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16. Abstract

This study had two objectives. The first, more general objective was to provide background information about the maximum rise time that should be allowed for high-intensity discharge headlamps. The second, more specific objective was to evaluate whether SAE's current, rather stringent, recommendations should be relaxed or retained. To achieve these objectives, we considered several scenarios in which having early illumination is potentially of consequence. The scenarios included turning on the headlamps when starting to drive, turning on the headlamps when entering a dark tunnel, and switching between beams. New empirical data collected for this study included actual delays between turning on headlamps at night and starting to drive, and rise and falloff functions of tungsten-halogen low beams and high beams.

We concluded that rise-time requirements should be more stringent for systems with noncontinuous low beam than for systems with continuous low beam, as is the case in the current SAE recommendations. Furthermore, we concluded that the current SAE recommendations for systems with noncontinuous low beam are justifiable. On the other hand, we concluded that the SAE recommendations for systems with continuous low beams could be relaxed by eliminating all minimum light-output requirements for delays of less than one second.

17. Key Words	18. Distribution Statement
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Contents

Introduction

High-intensity discharge (HID) light sources have inherently longer rise time than do tungsten halogen (TH) light sources. In other words, it takes HID lamps longer to reach their asymptotic output. While this disadvantage of HID lamps can be overcome or minimized by changes in the ballast and in the composition of the gasses, these changes result in shorter lamp life and increased cost. Consequently, there is interest in determining the extent to which fast rise is important, and what the minimum rise-time requirements should be from a safety point of view.

In the U.S., the Federal Motor Vehicle Safety Standard (FMVSS) does not regulate the rise time of HID lamps. However, SAE has developed a Recommended Practice (SAE, 1995) that specifies the recommended percent of the asymptotic light output as a function of time (see Table 1). The ECE Regulation No. 98 (ECE, 1998) requires one low-beam test point (50V) to have at least 10 lux after 4 seconds—83% of the asymptotic minimum for that point, which is 12 lux (see Table 1).

Table 1.
The current SAE and ECE minimum light-output specifications.
The entries are in percent of the minimum asymptotic values.

Time (sec)	SAE*		ECE**
	Noncontinuous low beam	Continuous low beam	
0.25	20	10	
0.50	30		
0.75	50		
1.00	60	25	
2.00	70	50	
3.00		70	
4.00			83

*Low beams or high beams.
**Low beams.

The general question of interest is "What should the minimum rise-time requirements be from the human factors point of view?" A specific question of primary interest is whether the more stringent SAE recommendations are justified or whether they should be relaxed. This report provides information regarding the former, more general question, and directly addresses the later, more specific question, by considering several possible situations in which rapid onset of light could be important.

Potentially Important Situations

The potentially relevant situations can be classified into two major groups: switching from no headlamps on to either beam on, and switching between the beams.

Switching from no headlamps on to either beam on

How quickly do people need functional light after they turn on their headlamps? A simple (and simplistic) answer to this question is "as soon as possible." However, we are not aware of any relevant empirical data. Furthermore, we will argue that in certain important situations it is possible to define a minimum time below which having available light is not critical.

Two different scenarios are of relevance here: turning on headlamps when starting to drive, and turning on headlamps while driving when there is a sudden need for illumination (e.g., entering a dark tunnel). With regard to drivers turning on their headlamps as they start to drive, it is important to realize that it is not critical to have illumination *before* moving (albeit illumination may be helpful for scanning prior to moving). Consequently, we operationally defined the maximum tolerable delay between turning on the lamps and having illumination as the actual delay between turning on headlamps and starting to move, and we performed an observational study on the delays between switching on lights and any discernible vehicle movement.

The second scenario deals with a moving vehicle during the daytime suddenly encountering a situation in which headlamp illumination is needed. A prototypical situation that will be discussed in this context is entering an unlit tunnel.

Switching between the beams

Switching between the beams is another class of situations where delayed onset of light (in comparison to the current TH lamps) could be of importance. To address such situations, we obtained rise and falloff data for a small set of current TH low beams and high beams. This information is relevant for understanding what changes in light output during beam switching are currently considered to be acceptable.

