NIGHTTIME VISIBILITY OF SIDE MARKER LAMPS

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16. Abstract

This study involved computer modeling of the effects of luminous intensity of side marker lamps on their nighttime visibility in a simple, dark environment. The luminous intensities that were investigated ranged from 0.25 to 4.0 cd. The predicted visibility distances were then compared with a criterion stopping distance. Analogous modeling was also performed for the side visibility of a car with no side marker lamps.

The results imply that at night (1) cars without side marker lamps will often be seen only at distances that are less than a safe stopping distance, and (2) cars with even the dimmest side marker lamps considered here will always be seen at several times the safe stopping distance.

Because of the limitations of the modeling, future research should field validate the model predictions. Furthermore, the effects of luminous intensity on the effectiveness of side marker lamps in complex environments should also be analyzed and evaluated.

17. Key Words
side marker lamps, visibility, nighttime, computer modeling, luminous intensity

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BACKGROUND

There is a wide disparity between current standards for the luminous intensities of side marker lamps in the United States and proposed standards for Europe. U.S. standards specify that candela values at HV be at least 0.25 for the rear location (red lamp) and 0.62 for the front location (amber lamp). Proposed European standards specify corresponding values of 2.0 and 4.0 cd (Hitzemeyer & Schmidt, 1989). This difference suggests a need to reexamine the criteria behind side marker standards. The purpose of the present study was to contribute to that effort by examining one particular criterion: how well the proposed and actual standards can insure that a side marker lamp will be visible at a distance great enough to allow an approaching driver to stop safely.

The approach that we used involved computer modeling of the distances at which side marker lamps could be seen, and comparison of those distances to a criterion stopping distance. It is important to recognize that there are several sources of uncertainty in modeling of this type. Although the model of visibility that we used has been validated for a variety of conditions, for present purposes we have extended it beyond those conditions—specifically, to assessment of the visibility of self-luminous targets of small size. In addition, it is important to recognize that visibility distance, although important, may not be the only criterion that should be considered in determining side marker standards. In order to be effective, side marker lamps must be not only visible but conspicuous, and the conspicuity of stimuli is not addressed by the modeling discussed here.

In the remainder of this report we will: (1) describe the computer model that we used to derive seeing distances, (2) present the results of the modeling and discuss them in terms of a correction for observer alertness, and (3) summarize the implications of these results for side marker intensity standards.

COMPUTER VISIBILITY MODEL

The computer model that we used to derive seeing distances was a slight modification of the DETECT model as described by Farber (1988). DETECT is a model developed by the Ford Motor Company that predicts the distances at which drivers will be able to see a variety of target objects when they are illuminated by any specified headlighting system. The model that we used differed from DETECT in only one substantial way. All of the targets that the Ford model handles are passive reflectors, so we had to modify it slightly to apply it to self-luminous side marker lamps.

At the heart of DETECT's visibility model, the contrast between the luminance of a target and the luminance of its background is calculated. The target is considered to be visible if its contrast is greater than a threshold value. Our modification was simply to add to a target's luminance an amount determined by its area and a specified candela value. We chose 5.5 in^2 as an area typical of current U.S. side marker lamps, and calculated corresponding luminances (assuming uniform distributions) for the cd values specified at HV for U.S. and European front and rear side marker lamps. Those values are given in Table 1.

TABLE 1
Four Standard cd Values and Corresponding Self-Luminance Values for Objects 5.5 in^2 in Area

Actual or Proposed Standard	Intensity (cd)	Self-Luminance (ft-L)
U.S. rear	0.25	20.58
U.S. front	0.62	50.99
European rear	2.00	164.51
European front	4.00	329.02

We used the computer model to determine seeing distance for side marker lamps of varying intensity using the following general scenario. It is night and a car with typical U.S. low beam headlights is traveling on a straight, level, two-lane road. Given the geometries that will be of importance here, only the central portion of the beam pattern matters. Candela values for the region within plus or minus one degree of HV (in steps of 0.5 degree) are given in Table 2. (The intermediate values were obtained by linear interpolation.) The car has a standard configuration of two headlights, one on each side, separated by four feet.

Ahead, a car equipped with a side marker lamp is encroaching at a right angle from the approaching driver's right. The side marker lamp itself is located 2 ft to the left of the right edge of the road; i.e. just onto the road and in the path of the approaching driver. The lane is 12 ft wide, and the driver's eye point is 1.5 ft left of the center of the lane.

