UMTRI-2004-23

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Report No. UMTRI-2004-23
September 2004

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-2004-23		

4. Title and Subtitle	5. Report Date
A Market-Weighted Description of Low-Beam Headlighting Patterns in the U.S.: 2004	September 2004
	6. Performing Organization Code 302753
7. Author(s) Schoettle, B., Sivak, M., Flannagan, M.J., and Kosmatka, W.J.	8. Performing Organization Report No. UMTRI-2004-23
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, Michigan 48109-2150 U.S.A.	10. Work Unit no. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address The University of Michigan Industry Affiliation Program for Human Factors in Transportation Safety	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

The Affiliation Program currently includes AGC America, Autoliv, Automotive Lighting, Avery Dennison, BMW, DaimlerChrysler, DBM Reflex, Denso, Federal-Mogul, Ford, 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, Renault, Samlip, Schefenacker International, Sisecam, Solutia Performance Films, Stanley Electric, TG North America, Toyota Technical Center USA, Truck-Lite, Valeo, Vidrio Plano, Visteon, 3M Personal Safety Products, and 3M Traffic Safety Systems.

Information about the Affiliation Program is available at: http://www.umich.edu/~industry

16. Abstract

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.

17. Key Words	18. Distribution Statement
headlighting, headlamps, photometry, U.S., low beams, passing beams, sales, market-weighted	Unlimited

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
None	None	15	

ACKNOWLEDGMENTS

Appreciation is extended to the members of the University of Michigan Industry Affiliation Program for Human Factors in Transportation Safety for support of this research. The current members of the Program are:

AGC America
Autoliv
Automotive Lighting
Avery Dennison
BMW
DaimlerChrysler
DBM Reflex
Denso
Federal-Mogul
Ford
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
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Samlip
Schefenacker International
Sisecam
Solutia Performance Films
Stanley Electric
TG North America
Toyota Technical Center, USA
Truck-Lite
Valeo
Vidrio Plano
Visteon
3M Personal Safety Products
3M Traffic Safety Systems

We wish to thank Jeff Erion, Bob Suzio, and Mike Moran of Visteon for their technical assistance and for allowing us to use their facilities to perform the photometry.

CONTENTS

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, Flannagan, Kojima, & Traube, 1997; Sivak, Flannagan, & Schoettle, 2000; Schoettle, Sivak, & Flannagan, 2001; and Schoettle, Sivak, Flannagan, & 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 1
Light sources used in the tested lamps.

Light source	Number of vehicles	Sales-weighted percentage of all vehicles
HB4 (9006)	12	57.8
HB5 (9007)	5	22.4
H13 (9008)	1	13.1
HB2 (9003)	1	3.6
H1	1	3.1
Total	20	100.0

Table 2
Optics of the tested lamps.

Optics	Number of vehicles	Sales-weighted percentage of all vehicles
Reflector optics	18	93.9
Lens optics	2	6.1
Total	20	100.0

Table 3
Specified aiming methods of the tested lamps.

Aiming method	Number of vehicles	Sales-weighted percentage of all vehicles
VOR	14	77.3
VOL	3	13.3
Mechanical	3	9.4
Total	20	100.0

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.)

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.)

