

	SURFACE VEHICLE DRAFT TECHNICAL REPORT	SAE J2584 FEB2011
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Headlamp Mounting Height for Passenger and Pickup Truck Vehicles		

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1. **Scope**—The Mounting Height Task Force was tasked to determine the extent of the problem(s) associated with vehicle headlamps mounted at or above the level of the mirror(s) in passenger vehicles; the level of glare exposure caused by high-mounted headlamps; the appropriate height differential needed to maintain a glare level consistent with past and/or current passenger vehicle headlamp mounting; and the necessary headlamp mounting height necessary to control mirror glare at an accepted/acceptable level. The report herein addresses these passenger vehicle mounting height issues.
2. **References**
 - 2.1 **Applicable Publications**—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.
 - 2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J2338—Report of the Task Force on Headlamp Mounting Height for Large Trucks
SAE Paper #740962 1974—Miller, Baumgardner, Mortimer, "An Evaluation of Glare in Nighttime Driving Caused by Headlights Reflected in Rearview Mirrors"
SAE Paper #970911 (1997)—Kosmatka, W., 1997, "Comparison of Models for Detection of Highway Obstacles with Headlamps"
 - 2.1.2 UMTRI PUBLICATIONS—Available from UMTRI, RPC, 2901 Baxter Road, Ann Arbor, MI 48109-2150. Email: umtridocs@umich.edu, 734-764-2171.
 1. Sivak, Flannagan, Traube, Kojima, UMTRI 97-23, The Influence of Stimulus Duration on Discomfort Glare for Persons With and Without Visual Correction, Univ. of Mich. Trans. Res. Inst., May 1997
 2. Sivak, Flannagan, Kojima, Traube, (1997). A market-weighted description of low-beam headlighting patterns in the U.S. Report UMTRI-97-37. Ann Arbor: The Univ. of Mich. Trans. Res. Inst.
 3. Rumar, Sivak, Traube, Miyokawa (1999), Nighttime Visibility of Retroreflective Pavement Markings from Trucks Versus Cars, No.UMTRI-99-34, Ann Arbor, Univ. of Mich. Trans. Res. Inst.

2.1.3 OTHER PUBLICATIONS

- a. Olson, P., Sivak, M., Glare from Automobile Rear Vision Mirrors, *Human Factors*, 26(3), 269-282, 1984
- b. Schmidt-Clausen, Bindels (1974) Assessment of discomfort glare in motor vehicle lighting. *Lighting Res. and Tech.*, 6, 79-88
- c. Kosmatka, W., Minutes of the Mounting Height Task Force, May 2, 1995, Southfield Michigan
- d. Consumer Reports Magazine, Jan – Sept, 1999 New vehicle driving test reports

3. Definitions

- 3.1 **Sport Utility Vehicle (SUV)**—Types of passenger vehicles designed with potential for off-road use. They generally have increased ground clearance and are higher than conventional passenger vehicles.
- 3.2 **De Boer Glare Rating Scale**—A nine-point scale for describing the relative levels of discomfort glare. Qualifiers, for the odd points, are as follows: 1 – unbearable; 3 – disturbing; 5 – just acceptable; 7 – satisfactory; 9 – just noticeable.
- 3.3 **Luxmeter Cell**—A light sensitive transducer capable of turning incident radiometric flux into current or voltage. The device output, in an appropriate electrical circuit, is proportional to the intensity of the incident radiation and can be reported by an output device as “lux,” “foot-candles” or “candela.”
4. **Background**—In 1996, the Mounting Height Task Force published SAE J2338 addressing the problems with high-mounted headlamps on heavy trucks. The report suggested that headlamp mounting height on these large vehicles be limited to 0.9 m to 1.0 m.

Due to the increased popularity of Sport Utility Vehicles (SUV's), there is evidence of increase in public awareness and dissatisfaction with mirror glare from the headlamps on these passenger vehicles. NHTSA had indicated an industry need to control this apparent problem with voluntary limits on headlamp placement or rulemaking actions. In May of 1999, in response to public sentiment and at the request of members of the Road Illumination Devices Committee, the chair reconvened the Mounting Height Task Force to evaluate problems associated with small vehicles, including pickup trucks and SUV's that were specifically omitted from the “heavy truck” recommendations.

The task force reviewed approximately 70 letters written by motorists to NHTSA (excerpts recorded in Task Force meeting minutes of September 1999). In general, the writers express dissatisfaction with glare from high-mounted headlamps (generally) on SUV vehicles. Both frontal and rear glare are mentioned. Side mirror glare is noted along with interior mirror glare. The interior mirror is dimmable at the driver's option. It was the opinion of the task force, that the location and relative height of the *side mirror represented the more extreme case* in the case of driver discomfort glare. For these reasons the task force focused its investigations on the driver side mirror in the matter of addressing mounting height for headlamps.