Summary of Issues

Table 3 summarizes the major potential concerns related to the rise time of HID lamps. Whether the low beam stays on with the high beam is important for the issue at hand. Therefore, both types of high beams are considered in Table 3. Furthermore, an explicit assumption in Table 3 is that the current situation with TH lamps is acceptable.

Table 3.
Summary of potential issues related to the rise time of HID lamps. (An explicit assumption is that the current situation with TH lamps is acceptable.)

Low beam	High beam	
	TH	HID
TH, continuous	• no issue	• no issue
TH, noncontinuous	• no issue	• starting up* • entering a tunnel* • switching between beams
HID, continuous	• starting up • entering a tunnel	• starting up • entering a tunnel
HID, noncontinuous	• starting up • entering a tunnel	• starting up • entering a tunnel • switching between beams

*If the beam switch is on "high" from the previous use.

Turning on the Headlamps: Starting to Drive

To provide some evidence concerning the question "How soon does one start to move after the ignition is turned on?" we collected field measurements in lighted parking lots of two shopping centers in Ann Arbor, Michigan.

The measurements were made by an experimenter who was positioned in a stationary vehicle in such a way that he was able to observe parked vehicles. He measured the time elapsed from when the headlamps were turned on until any movement of the vehicle could be discerned (either backward or forward). The measurements were made using a stopwatch with a resolution of 0.1 seconds. The observations were made in the evening, starting one hour after sunset.

A total of 150 measurements were made. The vehicles included passenger cars, light trucks, vans, and SUVs. Only cases in which the headlamps were turned on before the vehicle moved were included. In other words, cases in which a vehicle moved before the headlamps were turned on were excluded.

The minimum delay was 1.0 seconds and the median was 2.9 seconds. Table 4 provides a distribution of the delays.

Table 4.
Delays between the time the headlamps were turned on and the time the vehicle started to move. (Based on a total of 150 observations in two parking lots.)

Delay in seconds	Percentage
< 1.0	0
1.0 – 1.4	7
1.5 – 1.9	17
2.0 – 2.9	27
3.0 – 3.9	9
4.0 – 4.9	7
5.0 – 5.9	3
6.0 – 6.9	7
7.0 – 7.9	1
8.0 – 19.9	11
≥20.0	10

Turning on the Headlamps: Entering an Unlit Tunnel

Entering a dark, unlit tunnel on a bright, sunny day without functional headlamps is of concern. In such a situation, vision is substantially impaired because dark adaptation is an extended process. Most adaptation is completed in about 10 minutes, but full dark adaptation takes about 30 minutes.

Extended unlit tunnels, at least in the U.S., are a rarity. Furthermore, most tunnels have advanced warnings. Thus, reasonably alert drivers switch their headlamps on before entering a tunnel.

Nevertheless, if one enters a dark tunnel unexpectedly, the sooner the light is on, the better. However, we do not have sufficiently relevant information for setting an allowable maximum delay. On the other hand, existing regulations of concealable (retractable) headlamps provide one possible framework for this problem. Currently, both the U.S. and ECE regulations allow concealable lamps to take up to 3 seconds to be fully open (FMVSS, 1999; ECE, 2001). It could be argued that HID lamps should not have more stringent performance requirements than do concealable lamps. If that premise is accepted, then controlling the light output of HID lamps within the first 3 seconds is not justified.

Switching Between the Beams

For continuous low beam, switching between beams creates no safety problem (see Table 3). On the other hand, for noncontinuous low beam, switching between beams is a potential concern.

To make recommendations for HID lamps, it is important first to understand the fluctuations in the effective light that are currently deemed to be acceptable when switching between two TH beams. Both the falloff of the beam that is being turned off and the rise of the beam that is being turned on are gradual and not instantaneous.

Although analogous information, at least for the rise time, is available for signal lamps (Sivak et al., 1994), no published data on such functions are available for headlamps. Consequently, to provide some background information about the currently acceptable situation, we measured the rise time and falloff time of three low beams (HB4, H7, and H6024 [a sealed beam]) and three high beams (HB3, H1, and H6024 [a sealed beam]).

