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RECENT TRENDS IN THE PERFORMANCE OF TUNGSTEN-HALOGEN AND HID LOW BEAMS IN THE U.S.

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16. Abstract

This report (1) presents photometric data for a sample of high-intensity discharge (HID) low beams for model year 2004 vehicles in the U.S. and for the corresponding tungsten-halogen low beams manufactured for use on the same vehicles, and (2) analyzes the technological and photometric trends for low-beam headlighting in the U.S. from 1997 to 2004. There are two main findings. First, from 1997 to 2004 there was a general photometric improvement of both tungsten-halogen and HID low beams. Second, the photometric performance of the current HID low beams is superior to that of the current tungsten-halogen low beams.

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Contents

Introduction

Over the past several years, there have been major changes in several aspects of low-beam headlighting in the U.S. The changes include continuous shifts (1) from sealed beams to aerodynamic, vehicle-specific headlamps, (2) from lens to reflector and projector optics, (3) from glass to plastic lenses, and (4) from mechanical to visual aim. Furthermore, new bulbs, both tungsten-halogen based and HID based, have been introduced.

Starting with the 1997 model year, we have periodically documented the influence of these technological changes on headlamp photometric performance. The three studies of tungsten-halogen lamps that we have performed thus far used the same basic approach. Specifically, in these studies we measured the photometric output of the low beams for use on the 20 or 23 (depending on the study) best-selling vehicles in the U.S., and weighted each vehicle's measurements with the respective sales volume to calculate the 25^{th}, 50^{th} (median), and 75^{th} percentile market-weighted values. In one additional study we obtained data for a sample of 19 HID lamps.

The present study (1) provides new data for 5 HID low beams designed for use on the 5 best-selling vehicles that offered HIDs for model year 2004, and for 5 tungsten-halogen lamps for the same vehicles, (2) examines the photometric trends from 1997 to 2004 for both tungsten-halogen and HID low beams, and (3) documents the technological changes over the same time period.

Databases

The following six databases were used in the present analyses:

(1) 1997 market-weighted median tungsten-halogen low beam (Sivak, Flannagan, Kojima, and Traube, 1997); sample size: 23 lamps

(2) 2000 market-weighted median tungsten-halogen low beam (Schoettle, Sivak, and Flannagan, 2000); sample size: 20 lamps

(3) 2004 market-weighted median tungsten-halogen low beam (Schoettle, Sivak, Flannagan, and Kosmatka, 2004); sample size: 20 lamps

(4) 2000 median HID low beam (Sivak, Flannagan, Schoettle, and Nakata, 2002); sample size: 19 lamps

(5) 2004 median HID low beam (current study); sample size: 5 lamps

(6) 2004 median tungsten-halogen low-beam match (current study); sample size: 5 lamps

The 2004 HID sample that was photometered for this study consisted of low beams for the 5 best-selling vehicle models that offered HID low beams either as standard or optional equipment. The 2004 tungsten-halogen low-beam match sample included the tungsten-halogen lamps for the same vehicles as the 5 HID lamps. (Two of these lamps were already included in the 20 lamps measured for the 2004 tungsten-halogen low-beam study; the remaining three were photometered for this study.)

The 2004 HID and the corresponding 2004 tungsten-halogen lamps were purchased in April 2004 in Ann Arbor, Michigan. All were left-side lamps. The lamps were seasoned per SAE Recommended Practice J387 (SAE, 1995). All measurements were made at 12.8 V with standard production bulbs supplied with the lamps at the time of purchase. The measurements were made in a photometry lab using a goniometer. Visual aiming was used to align all lamps prior to the photometry.

Results

Technology trends

The light sources for the tungsten-halogen lamps are shown in Table 1. The types of lamp optics for these lamps are summarized in Table 2, while Table 3 lists the lamp aiming methods. The primary trends for the three market-weighted samples are (1) from HB5 to HB4 light sources, (2) from lens optics to reflector optics, and (3) from mechanical to VOR aiming.

Table 1
Light sources used in the tungsten-halogen lamps. The entries for the 1997, 2000, and 2004 samples are sales-weighted percentages, while the entries for the 2004 match sample are percentages. (Two of the 2004 match lamps are included in the 2004 sample.)

Light source	1997	2000	2004	2004 match
HB1 (9004)	9.3	5.6		
HB2 (9003)	12.5	12.3	3.6	20.0
HB4 (9006)	34.3	35.0	57.8	20.0
HB5 (9007)	43.9	47.0	22.4	
H1			3.1	20.0
H7				20.0
H13 (9008)			13.1	
HIR2 (9012)				20.0

Table 2
Optics of the tungsten-halogen lamps. The entries for the 1997, 2000, and 2004 samples are sales-weighted percentages, while the entries for the 2004 match sample are percentages. (Two of the 2004 match lamps are included in the 2004 sample.)

Optics	1997	2000	2004	2004 match
Reflector	33.4	51.2	93.9	80.0
Lens	66.6	48.8	6.1	
Projector				20.0

Table 3
Specified aiming methods of the tungsten-halogen lamps. The entries for the 1997, 2000, and 2004 samples are sales-weighted percentages, while the entries for the 2004 match sample are percentages. (Two of the 2004 match lamps are included in the 2004 sample.)

Aiming method	1997	2000	2004	2004 match
Mechanical	74.8	61.8	9.4	
VHAD	25.2	9.2		
VOL			13.3	60.0
VOR		29.0	77.3	40.0

The light sources for the HID lamps are shown in Table 4. The types of lamp optics for these lamps are summarized in Table 5, while Table 6 lists the lamp aiming methods. The most prominent trend is away from lens optics. In comparison to the tungsten-halogen lamps, the HID lamps are more likely to use projector as opposed to reflector optics, and VOL as opposed to VOR aiming method.

Table 4
Light sources used in the HID lamps. The entries are percentages.

Light source	2000	2004
D2R	52.6	40.0
D2S	47.4	60.0

Table 5
Optics of the HID lamps. The entries are percentages.

Optics	2000	2004
Reflector	21.0	40.0
Lens	31.6	
Projector	47.4	60.0

Table 6
Specified aiming methods of the HID lamps. The entries are percentages.

Aiming method	2000	2004
VHAD	10.5	
VOL	84.2	80.0
VOR	5.3	20.0

Photometry trends: Basic isocandela diagrams

Figures 1 through 6 present the isocandela diagrams corresponding to the six sample medians. The horizontal range for all data sets was from 45°L to 45°R. The vertical range was from 10°D to 10°U for four sets and from 5°D to 7°U for two sets.