	45L	40L	35L	30L	25L	20L	15L	10L	9L	8L	7L	6L	5L	4.5L	4L	3.5L	3L	2.5L	2L	1.5L	1L	0.5L	0
7U	15 21 35	20 25 34	24 26 33	25 30 33	27 37 45	42 49 56	51 73 79	71 90 105	71 98 116	70 107 119	70 109 128	72 116 141	76 111 147	75 108 151	75 103 148	75 100 143	77 101 143	79 102 146	80 104 145	81 107 141	82 115 136	81 124 134	81 123 135
6.5U	17 25 36	20 28 34	25 29 35	29 32 36	28 38 45	42 51 61	54 75 82	71 97 114	72 104 131	71 112 128	74 118 132	77 119 152	81 114 157	80 112 164	80 110 161	81 111 161	83 112 161	84 114 160	85 117 159	85 122 149	86 126 149	88 137 145	88 136 151
6U	17 27 37	21 31 37	26 34 37	30 36 38	29 39 47	44 54 66	59 76 87	74 103 127	76 112 133	78 119 140	81 124 153	84 126 163	86 119 183	87 118 188	87 116 188	84 115 191	89 120 194	91 126 179	91 131 169	91 137 164	92 143 164	96 152 163	99 148 168
5.5U	20 28 36	22 31 39	25 34 41	32 39 42	31 42 48	44 57 69	63 79 88	82 112 148	83 119 140	82 127 145	89 132 195	96 133 173	95 139 191	96 131 207	92 131 211	90 134 213	95 142 215	101 150 204	100 159 188	101 163 182	101 159 182	106 158 182	109 169 184
5U	18 27 36	22 31 40	26 38 45	34 42 46	33 46 53	45 61 77	67 88 102	90 121 153	90 125 158	93 135 152	99 144 204	104 139 188	106 140 210	108 155 218	105 154 221	101 159 211	102 168 212	107 180 229	113 185 210	113 188 204	113 183 204	115 178 202	116 182 204
4.5U	18 27 36	22 32 41	26 42 47	37 46 52	37 50 58	49 63 79	73 90 105	97 135 159	103 144 164	108 152 188	111 156 212	114 155 189	118 159 211	122 163 217	119 176 229	117 181 229	118 187 234	123 203 234	128 210 238	134 211 241	131 208 249	134 203 244	137 199 239
4U	17 26 36	22 34 42	26 43 49	39 50 55	43 56 61	57 67 82	81 96 114	104 147 177	113 159 185	116 169 200	128 168 190	129 174 201	138 176 225	143 180 236	139 188 245	137 197 253	138 208 245	141 195 250	146 200 261	144 201 263	145 203 284	148 208 298	146 211 292
3.5U	19 26 37	22 35 44	27 43 53	44 56 61	56 59 67	65 75 88	89 102 123	118 158 188	127 169 201	129 181 220	146 185 213	151 194 224	160 200 242	164 202 248	163 204 261	164 215 259	167 217 261	171 223 266	175 229 270	172 230 283	176 233 313	182 239 321	190 250 305
3U	20 26 36	23 35 46	30 44 55	48 60 66	63 69 73	71 87 99	102 111 130	137 180 193	146 192 205	146 204 226	163 203 230	164 211 237	176 215 258	177 221 271	179 228 283	183 233 305	183 237 307	197 246 317	196 254 330	197 257 353	197 262 345	197 266 353	189 269 349
2.5U	21 26 35	23 36 47	30 46 57	53 64 73	72 79 80	79 108 116	112 127 138	154 198 203	162 215 225	169 225 242	177 225 242	175 233 254	189 242 268	198 250 282	203 257 309	209 256 322	206 261 304	222 269 321	242 270 350	247 274 399	257 291 395	271 296 432	270 317 481
2U	23 25 35	24 35 43	34 48 59	58 71 75	81 90 92	91 118 134	130 146 152	175 219 229	183 223 242	197 234 256	196 253 271	198 263 297	204 276 306	208 286 336	211 298 372	214 295 407	218 297 417	234 305 421	257 332 428	269 333 444	275 348 455	273 360 516	247 376 572
1.5U	23 25 35	26 37 41	36 51 57	63 78 80	87 101 112	106 141 159	148 176 192	211 251 261	216 255 276	226 272 285	241 288 331	241 301 342	251 330 355	256 335 375	254 351 405	254 356 425	255 365 451	263 372 477	285 370 487	315 392 525	346 425 583	383 453 728	426 446 839
1U	23 25 38	30 38 40	43 50 56	74 80 86	103 115 125	135 178 204	190 208 272	268 288 336	278 297 353	296 318 387	298 336 405	282 362 438	290 390 458	298 412 458	306 426 494	326 443 524	344 467 555	362 507 606	372 500 642	411 532 700	461 567 761	499 607 887	490 619 952
0.5U	23 23 41	29 36 41	40 54 59	74 84 103	110 143 153	160 226 278	249 276 316	344 414 449	354 415 493	364 421 555	392 426 645	409 446 719	393 496 759	420 561 781	462 597 806	499 647 807	504 708 904	535 774 939	587 835 1004	701 932 1110	989 1087 1428	1148 1633 1975	1410 2159 2741