The measurements were made using a Minolta T-1 illuminance meter. The analog output of the illuminance meter was connected to a Fluke model 99 Scopemeter in order to record the output signal generated by the illuminance meter. The data from the Scopemeter were then plotted, with 0 on the time axis corresponding to the onset of voltage to the lamp. The output signal was sampled at 20-millisecond intervals. Each lamp was energized by a power supply running at 12.8 V. The measurements were made in a darkened laboratory.

The rise-time functions for all lamps (both the low beams and the high beams) were similar in terms of relative light output as a function of time. Analogously, the falloff functions for all lamps were also similar. As illustrations of the general trends, Figure 1 shows the falloff time for the HB4 low beam. Figure 2 presents the rise time for the HB3 high beam.

Figure 3 combines the falloff time of a low-beam lamp with the rise time of a high-beam lamp, assuming that the high beam directs twice as much light towards a particular point in space as does the low beam. Figure 4 shows the reverse situation of switching from a high beam to a low beam.

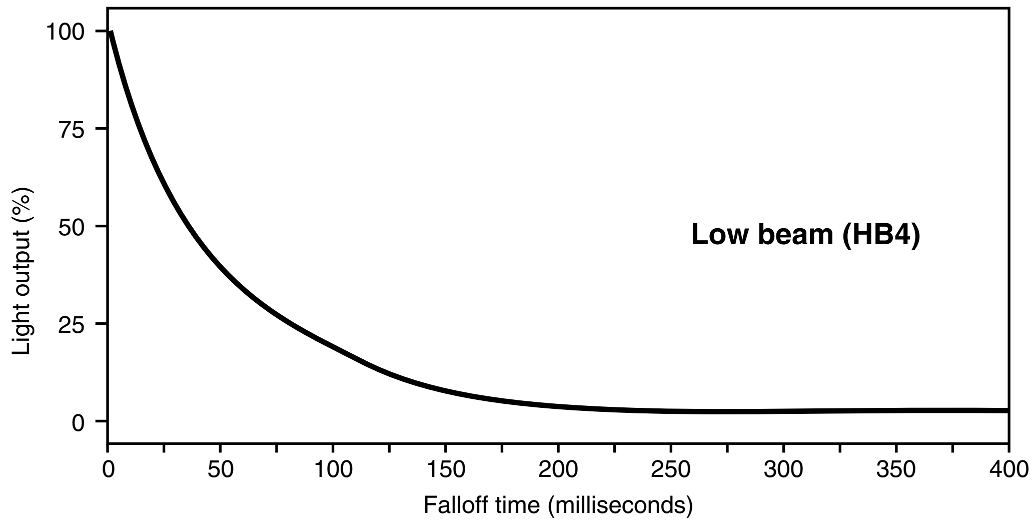

Figure 1. The falloff for the HB4 low beam. (The falloff functions for the other two low beams and three high beams were similar.)

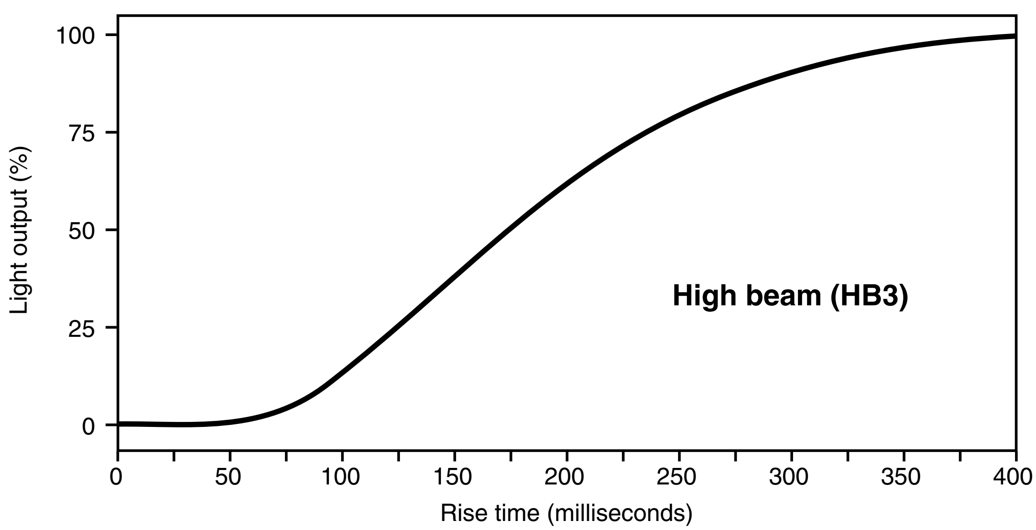

Figure 2. The rise for the HB3 high beam. (The rise functions for the other two high beams and three low beams were similar.)

