A MARKET-WEIGHTED DESCRIPTION OF LOW-BEAM HEADLIGHTING PATTERNS IN EUROPE: 2003

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### Abstract

This study was designed to provide updated photometric information about current European low-beam headlamps. The sample included 20 headlamps manufactured for use on the 20 best-selling passenger vehicles for model year 2003 in 19 European countries. The vehicles sampled represent 47% of all vehicles sold in these countries. The lamps were purchased directly from vehicle dealerships. The photometric information for each lamp was weighted by the sales figures for the corresponding vehicle.

The results are presented in tabular form for the 25th-percentile, the 50th-percentile (median), and the 75th-percentile luminous intensities (from 45° left to 45° right, and from 5° down to 7° up). The results are also presented in graphical form for the median luminous intensities (from 45° left to 45° right, and from 10° down to 10° up), as well as for the median illuminance incident on vertical surfaces at various locations on the roadway.
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INTRODUCTION

In 1997 we published a report that included a market-weighted description of low-beam headlighting patterns in the U.S. (Sivak, Flannagan, Kojima, & Traube, 1997). That information was based on photometry of headlamps on the 23 best-selling passenger vehicles for model year 1997. That study was followed by an analogous study in which market-weighted output for the low-beam headlamps on the 20 best-selling passenger vehicles for model year 2000 in Europe were collected (Sivak, Flannagan, & Schoettle, 2000). Most recently, another analogous study was conducted in which market-weighted descriptions of both low-beam and high-beam headlighting patterns for the U.S. and Europe were documented (Schoettle, Sivak, & Flannagan, 2001). The present study was designed to update the market-weighted database of current European low-beam headlamps for model year 2003.

The main features of this study were as follows:

• The lamps to be photometered were directly purchased from vehicle dealerships, thus avoiding the potential problem of self-selection with donated lamps.
• The selected lamps were designed for use on 47% of all passenger vehicles currently being sold in 19 European countries.
• The obtained photometric information was weighted by the current sales figures for the respective vehicle models.
METHOD

Approach

The approach consisted of the following steps:

(1) Obtain luminous-intensity matrix for lamps designed to be used on the best-selling passenger vehicles.

(2) Use the current sales data for the respective vehicles to derive a sales-weighted distribution of luminous intensities at each test point.

(3) For each test point, calculate selected percentiles—25th, 50th (median), and 75th—of the sales-weighted distribution of luminous intensities.

Photometry

The measurements were made in a photometry lab using a goniometer. Mounting fixtures provided by each lamp manufacturer were used to secure the lamps to the goniometer whenever possible. Visual aiming was used to align the lamps prior to the photometry. The horizontal aim placed the right end of the horizontal part of the vertical cutoff at the vertical axis. The vertical aim was set by first aligning the vertical cutoff on the left side with the horizontal, and then displacing the beam 0.6° (1%) down. The aiming of all lamps was supervised by the same person—a lighting engineer with 37 years of headlighting experience. We performed the photometry as defined by the following ranges of horizontal and vertical angles (in relation to the headlamp axes): in the horizontal direction, the angles ranged from 60° left (L) to 60° right (R) in steps of 0.2°; in the vertical direction, the angles ranged from 15° down (D) to 10° up (U) in steps of 0.2°.

The lamps were continuously energized for approximately 30 minutes each prior to performing the photometry. All measurements were made at 12.8 V with standard production bulbs supplied with the lamps at the time of purchase.

The purpose of the study was to obtain estimates of real-world light output; the study was not designed to evaluate compliance with regulations. Consequently, we used a fixed voltage (as opposed to voltage based on flux criterion), standard production bulbs (as opposed to accurate, rated bulbs), and no re-aiming (as opposed to re-aiming based on preliminary photometric results).