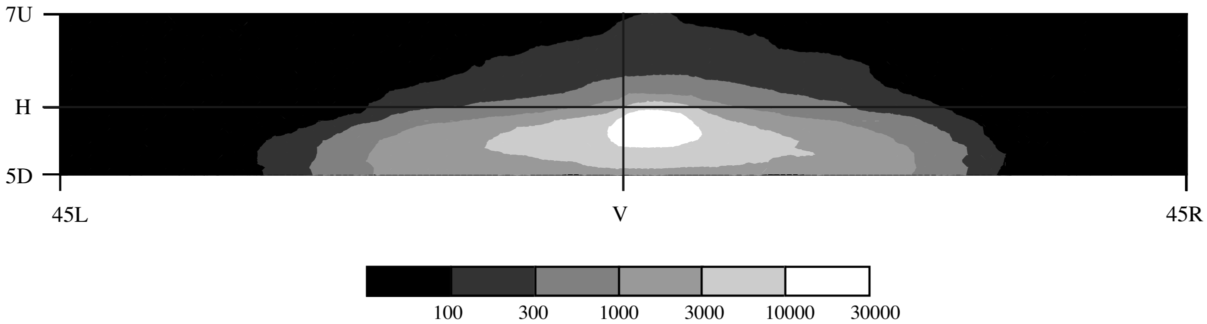

Figure 1. Isocandela diagram of the median luminous intensities (cd) for the sales-weighted sample representing the 1997 model year tungsten-halogen low beams.

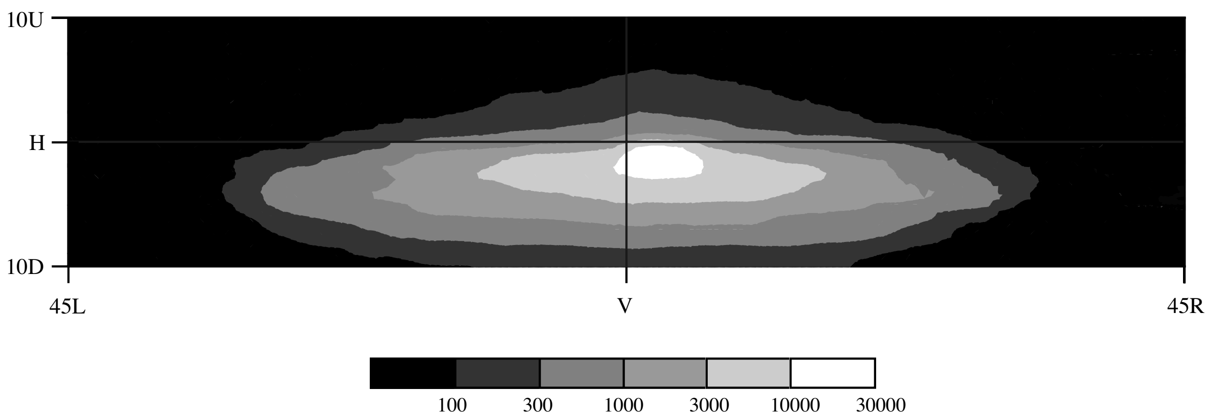

Figure 2. Isocandela diagram of the median luminous intensities (cd) for the sales-weighted sample representing the 2000 model year tungsten-halogen low beams.

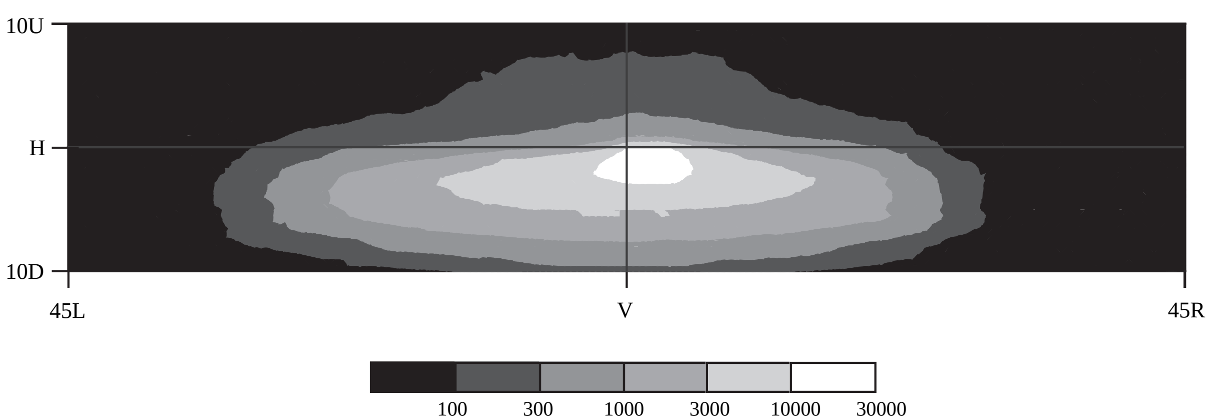

Figure 3. Isocandela diagram of the median luminous intensities (cd) for the sales-weighted sample representing the 2004 model year tungsten-halogen low beams.

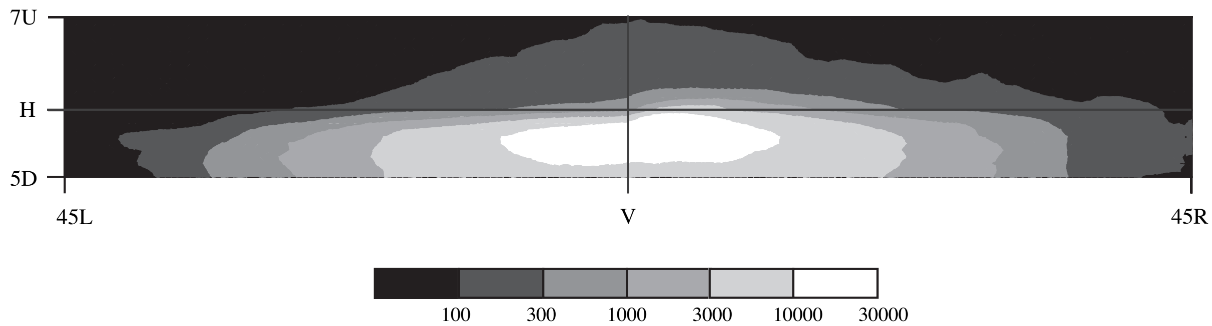

Figure 4. Isocandela diagram of the median luminous intensities (cd) for the sample representing the 2000 model year HID low beams.