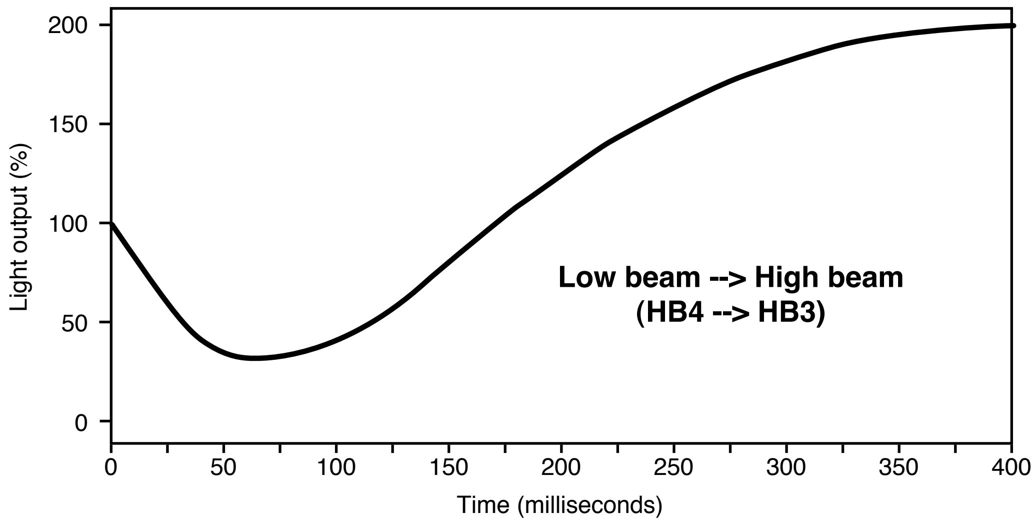

Figure 3. Light output during a switch from a low beam (HB4) to a high beam (HB3). The graph assumes that the high beam directs twice as much light towards a particular point in space as does the low beam.

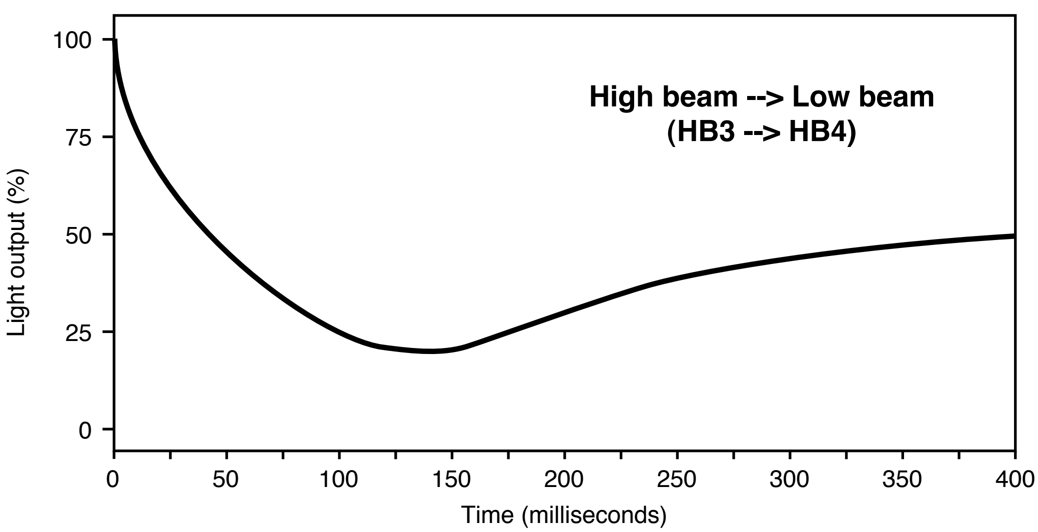

Figure 4. Light output during a switch from a high beam (HB3) to a low beam (HB4). The graph assumes that the high beam directs twice as much light towards a particular point in space as does the low beam.