0	21 23 40	30 38 43	50 55 62	80 101 132	131 177 211	206 323 388	337 417 614	459 673 954	480 715 922	508 775 1078	548 829 1290	620 939 1469	717 1093 1714	777 1221 1960	830 1213 2229	945 1315 2380	1071 1486 2529	1255 1672 2741	1706 2080 3130	2323 2796 3799	2576 4352 5459	3622 6272 8273	5758 8830 11846
0.5D	21 22 36	30 36 45	52 59 66	88 122 182	158 227 298	339 467 679	583 694 1319	1011 1307 2022	1273 1474 2184	1450 1699 2531	1577 2022 2858	1713 2338 3549	1868 2691 4081	1912 2921 4243	2062 3491 4565	2147 3663 4915	2235 4022 5659	2898 4541 7015	3713 5366 7625	5016 6760 8841	6435 8750 11333	9045 11788 15013	10401 14555 19338
1D	19 22 35	30 36 46	52 62 78	89 153 248	223 303 435	489 700 1074	938 1090 2077	1659 3062 3245	1907 3285 3820	2380 3455 4350	2600 3946 5039	2792 4747 5979	2937 5306 6756	3107 5904 6951	3319 6338 7598	3553 6573 8353	4205 6960 8915	6042 7130 9524	7292 8823 10668	8540 10570 12525	10782 12513 15053	13358 15840 17885	15520 18902 20419
1.5D	19 23 39	30 35 51	49 67 97	101 170 332	322 384 562	637 934 1426	1417 1525 2532	2385 3357 4545	2756 3677 5018	3137 4248 5714	3559 4850 6769	3725 5774 7761	4159 6926 8134	4395 7601 8898	4823 8102 10126	5481 8274 11280	6546 8301 11950	8022 8813 12603	8075 11410 13476	8842 13309 16152	10335 14406 17175	12772 15957 18259	15190 17099 20271
2D	20 24 43	30 34 49	48 68 101	109 208 357	356 521 740	912 1368 1806	1922 2310 2932	3138 4438 5182	3347 4781 5872	3671 5089 6743	4153 6034 7647	4524 6835 8101	5065 7404 8695	5523 7875 9250	6139 7865 9730	7091 8268 10475	7670 9082 11278	7918 10333 11879	8111 11921 12911	8730 12191 13995	9804 13083 14646	11479 14222 15636	13349 14705 16603
2.5D	21 23 42	30 33 50	50 72 112	120 213 377	437 596 867	1111 1749 1939	2202 3004 3336	3556 4614 5775	4037 4909 6265	4548 5315 7398	5127 5809 8074	5018 6670 8259	6119 7101 8712	6415 7096 8997	6825 7430 9300	7122 8229 9502	7114 8957 9881	7111 8845 11203	7373 9678 11317	8115 10064 11490	8587 10458 11753	9495 11126 12124	10410 11790 13292
3D	20 23 42	31 32 48	49 72 121	123 254 393	494 695 926	1084 1771 2126	2289 3075 3648	3348 5080 5461	3598 5262 6023	4153 5599 6825	4484 6035 7091	4591 6444 6995	4748 6481 7653	4908 6551 7919	5157 7016 8145	5393 7382 8511	5748 7597 9375	6000 7765 9597	6325 7899 9564	6633 8403 9514	7017 8624 10294	7160 8762 10470	7411 8905 10472
3.5D	20 23 40	30 32 47	51 71 110	128 258 388	501 775 934	1065 1794 2155	2412 2585 3538	3202 4652 5072	3540 5100 5574	3625 5275 6094	3992 5622 6030	4385 5256 6575	4509 5449 7124	4309 5702 7349	4290 5842 7558	4305 6015 7843	4375 5949 8094	4511 5932 8214	4682 6472 7917	4887 6580 7734	5032 6505 7722	5158 6572 7827	5280 6773 7960
4D	19 24 41	30 32 50	49 72 111	158 257 390	481 795 911	962 1612 2091	2076 2454 3166	2683 4004 4324	2781 4324 4809	3023 4568 5070	3150 4516 5123	3273 4390 5508	3374 4448 5745	3485 4581 5889	3672 4730 5991	3828 4855 6030	3825 4855 6098	3883 4955 5972	3930 4964 5837	3961 5017 6005	3984 4993 6068	4056 5052 5945	4149 5157 6047
4.5D	19 23 41	29 30 50	47 68 117	159 239 370	438 791 901	854 1575 1856	1784 2314 2607	2187 3220 3826	2365 3377 3884	2439 3677 3868	2558 3641 3984	2718 3579 4199	2861 3637 4490	2803 3669 4596	2701 3729 4594	2641 3873 4623	2626 3951 4658	2649 4006 4624	2737 3999 4665	2748 3937 4657	2672 3950 4695	2686 3961 4669	2722 3939 4652
5D	21 23 41	25 31 48	46 60 118	143 205 338	368 685 932	758 1334 1634	1501 1905 2338	1755 2476 3180	1976 2679 3198	2063 2895 3052	2122 2909 3209	2132 2941 3334	1978 2963 3515	1990 2976 3570	1999 3002 3557	2008 3010 3486	2020 3031 3526	2060 3007 3581	2094 3035 3650	2024 3024 3696	1953 2991 3703	1956 2992 3842	1969 2965 3764