For purposes of determining the contrast between the lamp and its background, it is assumed to be seen against the painted sheet metal of the car on which it is mounted. The sheet metal is a passive reflector, and its luminance is determined by its reflectivity and incident light from the approaching car's headlights, and ambient light from the sky (assumed to have a luminance of 0.01 ft-L). Two sheet metal reflectivities were chosen, corresponding to a dark car (10%) and a relatively light car (70%). For comparison with side marker lamp seeing distances, we also determined the seeing distances for passively reflecting objects with those reflectivities and of an area roughly equal to the front fender of a car (8 ft^2). These targets were considered to be seen against the road surface, which had a reflectivity of 6%. These distances are therefore estimates of how far away encroaching cars could be seen if they had no side marker lamps.

TABLE 2
Candela Values for the Central Portion of the Headlight Beam Pattern

	1.0 L	0.5 L	H	0.5 R	1.0 R
1.0 U	652	751	895	1097	1310
0.5 U	901	1088	1373	1780	2216
V	1415	1812	2456	3503	4650
0.5 D	2340	3120	4484	6712	9100
1.0 D	3451	4647	6761	10159	13924

Several other aspects of the present scenario are important in the DETECT modeling scheme. All of the predictions discussed here are for conditions in which: (1) no glare is present, (2) the observer driver has a windshield with 85% transmissivity, (3) the driver's performance is at the 50th percentile of the appropriate age group, and (4) potential decrements in visual performance due to atmospheric conditions are not considered. Also, DETECT allows target size to be specified in either of two ways: (1) as the diameter of a circle with the same projected area as the target, or (2) as the diameter of a circle with the same perimeter as the target. The present predictions are based on equal-area circles.

RESULTS

Predictions from the Model

Side marker lamp seeing distances were determined for each combination of two driver ages (20 and 65 years), two sheet metal reflectivities (10% and 70%), and four intensities (0.25, 0.62, 2.0, and 4.0 cd). Those distances are given in Table 3. Seeing distances for fender-like objects without self-luminous side marker lamps were determined for each combination of the same two driver ages and sheet metal reflectivities, and are given in Table 4.

TABLE 3
Predicted Seeing Distances in Feet for Side Marker Lamps Seen Against Car Sheet Metal

Driver Age	Sheet Metal Reflectivity	Self-Luminous Intensity (cd)			
		0.25	0.62	2.0	4.0
20	10%	7600	12600	24450	35800
	70%	7600	12600	24450	35800
65	10%	2981	4825	9013	13075
	70%	2981	4825	9013	13075

TABLE 4
Predicted Seeing Distances in Feet for Car Fenders Without Side Marker Lamps

Driver Age	Sheet Metal Reflectivity	Seeing Distance
20	10%	421
	70%	1083
65	10%	268
	70%	653

Several aspects of the results deserve comment. First, the differences in predicted seeing distances due to age are substantial. Drivers at age 20 are predicted to see all of the self-luminous targets at over twice the distances at which they are visible for drivers at 65. Second, a fairly large difference in car body reflectivity has no effect on the seeing distances for the side marker lamps. That is not surprising because their self-luminance allows them to be seen at distances so great that the headlights of the approaching car have negligible influence. Third, the predicted effect of car body reflectivity on seeing distances for cars without side marker lamps is substantial, more than doubling those distances for a 70% car versus a 10% car. Fourth, even the dimmest side marker lamps make a car visible at much greater distances than it would be without them. For the darker (10%) car even the 0.25 cd lamps result in seeing distances that are more than ten times greater than for a car without lamps. Fifth, seeing distance continues to increase as side marker intensity increases throughout the range tested here.

Adjustment for Alertness

Seeing distances predicted by DETECT are based on detection data from alerted observers; actual distances for a typical driver should be somewhat shorter. Therefore, it is desirable to make some correction for alertness before comparing the above seeing distances to a safe-stopping-distance criterion. Although the effects of alertness cannot be exactly predicted, two empirically-derived estimates are available as useful approximations. Roper and Howard (1938) measured detection distances for a mannequin lying in a roadway when observers were not expecting anything unusual, and also when the same observers were expecting the mannequin. Based on those data, they suggested halving detection distance for an alerted observer in order to predict unalerted detection distance. Based on a similar set of measurements—for detection of a stop sign—Olson (1988) suggested multiplying alerted detection distances by 0.61. The two estimates are substantially in agreement. Because Howard and Roper's correction factor is slightly more conservative (i.e., leads to shorter predicted seeing distances) we will adopt it here. Tables 5 and 6 reproduce the predictions in Tables 3 and 4, but with all of the seeing distances halved.

