the vehicles in normal traffic appear to be more randomly distributed. An increase in the luminance in B50L, however, can be perceived, which amounts to the factor 1:3.

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