A MARKET-WEIGHTED DESCRIPTION OF LOW-BEAM HEADLIGHTING PATTERNS IN THE U.S.: 2004

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This study was designed to provide updated photometric information about current U.S. low-beam headlamps. The sample included 20 headlamps manufactured for use on the 20 best-selling passenger vehicles for model year 2004 in the U.S. The vehicles sampled represent 39% of all vehicles sold in the U.S. The lamps were purchased directly from vehicle dealerships. The photometric information for each lamp was weighted by the sales figure for the corresponding vehicle.

The results are presented in tabular form for the 25th-percentile, 50th-percentile (median), and 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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- Federal-Mogul
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- GE
- General Motors
- Gentex
- Guide Corporation
- Hella
- Honda
- Ichikoh Industries
- Koito Manufacturing
- Lang-Mekra North America
- Magna International
- Mitsubishi Motors
- Muth
- Nichia America
- Nissan
- North American Lighting
- OLSA
- OSRAM Sylvania
- Philips Lighting
- PPG Industries
- Reflec USA
- Reflexite
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CONTENTS

ACKNOWLEDGMENTS .............................................................................................................. ii

INTRODUCTION .........................................................................................................................1

METHOD ....................................................................................................................................... 2

RESULTS ....................................................................................................................................... 5

DISCUSSION ............................................................................................................................... 10

REFERENCES .............................................................................................................................. 11
INTRODUCTION

This study is a continuation in a series of reports that document the market-weighted headlamp outputs for the top-selling vehicles in the U.S. and Europe (see Sivak, Flanagan, Kojima, & Traube, 1997; Sivak, Flanagan, & Schoettle, 2000; Schoettle, Sivak, & Flanagan, 2001; and Schoettle, Sivak, Flanagan, & Kosmatka, 2003). The present study was designed to update the market-weighted database of current U.S. low-beam headlamps for model year 2004.

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 39% of all passenger vehicles currently being sold in the U.S.
• The obtained photometric data were weighted by the current sales figures for the respective vehicle models.
METHOD

Approach

The approach consisted of the following steps:

1. Obtain luminous-intensity matrices 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. Visual aiming was used to align the lamps prior to the photometry. The aiming of all lamps was supervised by the same person—a lighting engineer with 38 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 10° down (D) to 10° up (U) in steps of 0.2°.

All lamps were seasoned per SAE Recommended Practice J387 (SAE, 1995) prior to performing the photometry. This process involves continuously energizing each lamp at 12.8 V for 1% of the installed bulb’s rated life or 10 hours, whichever is less. 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 a 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, 50th-percentile (median), and 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

The sample consisted of 20 lamps. All lamps were for model year 2004 and they were purchased in April 2004 in Ann Arbor, Michigan. The lamps were produced by eight lighting companies and were designed for vehicles produced by eight vehicle manufacturers. All were left-side lamps for use on the 20 best-selling passenger vehicles in the U.S. for the calendar year 2003 (which includes model years 2003 and 2004). The 20 vehicles were as follows (in descending order of sales): Ford F-Series, Chevrolet Silverado, Dodge Ram Pickup, Toyota Camry, Honda Accord, Ford Explorer, Ford Taurus, Honda Civic, Chevrolet Impala, Chevrolet TrailBlazer, Toyota Corolla, Chevrolet Cavalier, Dodge Caravan, Ford Focus, Ford Ranger, Jeep Grand Cherokee, Nissan Altima, Chevrolet Tahoe, GMC Sierra, and Ford Expedition. These 20 vehicles constituted 39% of all passenger vehicles sold in the U.S. during 2003 (Automotive News, 2004).

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 three different bulb manufacturers. A breakdown of lamps by light source for the 20 vehicle models surveyed is shown in Table 1. The lamp optics are summarized in Table 2, while Table 3 lists the lamp aiming methods.
<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>HB4 (9006)</td>
<td>12</td>
<td>57.8</td>
</tr>
<tr>
<td>HB5 (9007)</td>
<td>5</td>
<td>22.4</td>
</tr>
<tr>
<td>H13 (9008)</td>
<td>1</td>
<td>13.1</td>
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<tr>
<td>HB2 (9003)</td>
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<td>3.6</td>
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<tr>
<td>H1</td>
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<td>3.1</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>100.0</td>
</tr>
</tbody>
</table>

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<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>18</td>
<td>93.9</td>
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<tr>
<td>Lens optics</td>
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<td>6.1</td>
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<tr>
<td>Total</td>
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<table>
<thead>
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<th>Aiming method</th>
<th>Number of vehicles</th>
<th>Sales-weighted percentage of all vehicles</th>
</tr>
</thead>
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<tr>
<td>VOR</td>
<td>14</td>
<td>77.3</td>
</tr>
<tr>
<td>VOL</td>
<td>3</td>
<td>13.3</td>
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<tr>
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<tr>
<td>Total</td>
<td>20</td>
<td>100.0</td>
</tr>
</tbody>
</table>
RESULTS