	0.5R	1R	1.5R	2R	2.5R	3R	3.5R	4R	4.5R	5R	6R	7R	8R	9R	10R	15R	20R	25R	30R	35R	40R	45R
7U	84	91	90	90	89	87	84	78	75	73	68	61	56	57	55	44	34	23	14	8	4	2
	117	112	109	109	110	111	119	121	125	120	116	108	93	88	85	60	42	30	17	10	8	5
	137	136	137	135	133	130	130	134	138	137	143	144	122	107	100	66	47	36	25	13	11	9
6.5U	90	94	94	94	92	91	88	86	85	81	74	67	63	60	56	46	37	25	14	8	4	3
	132	128	131	130	127	130	135	137	138	138	134	129	101	94	91	66	47	33	18	10	8	5
	153	155	156	159	158	155	152	153	149	151	154	159	133	121	111	71	51	36	28	14	11	8
6U	98	98	99	102	99	98	96	94	93	90	80	76	73	67	62	51	39	26	14	7	4	3
	145	148	151	153	154	155	153	149	147	146	145	121	115	103	97	65	49	33	18	11	7	4
	171	176	186	192	196	194	188	176	175	171	161	173	156	131	122	75	53	35	29	14	10	9
5.5U	111	111	109	106	105	102	105	104	100	97	91	87	81	76	71	54	42	30	16	8	4	3
	169	174	176	175	173	181	187	192	185	169	149	157	122	114	105	69	50	35	20	11	7	4
	186	203	201	207	213	212	207	195	194	191	181	185	172	143	128	82	58	40	30	14	11	9
5U	116	116	117	115	114	119	116	112	112	109	103	99	90	89	83	57	47	31	16	7	4	3
	178	177	173	177	186	195	199	203	196	173	159	152	131	122	108	77	59	38	21	11	8	5
	215	213	214	217	227	232	232	227	226	225	215	206	187	157	138	90	62	44	33	15	12	10
4.5U	136	138	136	137	137	135	134	128	124	119	115	112	100	101	96	67	48	32	15	8	4	3
	200	198	198	198	207	196	214	215	202	192	165	162	143	136	115	86	65	39	21	12	8	5
	244	240	238	239	248	249	249	251	250	250	243	217	196	169	156	96	68	50	35	17	13	10
4U	148	156	155	149	149	149	142	139	139	136	130	124	113	113	108	74	50	35	16	8	5	2
	217	218	215	216	215	214	219	228	215	222	181	174	153	145	126	92	72	45	21	12	8	5
	274	262	250	247	251	255	265	272	274	281	264	247	217	187	167	106	77	55	38	19	14	11
3.5U	188	185	186	191	188	182	180	171	161	156	154	139	128	127	124	80	53	38	17	8	4	3
	253	244	236	234	233	234	236	240	246	223	215	191	182	172	152	102	78	50	23	13	8	5
	286	287	283	277	280	274	263	261	259	261	264	278	236	209	175	121	86	57	39	20	14	12
3U	189	205	207	195	193	189	176	179	182	182	170	153	159	142	138	94	61	41	20	8	4	3
	276	277	276	272	262	259	264	261	246	225	213	204	200	185	159	113	88	53	25	14	8	5
	335	330	323	279	278	280	284	286	290	291	286	271	263	233	214	150	101	66	44	25	16	12
2.5U	270	250	251	250	244	246	256	236	223	194	192	188	180	167	160	104	71	47	21	8	4	3
	329	330	314	300	296	295	298	291	274	276	271	264	231	207	185	129	97	63	27	16	7	4
	510	525	487	424	398	371	350	322	331	326	319	332	313	274	244	168	126	81	47	28	19	12
2U	234	250	267	258	258	240	247	251	256	253	244	233	216	193	178	132	80	49	23	9	4	3
	389	395	395	389	380	369	367	365	362	345	303	294	263	237	219	146	110	71	33	15	8	5
	562	580	553	508	484	462	404	408	409	402	375	351	338	288	286	189	160	97	51	29	23	11
1.5U	389	407	391	387	389	413	311	306	323	334	302	283	261	233	216	161	105	57	23	9	4	3
	452	448	419	432	435	440	440	424	479	423	370	342	332	294	282	188	127	75	38	14	8	4
	840	837	826	744	713	805	786	683	624	566	486	419	368	348	322	241	193	101	60	28	22	12
1U	438	494	473	527	426	443	458	431	404	375	354	325	321	324	293	209	109	67	26	9	4	3