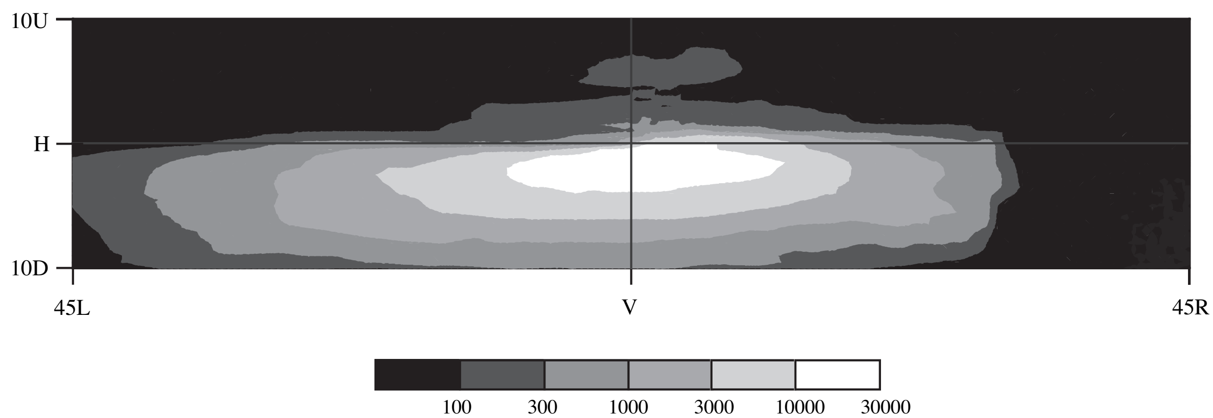

Figure 5. Isocandela diagram of the median luminous intensities (cd) for the sample representing the 2004 model year HID low beams.

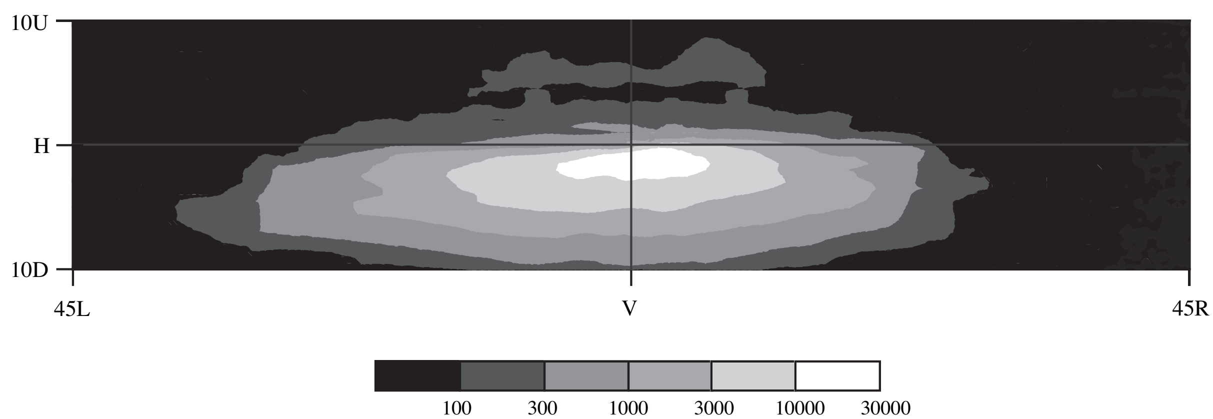

Figure 6. Isocandela diagram of the median luminous intensities (cd) for the sample representing the 2004 model year tungsten-halogen low beams that were evaluated as matched pairs to the 2004 HID sample.

Photometry trends: Tungsten-halogen low beams

Figure 7 shows the differences between the newest (2004) and the oldest (1997) median market-weighted luminous intensities for the central part of the beam pattern from 10° left to 10° right and from 5° down to 7° up. The main changes in the luminous intensities over time, as evident in Figure 7, are as follows: (1) increases just below the horizontal, both to the immediate right and left of the vertical, (2) general increases in the left half of the beam pattern, (3) decreases in the right part of the beam pattern in an area centered near 1.5° down and 3.5° right, and (4) general decreases in the right part of the beam pattern above the horizontal.