We determined the luminous intensities at the 25th-percentile, the 50th-percentile (median), and the 75th-percentile for test points in a rectangular matrix defined by the following ranges of horizontal and vertical angles (in relation to the headlamp axes): in the horizontal direction, from 45° left (L) to 45° right (R) in steps of 0.5°; in the vertical direction, from 10° down (D) to 10° up (U) in steps of 0.5°.
Sample

A total of 20 lamps constituted the sample. All lamps (and the corresponding bulbs for each lamp) were for model year 2003, and they were purchased in June 2003 in the Munich Metropolitan Area, Germany. The lamps were produced by three lighting companies and were designed for vehicles produced by 10 vehicle manufacturers. All were left-side lamps for use on the 20 best-selling passenger vehicles in Europe for the calendar year 2002 (which includes model years 2002 and 2003). The vehicle sales data included the following 19 countries (in descending order of total sales): Germany, United Kingdom, Italy, France, Spain, The Netherlands, Belgium, Switzerland, Austria, Greece, Sweden, Portugal, Ireland, Finland, Hungary, Denmark, Norway, Luxembourg, and Iceland (Automotive News, 2003).

The 20 vehicles were as follows (also in descending order of sales): Peugeot 206, Volkswagen Golf, Ford Focus, Renault Clio, Peugeot 307, Fiat Punto, Volkswagen Polo, BMW 3 Series, Opel Astra, Opel Corsa, Ford Fiesta, Volkswagen Passat, Audi A4, Renault Mégane, Mercedes C-Class, Renault Scénic, Ford Mondeo, Renault Laguna, Citroën Xsara Picasso, and Opel Zafira (Automotive News Europe, 2003). These 20 vehicles constituted 47% of all passenger vehicles sold in Europe during 2002 (Automotive News Europe, 2003).

Several vehicles offered optional high-intensity discharge (HID) lamps, along with standard tungsten-halogen lamps. Our sample included only lamps with tungsten-halogen bulbs, made by four different bulb manufacturers. A breakdown of lamps by light source for the 20 vehicle models surveyed is shown in Table 1. Summaries of several design features of the tested lamps are shown in Table 2 (optics) and Table 3 (lens materials).
Table 1
Breakdown of the light sources used in the tested lamps.

<table>
<thead>
<tr>
<th>Light source</th>
<th>Number of vehicles</th>
<th>Sales-weighted percentage of all vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>H7</td>
<td>16</td>
<td>77.1</td>
</tr>
<tr>
<td>H4</td>
<td>4</td>
<td>22.9</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 2
Optics of the tested lamps.

<table>
<thead>
<tr>
<th>Optics</th>
<th>Number of vehicles</th>
<th>Sales-weighted percentage of all vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflector optics</td>
<td>14</td>
<td>69.6</td>
</tr>
<tr>
<td>Lens optics</td>
<td>4</td>
<td>20.5</td>
</tr>
<tr>
<td>Projector</td>
<td>2</td>
<td>9.9</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 3
Lens materials of the tested lamps.

<table>
<thead>
<tr>
<th>Lens material*</th>
<th>Number of vehicles</th>
<th>Sales-weighted percentage of all vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>18</td>
<td>87.2</td>
</tr>
<tr>
<td>Glass</td>
<td>2</td>
<td>12.8</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>100.0</td>
</tr>
</tbody>
</table>

* Outermost lens material only. Does not include the glass in projector optics.
RESULTS

Table 4 lists the 25th-percentile, the 50th-percentile (median), and the 75th-percentile luminous intensities. The horizontal steps in Table 4 are 0.5° between 0° and 5°, 1° between 5° and 10°, and 5° between 10° and 45° (all for left or right). Because of space limitations, the vertical range in Table 4 has been reduced. (The full available data range is from 10° up to 10° down; the range in Table 4 is from 7° up to 5° down.)

Figure 1 presents isocandela diagrams corresponding to the median luminous intensities for the sales-weighted sample representing the low-beam headlamps on current European passenger vehicles.