	589	662	620	578	577	551	600	560	547	576	511	451	426	373	354	241	171	79	44	13	7	4
	1033	987	1372	1270	1175	1159	1053	904	939	889	787	732	662	589	494	318	265	119	61	31	19	11
0.5U	1587	1772	1877	1808	1795	1531	1277	1158	906	850	720	641	560	468	449	283	130	76	24	8	3	3
	2393	2391	2387	2578	2815	2520	2206	1684	1415	1201	875	694	582	560	519	340	224	97	52	13	7	4
	3464	4032	4592	4437	4618	4562	4307	4094	3449	2776	1955	1328	1100	1000	967	620	355	162	60	30	15	10
0	6928	7419	7738	8033	7423	6556	5558	3920	3323	2226	1429	1133	941	702	596	412	183	88	26	7	4	3
	10124	11952	11972	12662	11838	10688	9678	7168	6261	4717	3092	2319	1540	1200	1120	514	333	107	55	13	6	4
	14864	15369	15235	15814	15970	14869	13281	11026	9013	7011	4761	3467	2855	2155	1706	1013	464	194	66	31	13	8
0.5D	12314	14520	15545	15293	14282	11186	8573	6891	5452	4285	2760	1873	1542	1175	933	680	278	94	28	7	4	3
	18927	18885	18564	17318	16958	15969	14287	12020	9411	7896	5457	3918	3290	2632	2275	859	486	111	53	12	7	4
	21634	26203	27227	26806	25316	21204	18768	15194	12777	10831	8539	7096	4244	3345	3464	1625	630	230	91	26	14	8
1D	17681	19353	19917	18788	16805	14120	12214	10531	8572	6854	4400	3206	2732	2615	2020	1202	421	113	25	6	4	2
	21929	22740	21595	20174	19033	16962	14921	13178	11174	9898	7295	5378	4221	3551	2801	1401	691	140	50	15	7	4
	22842	25640	25869	24478	23635	22360	20750	17065	14828	12662	9794	8753	7206	5310	4507	2015	814	260	101	28	13	7
1.5D	16911	17472	17127	16187	15185	14510	13330	10828	10003	8244	6322	5052	3756	3150	2956	1731	563	140	25	6	4	3
	19076	20241	19534	18785	18074	17209	16324	13592	11002	10257	8096	6429	5195	4632	4237	1968	867	191	50	14	6	4
	20835	24181	27177	25605	22788	19771	17922	16056	15223	13945	11359	9376	8797	6703	6229	2234	1116	303	125	31	13	7
2D	13339	12826	12447	12706	11982	11339	10618	9850	9072	8624	6121	4973	4389	3973	3635	1931	731	162	30	7	3	3
	16457	16273	16247	15821	15442	15130	14545	13626	11242	10498	8180	7105	5902	5122	4399	2516	1089	235	51	12	7	4
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	12335	12550	12603	12605	12491	12265	11860	11221	10115	9231	7600	6701	5599	5155	4932	3108	1103	290	50	13	6	4
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4D	4154	4102	4041	4009	4076	4153	4014	3720	3408	3374	3371	3203	3011	2842	2705	1355	660	166	25	6	3	3
	4990	5025	5137	5152	5347	5237	5072	4964	4830	4708	4513	4306	4138	3880	3785	2301	1276	355	49	13	7	4
	5968	6099	6083	6152	6175	6201	6360	6151	5880	5610	5212	4994	4826	4803	4550	3339	1665	623	123	34	15	9
4.5D	2753	2715	2689	2692	2746	2838	2935	2894	2698	2481	2490	2541	2424	2310	2261	1182	558	148	22	6	3	2
	3962	3936	3911	3884	4107	4085	3899	3792	3658	3552	3564	3490	3287	3111	2978	2170	1216	368	50	12	7	4
	4629	4583	4552	4512	4515	4591	4608	4600	4408	4232	4048	3968	3876	3826	3703	2876	1526	562	116	32	14	8
5D	2046	2031	2014	2000	2004	2028	2048	2018	2072	2023	2038	2070	1946	1847	1822	945	422	112	20	6	4	2
	2960	2930	2953	2973	3027	2993	2970	2929	2845	2813	2819	2662	2625	2582	2367	1721	1097	319	57	13	6	4
	3740	3722	3643	3573	3507	3474	3563	3469	3397	3322	3217	3147	2982	3048	2910	2463	1406	493	108	33	12	8