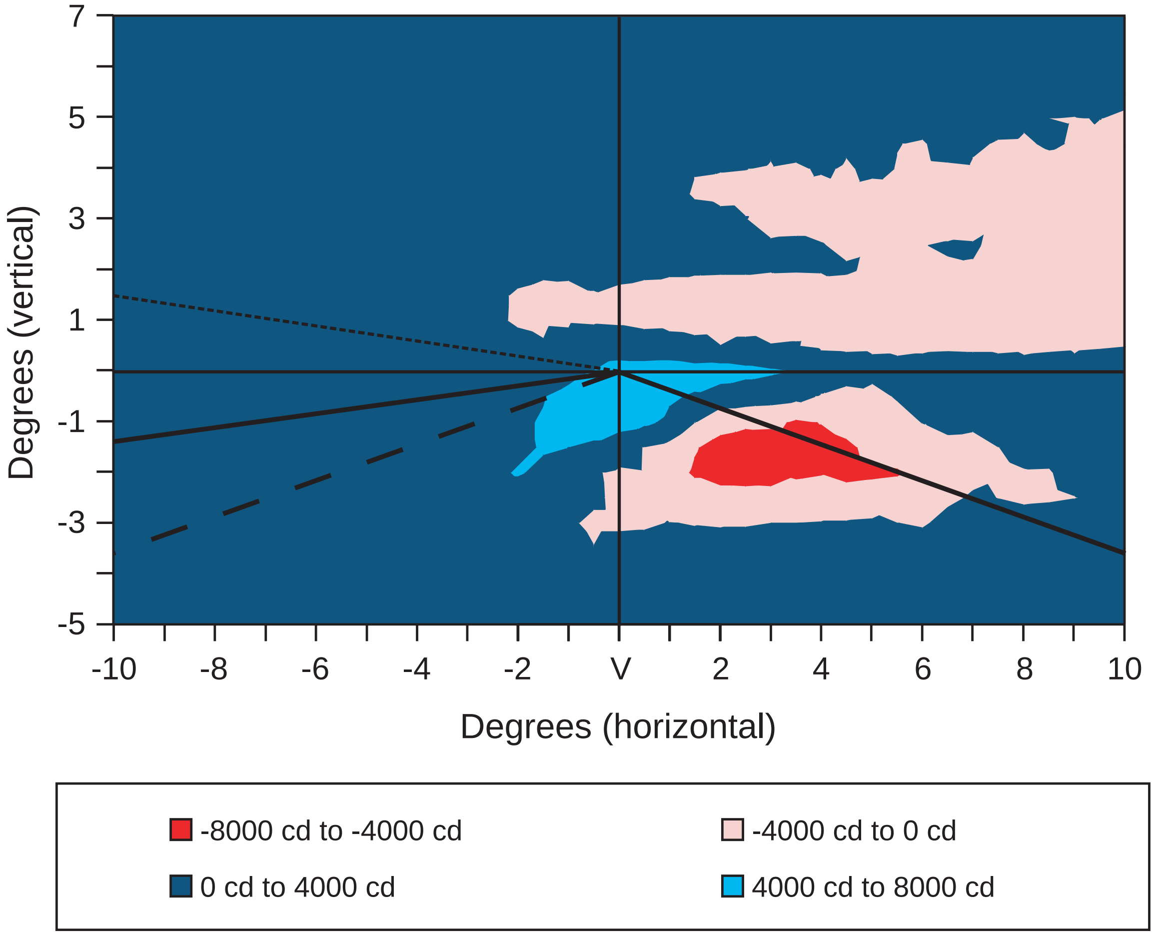

Figure 7. Differences between the 2004 and the 1997 median market-weighted luminous intensities in the central part of the beam pattern of the tungsten-halogen low beams (2004 intensities minus 1997 intensities). (The solid lines below the horizontal represent the edges of a roadway with two 3.7-m lanes. The dashed line below the horizontal represents the road midline. The dotted line above the horizontal represents the trajectory of the eyes of an oncoming driver in the left adjacent lane.)

Photometry trends: HID low beams

Figure 8 presents the differences between the 2004 and the 2000 luminous intensities for HID low beams. The main differences, as evident in Figure 8, are as follows: (1) major increases just below the horizontal, both to the right and left of the vertical, with the largest increase in an area centered near 0.5° down and 1.5° right, (2) general decreases to the right of the vertical below about 1.5° down, and (3) general decreases to the left of the vertical below about 2.5° down.

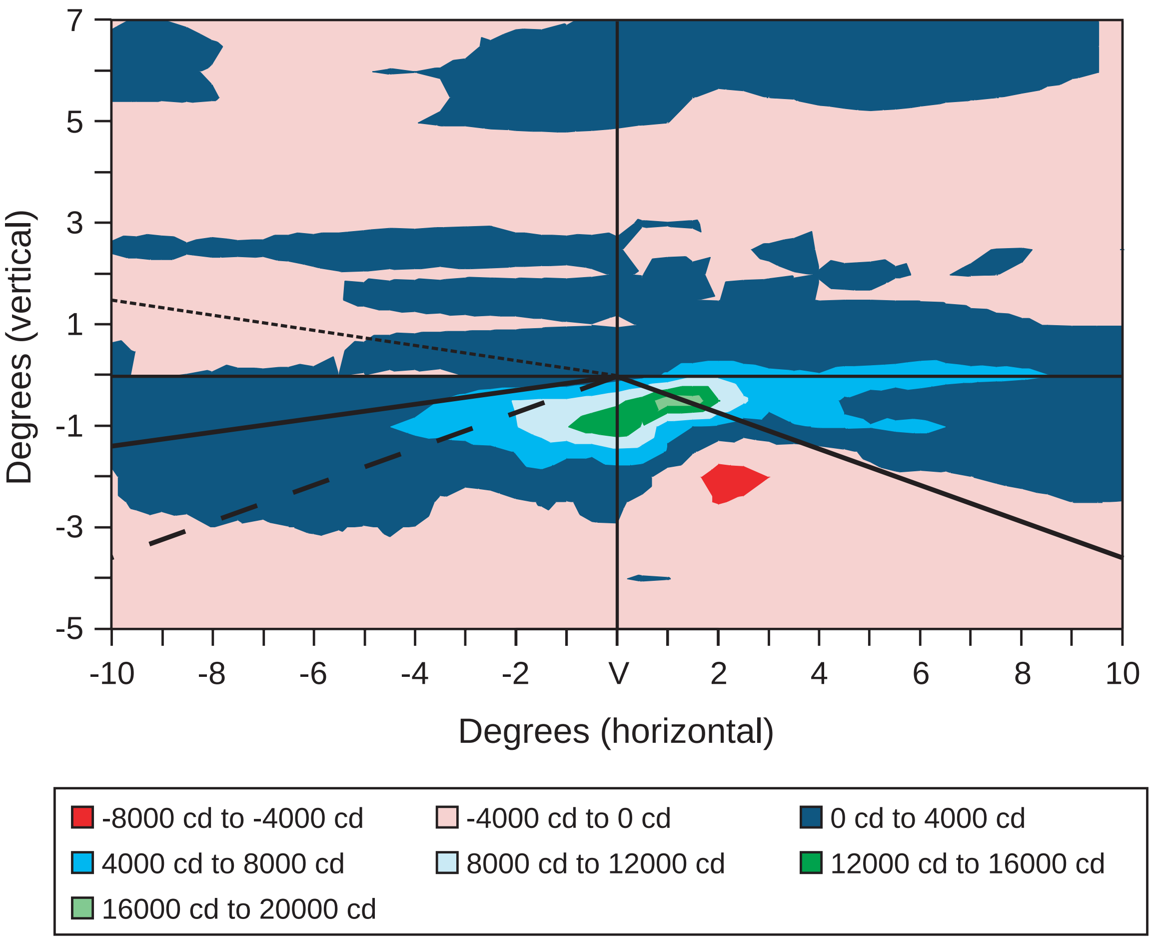

Figure 8. Differences between the 2004 and the 2000 median luminous intensities in the central part of the beam pattern of the HID low beams (2004 intensities minus 2000 intensities.

Photometry trends: HID vs. tungsten-halogen low beams

Figure 9 presents the differences between the median 2004 HID luminous intensities and the median market-weighted 2004 tungsten-halogen luminous intensities. The main differences, as evident in Figure 9, are as follows: (1) HIDs produce greater intensities below the horizontal, both to the right and left of the vertical, (2) tungsten-halogen low beams produce greater intensities above the horizontal to the left of the vertical, and above about 1° to the right of the vertical, and (3) tungsten-halogen low beams produce greater intensities near the intercept of the horizontal and the vertical.