5. **Review of Discomfort Glare Studies**—The task force reviewed several published glare studies as part of reevaluation of headlamp mounting height.
- 5.1 **Foveated Source**—Miller *et al.* (1974) used driver voluntary dimming as a measure of the level of glare from a foveated source that drivers were willing to tolerate. They found that 60% of drivers dimmed their headlamps at 360 m (1200 ft) or greater and that another 28% had dimmed them by 180 m (600 ft). Using information about headlamps of that vintage, the authors concluded that drivers would accept near-foveal illuminance of 0.43 to 1.72 lux (the report actually found “0.04 to 0.16 fc”). Miller *et al.* determined that side mirrors were exposed to 1.9 lux for normally aimed headlamps and 11.9 lux for misaimed headlamps.

- 5.2 Peripheral Source**—Olson and Sivak (1984) studied glare from peripheral sources. They found side mirror glare levels just below “admissible” for eyepoint illumination of 2.37 to 8.61 lux (for “long” exposure durations and “short” exposure durations respectively). They also noted *disability effects* for side mirror glare at peripheral eyepoint illumination levels of 7.75 and 75.5 lux.
- 5.3 Admissible Level**—Sivak *et al.* (1997) studied “oncoming” vehicle glare and concluded that the “just admissible” level, (De Boer level 5) and the less than “admissible” level (De Boer level 4) ranged from 3 lux to 4 lux. This study used a controlled glare angle of 3.5 degrees and a controlled glare duration time of 3 s.
- 5.4 Peripheral Angle**—Schmidt-Clausen and Bindels (1974) documented discomfort glare as a function of the peripheral angle to the point-of-focus. They found an inverse relationship of the 0.46 power between the angle of the glare source to the driver’s point-of-focus, to the De Boer rating.
- 6. Acceptable Discomfort Limits for Side Mirror Glare**—With the information previously, along with an assumption for windshield losses (10%) and side-mirror/side-window losses (50%), the task force was able to define a range for “acceptable” discomfort glare in various driving situations. The progression of the calculations of acceptable mirror glare is described in Table 1.
- Miller *et al.*: – Direct Glare at the Eyepoint: 0.4 to 1.6 lux near-foveal glare (applying a 90% for “windshield transmittance” for vehicles *circa* 1974 and rounding to the first decimal place)
 - Olson and Sivak – Side Mirror Illuminance: 2.37 to 8.61 lux for approximate De Boer “level 5” side mirror glare (“3 minute” and “10 second” exposure; no side mirror/window transmittance factor)
 - Sivak *et al.* – Duration Effect: Interpolation from “Figure 4” (see Appendix A), long durations increase the discomfort effect by about 1 to 2 De Boer units. *E.g.*, acceptable range for near-foveal glare ranges from 3.0 to 0.8 lux.
 - Schmidt-Clausen & Bindels – Glare Angle: The glare angle algorithm allows calculation of a transfer function of “3.06” to “3.24” for side mirror glare at peripheral angles of 35 to 45 degrees (relative to the 3.5 degree angle in Sivak *et al.*).
- 6.1 Exposure Duration**—Sivak *et al.* propose a glare tolerance algorithm – De Boer glare rating = $5.05 - 1.405 \log$ (exposure seconds). The glare tolerance limit, experimentally determined for short duration exposure, is 3.0 lux. The exposure algorithm then allows definition of tolerance at longer exposure times. A 10 to 20 second time would imply a reduction of one De Boer level, so, in order for a driver to tolerate glare for this length of time, the glare must be reduced *e.g.*, De Boer level 6. Similarly, in order for glare to be tolerable for one minute, the implied shift in glare tolerance is 1.8 De Boer units. For a three-minute exposure, the shift is about 2.5 De Boer units.
- The time-dependent glare tolerance was interpolated using figure 4 in UMTRI 97-23 (Appendix A) at Discomfort Glare levels of “5” for short duration; “6” for intermediate duration; and “7” for long durations. The interpolation yielded eyepoint illuminance of 3 lux, 1.5 lux, and 0.8 lux respectively.
- 6.2 Peripheral Glare Tolerance**—The glare tolerance levels previously are for foveated glare at the nominal angle of 3.5 degrees (210 arc-min) to the point-of-focus. In order to account for the peripheral nature of the side mirror glare (versus the foveal tolerance values) angular-ratio factors were calculated for angles of 35, 40, and 45 degrees using Schmidt-Clausen and Bindels’ algorithm. The algorithm shows that discomfort glare is *inversely proportional to the angle between the point-of-focus and the peripheral glare source (minutes of arc), raised to the 0.46 power*. The implied effect of peripheral glare light is less than that of foveated glare light. The tolerance ratios for the angles previously are 3.06, 3.15, and 3.24 respectively for the three angles previously. The products of the peripheral-glare-ratios and the glare tolerances for different exposure durations are in Table 1.