Figure 2 presents the isoilluminance diagram (in lux) corresponding to the median illuminance incident on a vertical surface at various roadway locations from the low-beam headlamps on current European passenger vehicles. (The headlamp height and separation used are from Schoettle, Sivak, & Nakata, 2002.)
<table>
<thead>
<tr>
<th>45L</th>
<th>40L</th>
<th>35L</th>
<th>30L</th>
<th>25L</th>
<th>20L</th>
<th>15L</th>
<th>10L</th>
<th>9L</th>
<th>8L</th>
<th>7L</th>
<th>6L</th>
<th>5L</th>
<th>4.5L</th>
<th>4L</th>
<th>3.5L</th>
<th>3L</th>
<th>2.5L</th>
<th>2L</th>
<th>1.5L</th>
<th>1L</th>
<th>0.5L</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>7U</td>
<td>11</td>
<td>13</td>
<td>14</td>
<td>21</td>
<td>29</td>
<td>33</td>
<td>39</td>
<td>46</td>
<td>48</td>
<td>53</td>
<td>55</td>
<td>54</td>
<td>56</td>
<td>59</td>
<td>59</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>61</td>
<td>60</td>
<td>61</td>
<td>62</td>
</tr>
<tr>
<td>6.5U</td>
<td>11</td>
<td>13</td>
<td>14</td>
<td>21</td>
<td>29</td>
<td>33</td>
<td>39</td>
<td>46</td>
<td>48</td>
<td>53</td>
<td>55</td>
<td>54</td>
<td>56</td>
<td>59</td>
<td>59</td>
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<td>60</td>
<td>61</td>
<td>60</td>
<td>61</td>
<td>62</td>
</tr>
<tr>
<td>3U</td>
<td>19</td>
<td>20</td>
<td>24</td>
<td>33</td>
<td>39</td>
<td>46</td>
<td>48</td>
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<td>61</td>
<td>62</td>
<td>65</td>
</tr>
<tr>
<td>2U</td>
<td>19</td>
<td>20</td>
<td>24</td>
<td>33</td>
<td>39</td>
<td>46</td>
<td>48</td>
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<td>65</td>
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<tr>
<td>1U</td>
<td>19</td>
<td>20</td>
<td>24</td>
<td>33</td>
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<td>61</td>
<td>62</td>
<td>65</td>
</tr>
</tbody>
</table>

Table 4

Luminous intensities (cd) for the sales-weighted sample representing the low-beam headlamps on current passenger vehicles in Europe. The entries in each cell are (from top to bottom) the 25th-percentile, the 50th-percentile (median), and the 75th-percentile. (Test voltage: 12.8 V.)
Figure 1. Isocandela diagrams of the median luminous intensities for the sales-weighted sample representing the low-beam headlamps on current passenger vehicles in Europe. The two panels represent the same information in two different formats. (Test voltage: 12.8 V.)
Figure 2. Isoilluminance diagram (in lux) on a vertical surface at the road surface from a pair of lamps with the median luminous intensities for the sales-weighted sample representing the low-beam headlamps on current passenger vehicles in Europe. The shaded area represents a standard two-lane road. (Test voltage: 12.8 V. Lamp mounting height: 0.66 m. Lamp separation: 1.20 m. Lane width: 3.7 m.)
DISCUSSION

The present analysis is not based on a complete census of current low-beam headlamps in Europe, but on a sample constituting 47% of all lamps for passenger vehicles sold in 19 European countries. However, we do not have reasons to believe that there are systematic differences between the lamps that were sampled and those that were not (with the exception of HID headlamps). We believe that the data presented in this report provide valid estimates of the luminous intensities that can be expected at various angles with respect to the headlamp axes of low-beam tungsten-halogen headlamps currently used in Europe. Thus, the data could be used to calculate the expected illuminance reaching targets with known geometric relationships to the headlamps, such as traffic signs, road delineation, the eyes of oncoming drivers, or rearview mirrors on preceding vehicles.

As we pointed out in our previous market-weighted low beam descriptions (Sivak et al., 1997; Sivak et al., 2000; Schoettle et al., 2001), data such as these should not be used to calculate gradients of luminous intensities for adjacent points in space (e.g., for estimating the sharpness of the cutoff that is important for visual aiming of the beam pattern). This is because the transitions from the more intense to the less intense parts of the beam pattern are not precisely in the same locations for all lamps. Consequently, although the present analysis provides valid estimates of luminous intensities for individual points, a computation of gradients between points based on the present analysis would underestimate the actual gradients. This caveat applies not only to the present data, but also to any aggregate data for non-identical beam patterns.

As indicated above, this study was not designed to evaluate compliance with ECE regulations, and thus standard procedures for compliance testing were not followed. Consequently, comparison of the present data with the regulations would be inappropriate.
REFERENCES