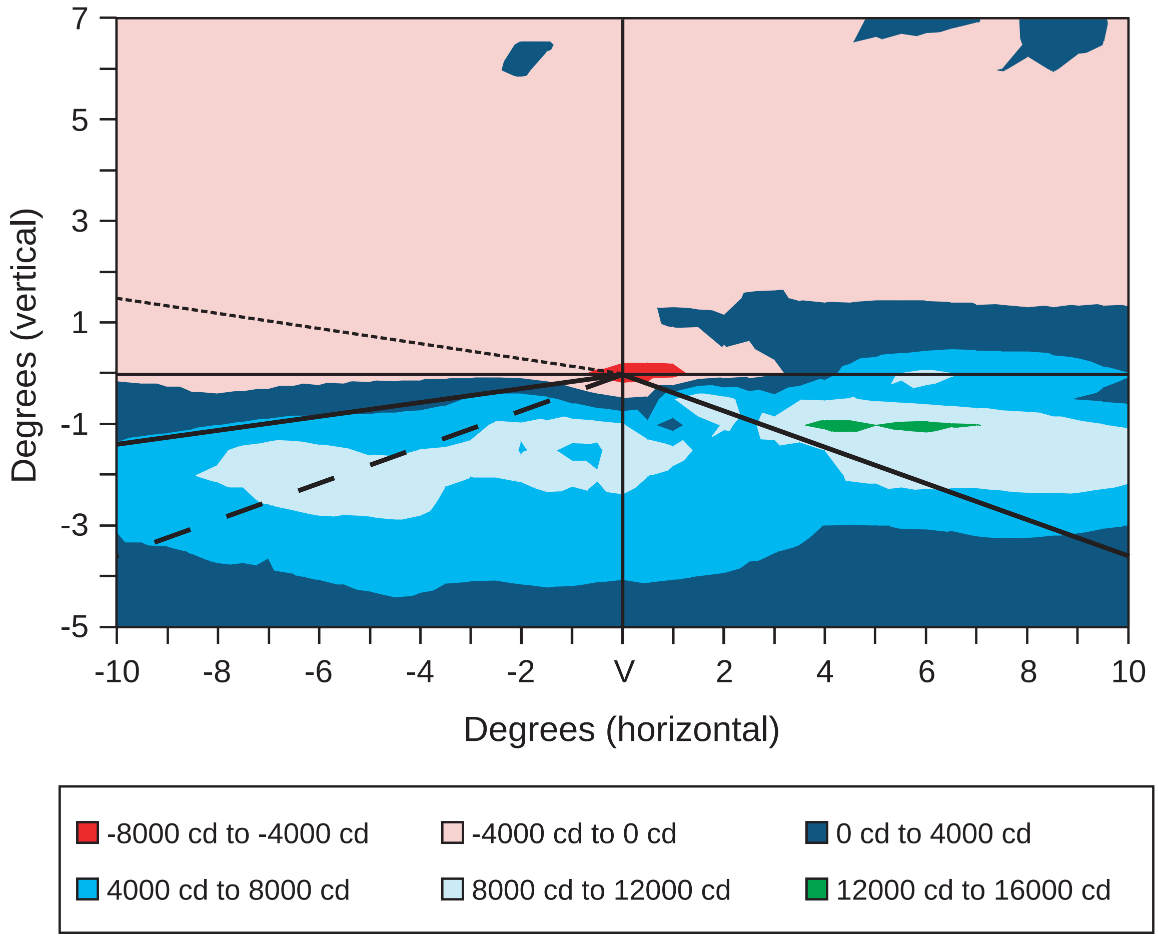

Figure 9. Differences between the median 2004 HID luminous intensities and the median market-weighted 2004 tungsten-halogen median luminous intensities in the central part of the beam pattern of the low beams (HID intensities minus tungsten-halogen intensities).

The immediately preceding analysis compared the median 2004 HIDs to the median 2004 market-weighted tungsten-halogens. Figure 10 consists of an analogous comparison involving matched headlamp pairs. Specifically, Figure 10 compares the median luminous intensities of the 2004 HIDs with the median luminous intensities of 2004 tungsten-halogens manufactured for use on the same vehicles. With one exception, the main findings in Figure 10 are consistent with those in Figure 9. The exception is that the HIDs in the present analysis produced greater luminous intensities near the intercept of the horizontal and the vertical.