TABLE 1—METHODOLOGY FOR DEFINING “JUST ADMISSIBLE” LIMITS FOR SIDE MIRROR GLARE⁽¹⁾

	Sivak, Flannagan, Traube, Kojima (UMTRI 97-23) 3 s Exp	Sivak, Flannagan, Traube, Kojima (UMTRI 97-23) 3 s Exp	Sivak, Flannagan, Traube, Kojima (UMTRI 97-23) 3 s Exp	Sivak, Flannagan, Traube, Kojima (UMTRI 97-23) 10 to 20 s Exp	Sivak, Flannagan, Traube, Kojima (UMTRI 97-23) 10 to 20 s Exp	Sivak, Flannagan, Traube, Kojima (UMTRI 97-23) 10 to 20 s Exp	Sivak, Flannagan, Traube, Kojima (UMTRI 97-23) 1 to 3 Min Exp	Sivak, Flannagan, Traube, Kojima (UMTRI 97-23) 1 to 3 Min Exp	Olson & Sivak, 1984 Exposure Duration 10 s	Olson & Sivak, 1984 Exposure Duration 3 Min
Interpolate De Boer level 5 “Just Admissible” from UMTRI 97-23, figure 5	3.0 lux	3.0 lux	3.0 lux	X	X	X	X	X	X	X
Adjust for Long Exposure duration: UMTRI 97-23 algorithm; 1.0 and 2.0 De Boer units	X	X	X	1.5 lux	1.5 lux	1.5 lux	0.8	0.8	X	X
Peripheral Glare 45 deg	11.3			4.86	4.6	2.45			8.61 lux	2.37 lux
Adjust UMTRI 97-23 data 40 deg using Schmidt-Clausen & Bindels algorithm.		10.7	10.1				2.52	2.59	8.61 lux	2.37 lux
Side Mirror Illuminance 45 deg	22.6			9.7	9.2	4.9			17.2	4.7
(multiply by 2 for 50% mirror & window trans.) 35 deg		21.4	20.2				5.0	5.2	17.2	4.7
X-bar “Just Admissible” (De Boer level 5) Side-Mirror Illumination	21 lux	21 lux	21 lux	9.2 lux	9.2 lux	5.0 lux	5.0 lux	5.0 lux	17.2 lux	4.7 lux
Task Force’s “rounded” number for “Just Admissible” Side-Mirror Illumination	10 lux	10 lux	10 lux	10 lux	10 lux	10 lux	10 lux	10 lux	10 lux	10 lux

1. *Italicized numbers* are from the actual study; other values are derived by application of appropriate ratio factors.

- 6.3 Window and Side Mirror Loss**—Assuming a 50% side mirror- side window transmittance factor, side mirror illuminance would be reduced by half. The eye-illumination numbers in Table 1 were doubled to give results in terms of mirror illuminance.
- 6.4 Agreement with Prior Research**—The rounded averages for the “short,” “intermediate,” and “long” exposure duration levels are summarized in Table 1 as 21 lux, 9.2 lux, and 5.0 lux. The side-mirror tolerance levels found by Olson & Sivak (adjusted for 50% mirror/window transmission) are: 17.2 and 4.7 lux for 10 second and 3 minute exposures. The order of magnitude calculated for short to long peripheral glare exposure durations, essentially agree with experimental results.
- 6.5 Task Force Selection of Side Mirror Glare Limit**—A reasonable level of 10 lux was selected for the side mirror illumination limit. The rationale for this was not an average, but selected in recognition of the realities of driving situations. While 10 to 20 second, “vehicle-passing” situations are no doubt difficult to avoid, long duration, “vehicle-following” situations are substantially more under the control of the driver being followed by a glare vehicle and could conceivably be avoided or minimized. One could argue that objectionable “long-duration” side mirror glare is less likely in this context, than is intermediate duration “vehicle-passing” scenario; e.g., selection of the “10 lux” side-mirror glare limit.
- The task force concluded that “*acceptable*” side mirror glare is 10 lux in the majority of driving situations that have intermediate exposure times, less than a minute in length.
- 7. Side Mirror Illumination from Headlamps**—Several studies of side mirror glare were undertaken in order to quantify the actual levels of driver's exposure to side mirror glare light.
- 7.1 Field Measurements**—Mirror illumination measurements were made for eight vehicles engaged in passing or following a test vehicle on Cleveland area expressways. A color corrected Luxmeter cell was mounted at the lower extreme of a side mirror centered at a height of approximately 900 mm (36 in). The vehicle was driven along interstates having a reasonable amount of pre-dawn traffic. At such times as the vehicle was being followed or passed by other vehicles; illumination readings of the side mirror illumination were recorded. The measured mirror illumination levels are listed in Table 2:

TABLE 2—MEASURED MIRROR ILLUMINATION LEVELS

Vehicle Type and Location	Side Mirror Illumination
Heavy truck following in the right lane	5 to 15 lux (during the measurement interval)
Heavy truck following in the right lane	5 to 10 lux
Heavy truck passing on the left	20 to 60 lux (as the vehicle overtook/passed)
Heavy truck passing on the left	5 to 30 lux
Heavy truck passing on the left	5 to 20 lux
Passenger vehicle following in the right lane	3 to 6 lux (during the measurement interval)
Passenger vehicle following in the right lane	3 to 8 lux
SUV's following in the right lane	5 to 15 lux (during the measurement interval)