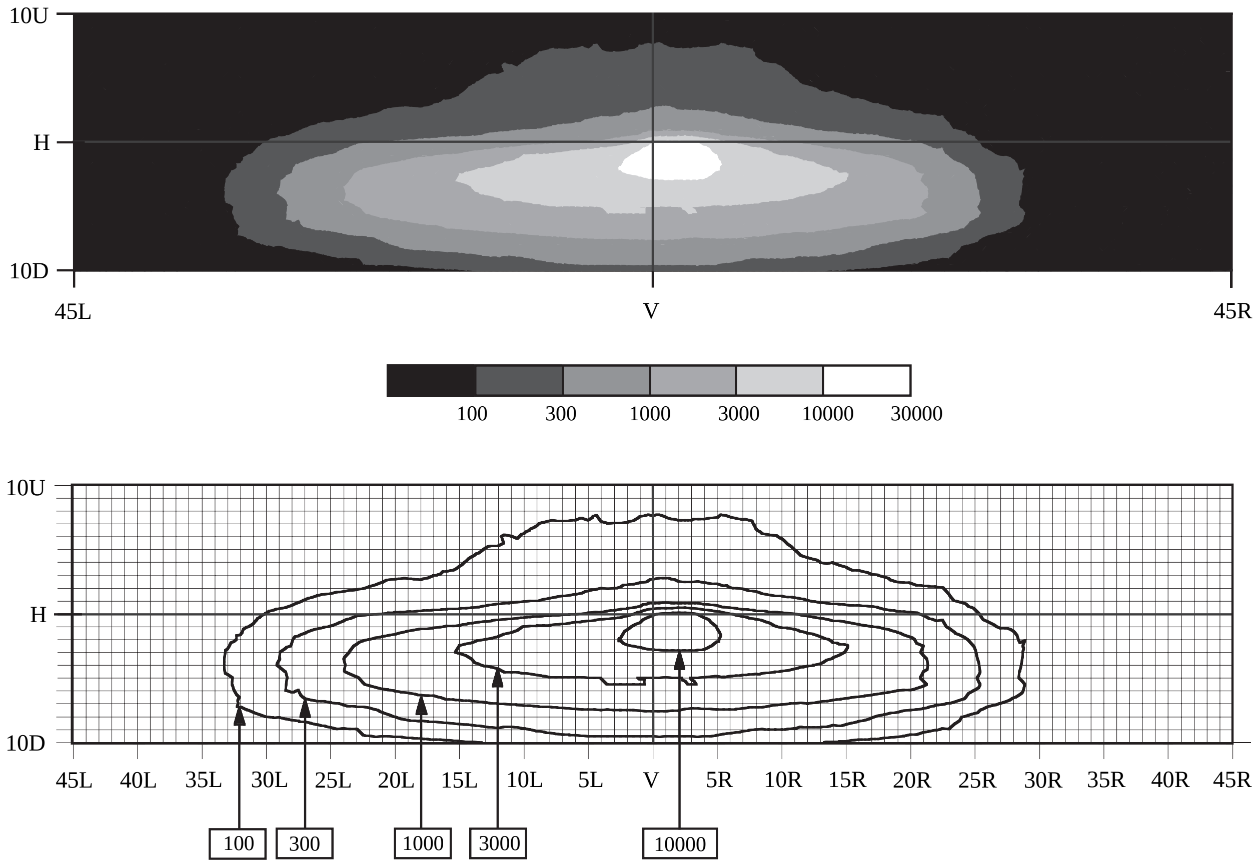

Figure 1. Isocandela diagrams of the median luminous intensities for the sales-weighted sample representing the low-beam headlamps on current passenger vehicles in the U.S. The two panels represent the same information in two different formats. Maximum intensity: 22740 cd at 1.0°R, 1.0°D. (Test voltage: 12.8 V)