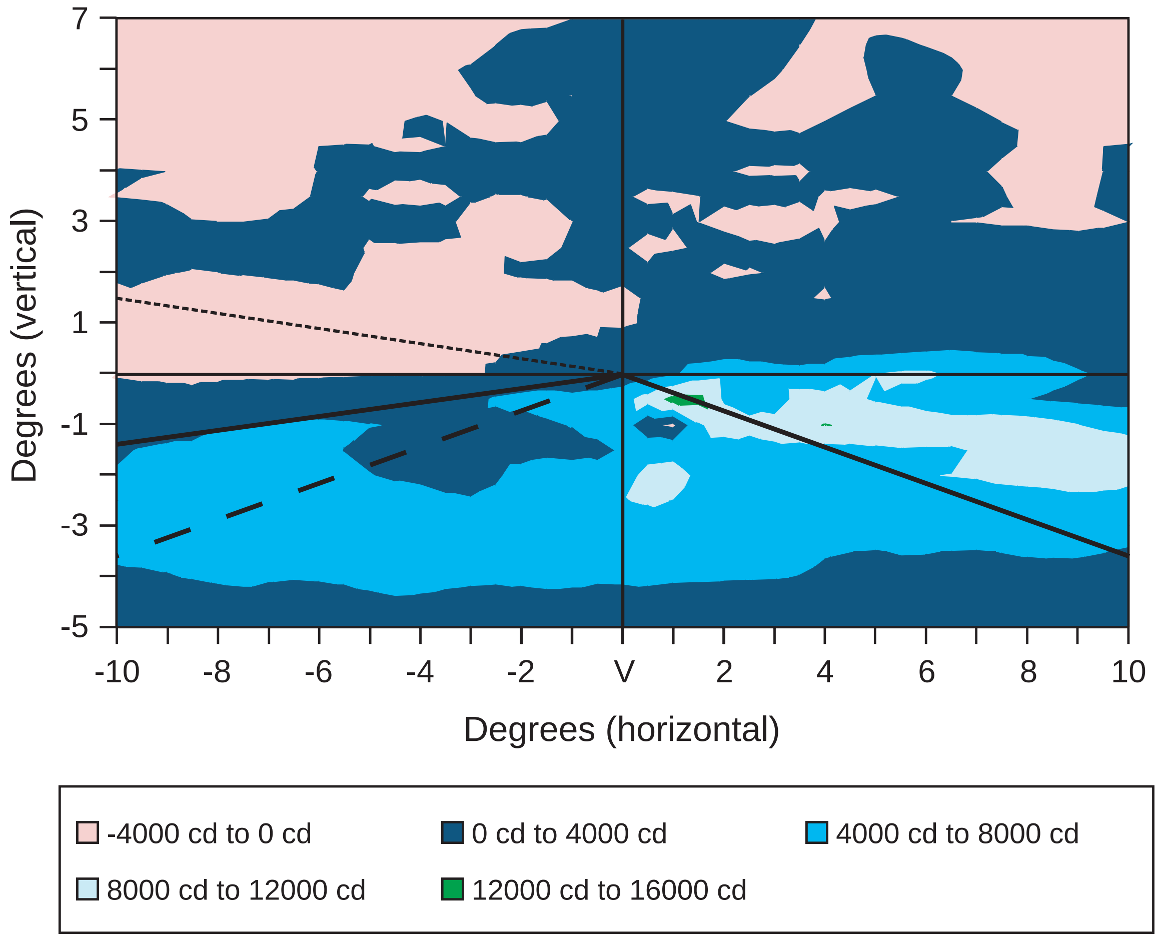

Figure 10. Differences between the 2004 HID and 2004 tungsten-halogen median luminous intensities (HID intensities minus tungsten-halogen intensities). The two samples involve low beams manufactured for use on the same vehicles.

The differences between the tungsten-halogen and HID low beams for the same vehicles in terms of the illuminances for vertical surfaces at a range of locations on the roadway are illustrated in Figure 11. The calculations underlying the information in Figure 11 are based on two lamps, and they assume a lamp mounting height of 0.66 m and a lamp separation of 1.20 m (Schoettle, Sivak, and Nakata, 2002). The main finding of this analysis is that the HID lamps deliver more illuminance throughout the investigated region of the roadway ahead (laterally 25 m to the left and right of the center of the lane of travel, and longitudinally up to 100 m).

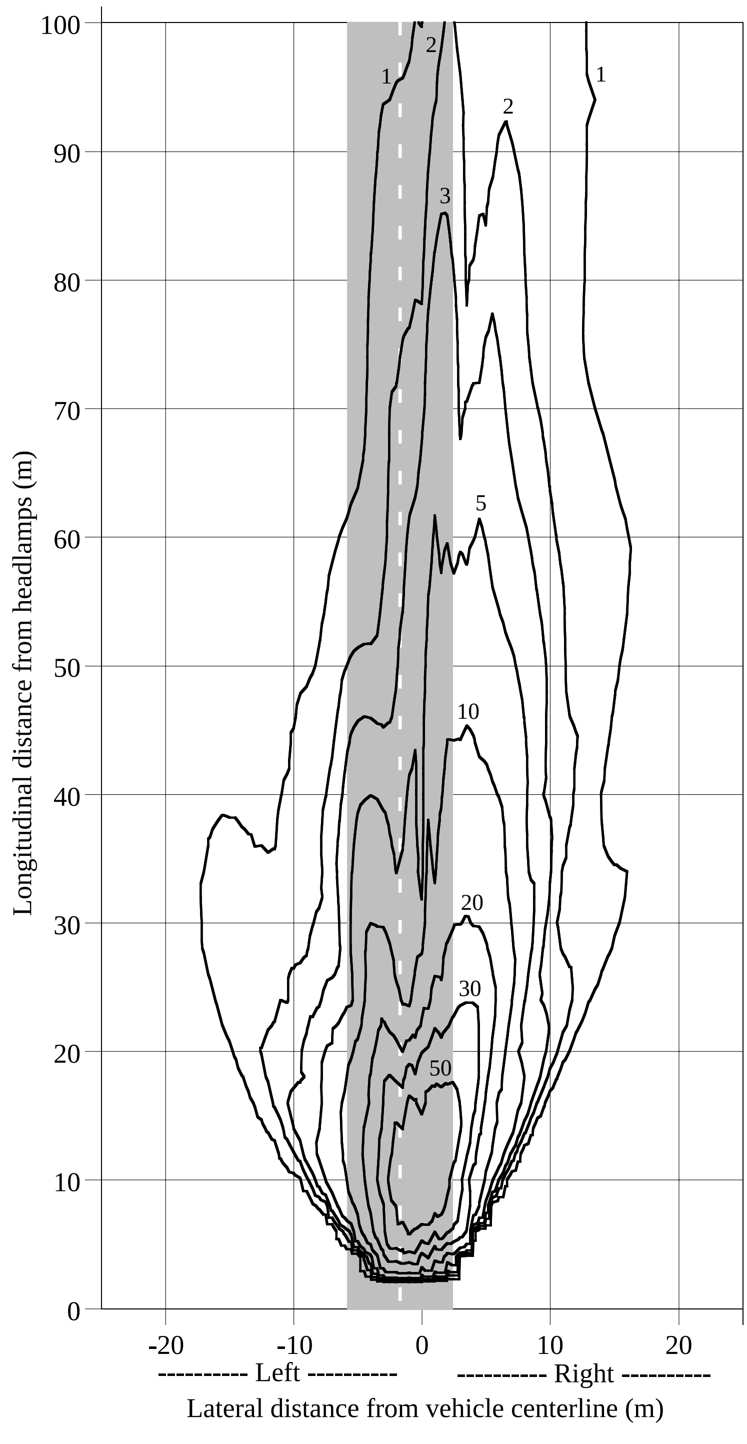

Figure 11. Differences in illuminances (in lux on a vertical surface at various locations on the roadway) between the median 2004 HID and the median 2004 tungsten-halogen low beams. The two samples involve lamps manufactured for use on the same vehicles. The calculations are based on two lamps, and they assume a lamp mounting height of 0.66 m and a lamp separation of 1.20 m. The shaded area represents a standard two-lane road, with a lane width of 3.7 m. All of the differences are positive (HID values higher than tungsten-halogen values).