Table 4 lists the 25th-percentile, 50th-percentile (median), and 75th-percentile luminous intensities. The horizontal increments in Table 4 are 0.5° between 0° and 5°, 1° between 5° and 10°, and 5° between 10° and 45° (for left and 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 U.S. 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 a pair of low-beam headlamps on current U.S. passenger vehicles. These calculations assume a lamp mounting height of 0.66 m and a lamp separation of 1.20 m (Schoettle, Sivak, & Nakata, 2002.)
| 4SL | 40L | 35L | 30L | 25L | 20L | 15L | 10L | 9L | 8L | 7L | 6L | 5L | 4.5L | 4L | 3.5L | 3L | 2L | 1.5L | 1.25L | 1L | 0.75L | 0.5L | 0.375L | 0.25L | 0.2L | 0.15L | 0.125L | 0.1L | 0.075L | 0.05L | 0.04L | 0.03L | 0.025L | 0.02L | 0.015L | 0.0125L | 0.01L | 0.0075L |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 7U  | 15  | 20  | 24  | 25  | 29  | 32  | 34  | 35  | 37  | 39  | 43  | 47  | 51  | 55  | 59  | 63  | 67  | 71  | 75  | 79  | 81  | 83  | 85  | 87  | 89  | 91  | 93  | 95  | 97  | 99  | 101  |
| 6.5U | 15  | 20  | 24  | 25  | 29  | 32  | 34  | 35  | 37  | 39  | 43  | 47  | 51  | 55  | 59  | 63  | 67  | 71  | 75  | 79  | 81  | 83  | 85  | 87  | 89  | 91  | 93  | 95  | 97  | 99  | 101  |
| 6U  | 15  | 20  | 24  | 25  | 29  | 32  | 34  | 35  | 37  | 39  | 43  | 47  | 51  | 55  | 59  | 63  | 67  | 71  | 75  | 79  | 81  | 83  | 85  | 87  | 89  | 91  | 93  | 95  | 97  | 99  | 101  |
| 5.5U | 15  | 20  | 24  | 25  | 29  | 32  | 34  | 35  | 37  | 39  | 43  | 47  | 51  | 55  | 59  | 63  | 67  | 71  | 75  | 79  | 81  | 83  | 85  | 87  | 89  | 91  | 93  | 95  | 97  | 99  | 101  |
| 5U  | 15  | 20  | 24  | 25  | 29  | 32  | 34  | 35  | 37  | 39  | 43  | 47  | 51  | 55  | 59  | 63  | 67  | 71  | 75  | 79  | 81  | 83  | 85  | 87  | 89  | 91  | 93  | 95  | 97  | 99  | 101  |
| 1.5D | 15  | 21  | 26  | 30  | 34  | 39  | 44  | 50  | 56  | 60  | 66  | 72  | 78  | 84  | 90  | 96  | 102  | 108  | 114  | 120  | 126  | 132  | 138  | 144  | 150  | 156  | 162  | 168  | 174  |
| 1.5U | 15  | 21  | 26  | 30  | 34  | 39  | 44  | 50  | 56  | 60  | 66  | 72  | 78  | 84  | 90  | 96  | 102  | 108  | 114  | 120  | 126  | 132  | 138  | 144  | 150  | 156  | 162  | 168  | 174  |
| 0.5D | 15  | 21  | 26  | 30  | 34  | 39  | 44  | 50  | 56  | 60  | 66  | 72  | 78  | 84  | 90  | 96  | 102  | 108  | 114  | 120  | 126  | 132  | 138  | 144  | 150  | 156  | 162  | 168  | 174  |

Table 4
Luminous intensities (cd) for the sales-weighted sample representing the low-beam headlamps on current passenger vehicles in the U.S. 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.)
<table>
<thead>
<tr>
<th>0.5R</th>
<th>1R</th>
<th>1.5R</th>
<th>2R</th>
<th>2.5R</th>
<th>3R</th>
<th>3.5R</th>
<th>4R</th>
<th>4.5R</th>
<th>5R</th>
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<th>25R</th>
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<tbody>
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<td>502</td>
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<tr>
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<td>132</td>
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</tbody>
</table>

**Note:** The table contains numerical data, possibly related to measurements or calculations in a scientific context. The specific units or context are not clear from the image. The table seems to have rows and columns with values increasing in a pattern, but without clear labels or a clear title, the exact nature of the data is unclear.
Figure 1. Isocandela diagrams of the median luminous intensities for the sales-weighted sample representing the low-beam headlamps on current passenger vehicles in the U.S. The two panels represent the same information in two different formats. Maximum intensity: 22740 cd at 1.0°R, 1.0°D. (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 the U.S. 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 the U.S., but on a sample constituting 39% of all lamps for passenger vehicles sold in the U.S. 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 the U.S. 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. These data have also proven useful in calculating and/or simulating the general effects of adaptive curve-lighting strategies (Sivak et al., 2001; 2004).

As we pointed out in our previous market-weighted low-beam descriptions (Sivak et al., 1997; Sivak et al., 2000; Schoettle et al., 2001; and Schoettle et al., 2003), 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 FMVSS regulations, and thus standard procedures for compliance testing were not followed. Consequently, comparison of the present data with the regulations would be inappropriate.
REFERENCES