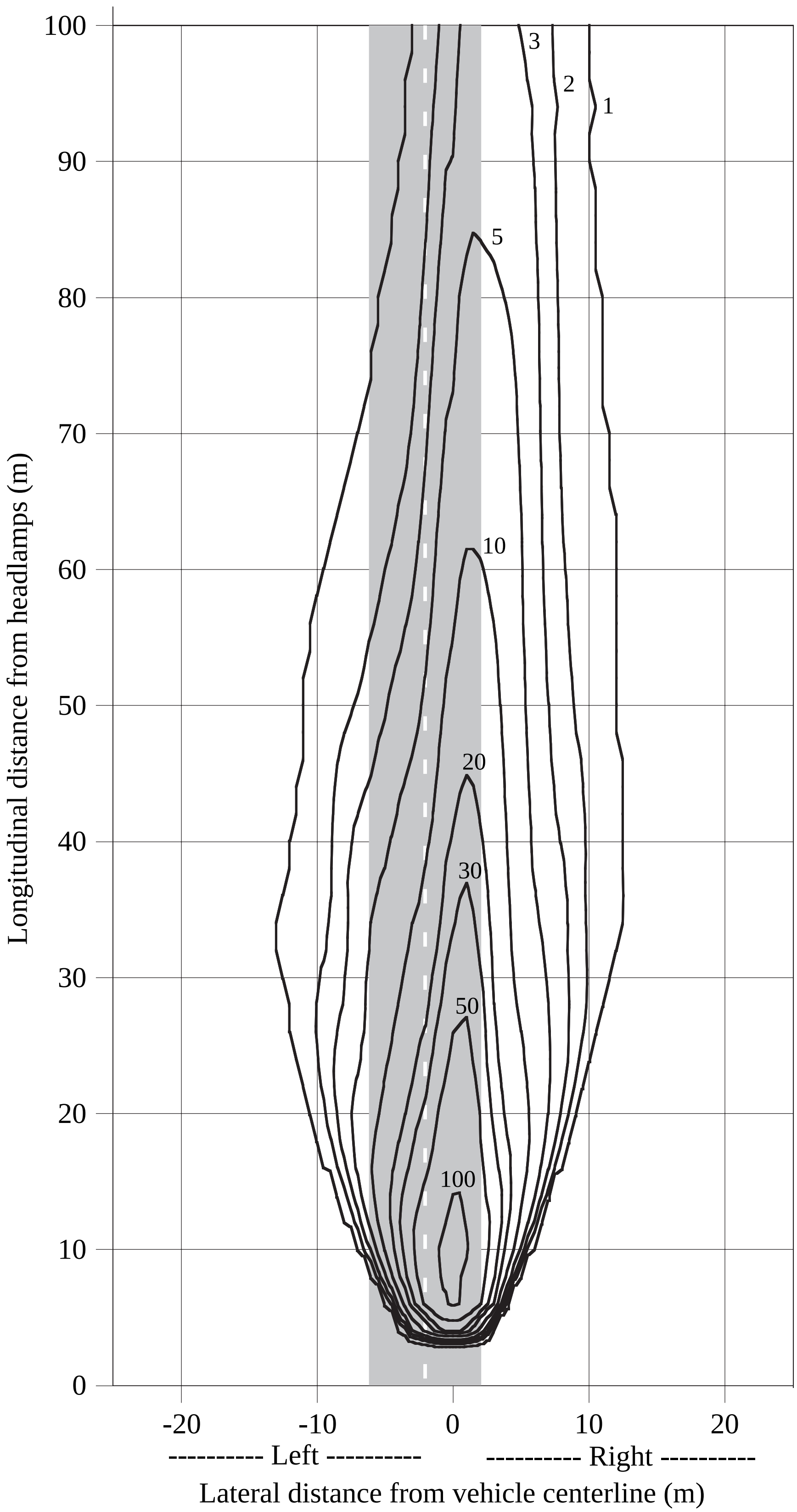

Figure 2. Isoilluminance diagram (in lux) on a vertical surface at the road surface from a pair of lamps with the median luminous intensities for the sales-weighted sample representing the low-beam headlamps on current passenger vehicles in the U.S. The shaded area represents a standard two-lane road. (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.

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