TABLE 5
Predicted Seeing Distance in Feet for Side Marker Lamps Seen Against Car Sheet Metal (adjusted for an unalerted observer)

Driver Age	Sheet Metal Reflectivity	Self-Luminous Intensity (cd)			
		0.25	0.62	2.0	4.0
20	10%	3800	6300	12225	17900
	70%	3800	6300	12225	17900
65	10%	1490	2412	4506	6538
	70%	1490	2412	4506	6538

TABLE 6
Predicted Seeing Distances in Feet for Car Fenders Without Side Marker Lamps (adjusted for an unalerted observer)

Driver Age	Sheet Metal Reflectivity	Seeing Distance
20	10%	210
	70%	542
65	10%	134
	70%	326

Safe-Stopping-Distance Criterion

The American Association of State Highway and Transportation Officials recommend stopping sight distance of 450–550 ft (depending on the coefficient of road friction) for a road design speed of 55 mph (AASHTO, 1984). (This recommendation takes into account a number of factors, including human reaction times and vehicle stopping characteristics.) Adopting the upper end of this range as a criterion and applying it to the predictions in Tables 5 and 6 indicates two things: (1) cars without side marker lamps will often not be seen at a safe stopping distance, and (2) cars with even the dimmest side marker lamps considered here will always be seen at several times the safe stopping distance.

DISCUSSION

The purpose of this study was limited to evaluation of the distances at which cars with side marker lamps of various intensities could be seen in a simple, dark environment. Within that limitation, two conclusions are clear: (1) side marker lamps of the intensities considered here are of substantial benefit in increasing the distances at which vehicles can be seen at night from the side, and (2) within the tested range of 0.25 to 4.0 cd greater intensities will lead to greater detection distances, but those increases are probably not of practical consequence. All of the seeing distances for side marker lamps are well beyond a reasonable criterion for safe stopping distance. Also, in many roadway situations the predicted seeing distances for even the lowest side marker intensity will exceed the length of the unobstructed sight line down the road.

The following limitations should be kept in mind when interpreting the results of this study. First, the seeing distances predicted here are based on a computer model that has been extended somewhat beyond the circumstances for which it was developed. The model, in turn, is based on the data from Blackwell (1952) and CIE (1981). Those data apply to detection of visual targets ranging from 1 to 64 minutes in visual angle. Side marker lamps were modeled here as circular targets having area of 5.5 in^2 and diameter of 2.65 in. At any distance over 760 ft such a target will subtend less than one minute of arc, and thus be beyond the range for which the visibility model was designed. However, 760 ft exceeds the criterion for a safe stopping distance that we have adopted, meaning that inaccuracies of the model are not of much importance provided it can be concluded that the target would be visible at least 760 ft away. Our use of the visibility model also departs from its original application in that we have made predictions for self-luminous targets. However, no aspect of the model specifies how a luminance is produced. Therefore adapting it to self-luminous surfaces does not involve changing any of the model's essential properties. In fact, Blackwell's (1952) original stimuli were self-luminous.

A second limitation of the present study is that it does not consider the possible effects of background complexity on visual detection. There is no question that side marker lamps make vehicles more visible (and therefore more detectable) against simple, dark backgrounds. But how they affect the detection of vehicles in complex environments is a more complicated issue. The degradation of detection by complex backgrounds is well documented. Olson (1988) measured detection distances for several types of highway signs in environments with three levels of complexity: dark rural roads, suburban streets, and cluttered urban commercial areas. Detection distances decreased substantially as visual complexity increased.

Olson's data could be used to adjust the predicted seeing distances for background complexity in a way similar to the adjustment that we made for driver alertness. However, it might be inappropriate to apply data from that study, in which the targets were square sections of sign material 30 inches on a side, to detection of side marker lamps that are considerably smaller. Detection distances in Olson's study ranged from just under 500 ft to a little over 1000 ft. At 1000 ft, a 30 in sign would subtend about 8 minutes of arc. In order to produce the same angle our side marker would have to be viewed at only 95 ft, much closer than the range of detection distances that would have to be adjusted.

However, depending on what situations one considers important for side marker lamp performance, adjustment for complex backgrounds may not be necessary. Where the background is simple, as it will be in most dark rural or suburban settings, the distances predicted here should be appropriate. In more cluttered environments, such as urban commercial districts, the level of ambient lighting will usually be high, potentially compensating for the presence of the increased number of distracting/competing stimuli. However, the nature and extent of such a tradeoff is unknown, and would have to be empirically determined.

The above discussion implies that the results of the present analytical study need to be field validated. Additionally, effects of luminous intensity on the effectiveness of side marker lamps in complex environments should be analyzed and evaluated.

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