The final analysis consisted of evaluating each beam pattern's performance at four important test points. In 1993 (Sivak and Flannagan, 1993), we provided evidence for using four specific test points as a minimum set for evaluating low-beam performance. These four test point locations, with minor modifications, were incorporated into the U.S. requirements for visual/optical aiming, and they also play an important role in the current Japanese regulations and in current proposals from SAE and GTB for worldwide harmonization. The modified coordinates within the U.S. FMVSS 108 (FMVSS, 2003) were selected for analysis in this study. These test points evaluate visibility to the right, visibility straight ahead, visibility to the left, and oncoming glare. The analyzed test points are graphically displayed in Figure 12. The results of this analysis are presented in Figures 13 through 16.

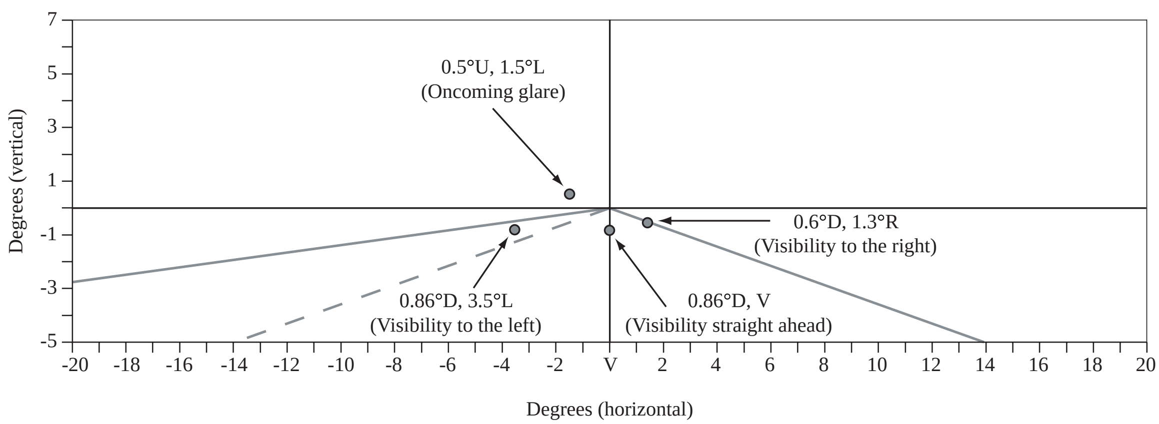

Figure 12. Locations of the four evaluated test points. (Lane width: 3.7 m; lamp height: 0.66 m.)

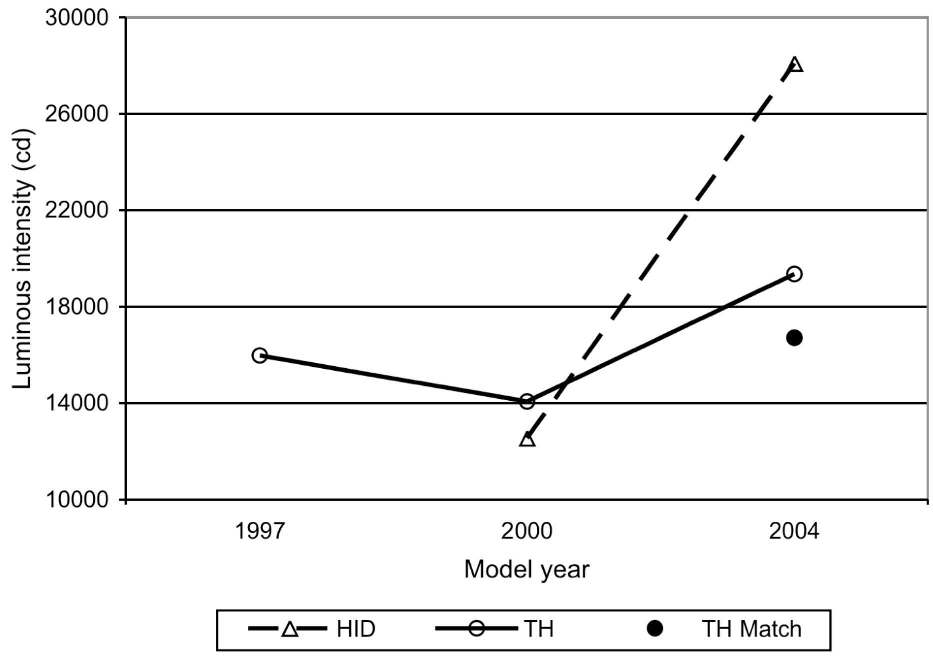

Figure 13. The median luminous intensities for the six samples at 0.6°D, 1.3°R—a test point that evaluates visibility to the right.

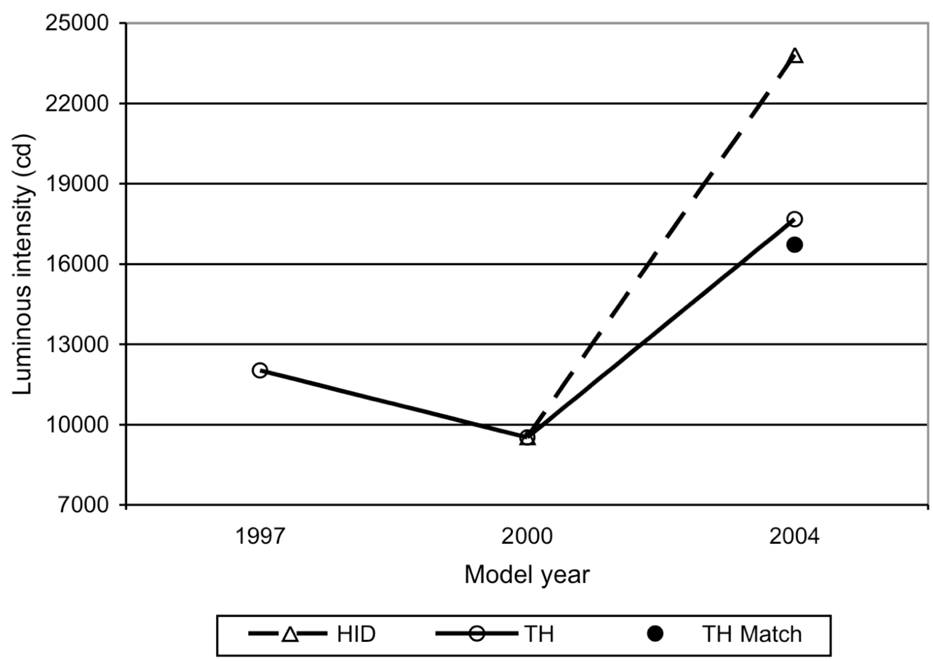

Figure 14. The median luminous intensities for the six samples at 0.86°D, V—a test point that evaluates visibility straight ahead.