Although long transitions between beams in systems with continuous low beams are unlikely to have negative safety consequences, a study by Olson et al. (1991) indicates that drivers would find long transition times objectionable. That study investigated driver acceptance of different delays for a mechanical beam-switching system. Also included was a baseline condition that involved current electrical switching from one beam to another. The mechanical system involved a continuous change from one beam to another. This was accomplished by the use of a shutter and a change in the relative position of the lens and bulb. Both systems used TH lamps. The subjects rated each beam change using a five-point scale, with 1 being "good" and 5 being "too slow."

Electrical switching between the beams (i.e., the current state of affairs; see Figures 3 and 4) was rated as 1.75 (close to "good"). Mechanical switching that took 0.3 seconds to complete was rated equally good as electric switching (a rating of about 1.75). However, as the time for the completion of mechanical switching increased, the rated quality of the change decreased. Mechanical switching that took 0.9 seconds to complete began to approach "too slow" (a rating of about 4.1) when going from a high beam to a low beam. The same delay from a low beam to a high beam was still rated as acceptable (a rating of about 3.2).

Implications

Turning on the headlamps: Starting to drive

Our data indicate that the shortest time interval between turning on the headlamps and starting to drive is about 1 second. Consequently, for starting-to-drive considerations there does not appear to be any need to regulate the light output within the first second.

Turning on the headlamps: Entering an unlit tunnel

This situation is of concern, but it is rare. Furthermore, concealable headlamps are allowed to have a delay of 3 seconds. Consequently, the regulations within the first second could be removed.

Switching between the beams

There are no safety problems with continuous low beam at any delays, but there is some evidence that consumer acceptance would be an issue at long delays. On the other hand, noncontinuous low beam is of concern.

Summary and Recommendations

This study had two objectives. The first, more general objective was to provide background information about the maximum rise time that should be allowed for high-intensity discharge headlamps. The second, more specific objective was to evaluate whether SAE's current, rather stringent, recommendations should be relaxed or retained. To achieve these objectives, we considered several scenarios in which having early illumination is potentially of consequence. The scenarios included turning on the headlamps when starting to drive, turning on the headlamps when entering a dark tunnel, and switching between beams. New empirical data collected for this study included actual delays between turning on headlamps at night and starting to drive, and rise and falloff functions of tungsten-halogen low beams and high beams.

We concluded that rise-time requirements should be more stringent for systems with noncontinuous low beam than for systems with continuous low beam, as is the case in the current SAE recommendations. Furthermore, we concluded that the current SAE recommendations for systems with noncontinuous low beam are justifiable. On the other hand, we concluded that the SAE recommendations for systems with continuous low beams could be relaxed by eliminating all minimum light-output requirements for delays of less than one second. These conclusions are summarized in Table 5.

Table 5.
Recommendations concerning SAE Recommended Practice J2009 on the rise-time requirements for HID headlamps.

<table>
<tr><th colspan="2">Beam</th><th rowspan="2">Recommendation</th></tr>
<tr><th>Low</th><th>High</th></tr>
<tr><td>HID, continuous</td><td>TH or HID</td><td rowspan="2">There is no need to regulate the light output within the first second. The current SAE recommendations for a system with continuous low beams could be relaxed by eliminating all recommendations for less than one second. The current SAE recommendations for one second and beyond should be retained.</td></tr>
<tr><td>TH, continuous</td><td>HID</td></tr>
<tr><td>HID, noncontinuous</td><td>TH or HID</td><td rowspan="2">Regulations covering the first second are justifiable. Therefore, the current SAE recommendations for noncontinuous low beams should be retained unchanged.</td></tr>
<tr><td>TH, noncontinuous</td><td>HID</td></tr>
</table>

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