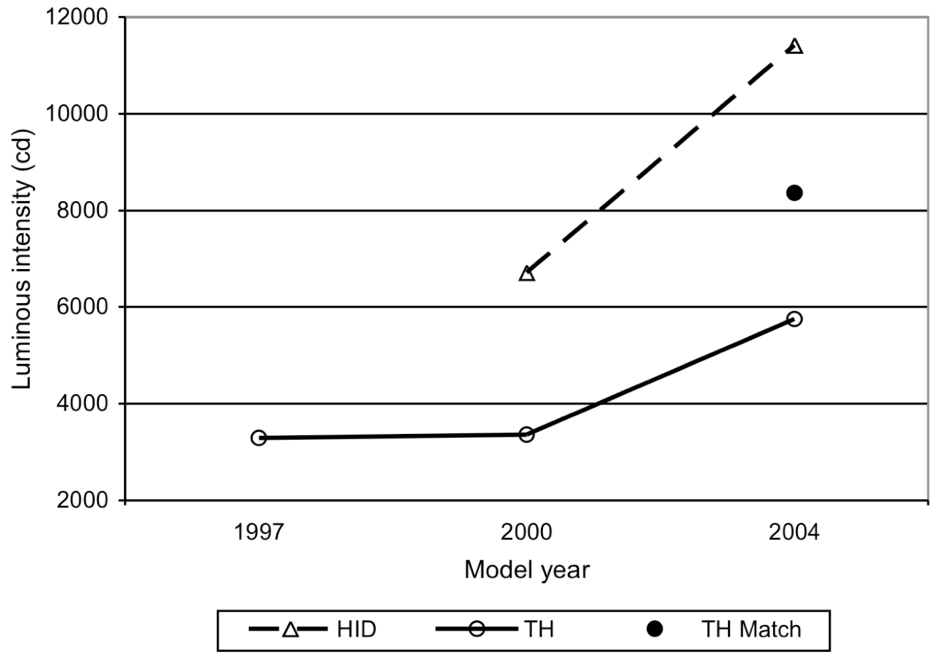

Figure 15. The median luminous intensities for the six samples at 0.86°D, 3.5°L—a test point that evaluates visibility to the left.

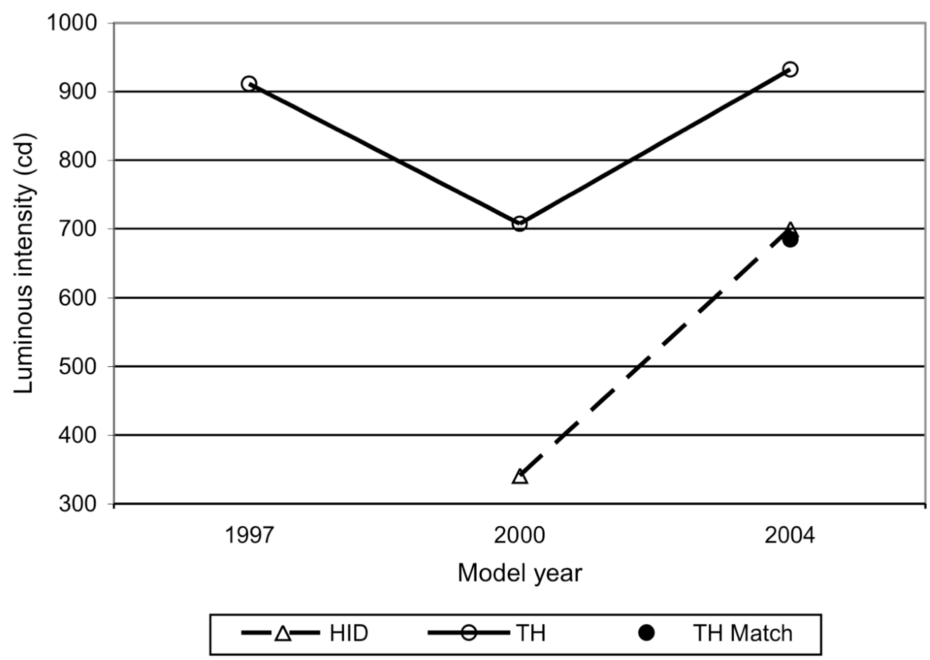

Figure 16. The median luminous intensities for the six samples at 0.5°U, 1.5°L—a test point that evaluates oncoming glare.

The main results of the analyses in Figures 13 through 16 are as follows:

(1) For the tungsten-halogen low beams, there were substantial increases from 1997 to 2004 in the median market-weighted luminous intensities at all three visibility test points (increases of 3,388 cd to the right, 5,657 cd straight ahead, and 2,469 cd to the left), and virtually no change at the glare point (an increase of 21 cd).

(2) For the HID low beams, there were major increases from 2000 to 2004 in the median luminous intensities at all three visibility test points (increases of 15,527 cd to the right, 14,269 cd straight ahead, and 4,708 to the left), and an increase at the glare test point (of 360 cd).

(3) The median luminous intensities for the 2004 HID low beams at all three visibility test points were substantially greater than the luminous intensities for the 2004 tungsten-halogen low beams. The differences to the right, in favor of the HIDs, were 8,725 cd in comparison to the median market-weighted tungsten-halogens and 11,368 cd in comparison to the median tungsten-halogens for the same vehicles. The analogous differences, again in favor of the HIDs, were 6,130 cd and 6,304 cd straight ahead, and 5,664 cd and 3,063 cd to the left.

(4) At the glare test point, the median 2004 HID luminous intensity was substantially lower than the median market-weighted luminous intensity of the 2004 tungsten-halogens (by 232 cd, or 25%), and it was very close to the median luminous intensity of the tungsten-halogens for the same vehicles (a difference of 15 cd in favor of the tungsten-halogens).

Conclusions

This report (1) presented photometric data for a sample of HID low beams for model year 2004 vehicles in the U.S. and for the corresponding tungsten-halogen low beams manufactured for use on the same vehicles, and (2) analyzed the technological and photometric trends for low-beam headlighting in the U.S. from 1997 to 2004.

There were two main findings. First, from 1997 to 2004 there was a general photometric improvement of both tungsten-halogen and HID low beams. Second, the photometric performance of the current HID low beams is superior to that of the current tungsten-halogen low beams.

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