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Assessment of Headlamp Aim for New Vehicles

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Nick Voyzey, Transportation Research Center Inc. Elizabeth N. Mazzae, National Highway Traffic Safety Administration, and Adam Andrella, Transportation Research Center Inc.	DOT-VNTSC-NHTSA-xx- xx

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16. Abstract

This report summarizes an evaluation of new vehicle lower beam headlamp aim state, or how well a new vehicle's lower beam headlamps are vertically aimed at the time of vehicle delivery to the purchaser. Using the inspection method in SAE J599, "Lighting Inspection Code," headlamp aim angles were determined for a set of 15 vehicles. Assessing lower beam headlamps' vertical aim angle state involves shining the lamps at a screen and visually determining the location of the gradient cutoff location. The headlamp aim angles were measured for both passenger and driver-side headlamps. The headlamp aim angles were also measured with the vehicle empty (no load) and with the vehicle loaded with weight to simulate a person in the driver seat (driver load). Headlamp aim was judged based on the limits specified in SAE J599 as well as the manufacturers' specifications for both test conditions. A subset of 5 of the 15 test vehicles' lower beam headlamps were also tested photometrically to permit a comparison of aim state results obtained via visual and photometric measurement methods. Analysis of test results showed that lower beam headlamps were more likely to meet SAE J599 since the manufacturers' aim targets are as stringent or more stringent than SAE J599. The presence of a driver load had a limited effect on headlamp performance, but in most cases the aim was better with a driver load present. Headlamps on the driver side performed better than headlamps on the passenger side, with cases of driver-side aim being outside of the specified tolerance usually coinciding with the passenger side also being outside of the specified tolerance. For the subset of test vehicles for which headlamp aim was measured via both visual and photometric measurement methods, the average magnitude of difference between measurements was 0.12°. This test effort provided a good initial assessment of the new vehicle aim state of current vehicles on the market and a comparison of aiming accuracy attainable via visual and photometric methods.

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Executive Summary

This report describes an assessment of new vehicle lower beam headlamp aim state, or the quality of headlamp aim at the time a new vehicle is delivered to the purchaser. Correct vehicle headlamp aim is important to the performance quality of a vehicle's headlamp system and driving safety. A low headlamp aim can result in diminished visibility for the driver. High headlamp aim can result in an abundance of glare for drivers of oncoming and preceding vehicles. There are currently no Federal Motor Vehicle Safety Standard (FMVSS) requirements for aiming headlamps on vehicles. However, SAE J599,[1] Lighting Inspection Code provides guidance on the inspection and aiming of headlamps.

The research team tested 15 vehicles, all from the 2022 or 2023 model year. Vehicles varied in headlamp mounting height, headlamp optic type, and designed aim method. All headlamps tested used visual optical aim (VOA), and were aimed based on a region of sharp transition between dark and light in the beam pattern called the cutoff. Depending on factors such as the height of the headlamp, the target location specified in SAE J599 for the cutoff can vary. Manufacturers may also have their own target for the cutoff location that maximizes headlamp performance.

To evaluate a new vehicle's lower beam headlamp aim vertical angles, headlamps were measured using the inspection and aim procedures in SAE J599 as a guideline, which states that the lower beam pattern of the headlamps was shone onto a vertical matte finish aiming screen for measurement. Vertical aim angle was determined by measuring the difference between the height of the headlamp and the vertical location of the headlamp's lower beam cutoff. The aim was then judged based on both SAE J599 targets and manufacturer specifications for each vehicle.

A subset of 5 of the 15 test vehicle headlamps were also tested photometrically to permit a comparison of aim state results obtained via visual and photometric measurement methods.

When judged against SAE J599, measurement results showed that most lower beam headlamps met the standard. Although most lamps deviated from the target aim, only a few were aimed outside the bounds of the SAE J599 standard criteria. When equipped with a load simulating the weight of an average driver (as specified in SAE J599), all driver-side lamps were within the limits, but 3 of the 15 passenger side lamps were outside the limits. Overall, several of the headlamps met aiming criteria, particularly when judged against the targets in SAE J599. Fewer headlamps met aim criteria, however, when the headlamps were judged against their own manufacturers' aim targets, particularly for passenger side headlamps. Table 1 summarizes the percentage of headlamps found to be within the performance limits.

[1] SAE J599 is not an incorporated reference standard to FMVSS No. 108.

Table 1. Lower Beam Aim Angle Deviation Results

			Percentage of Lamps That Meet Aim Target		Number of Lamps That Met Aim Target Out of Total	
	Headlamp Aim Target	**Driver Load**	**Driver-Side Lamp (%)**	**Passenger-Side Lamp (%)**	**Driver-Side Lamp**	**Passenger-Side Lamp**
Visual Measurement	SAE J599	None	100	87	15 / 15	13 / 15
		165 Pounds	100	80	15 / 15	12 / 15
	Vehicle Manufacturer Specification	None	70	40	7 / 10	4 / 10
		165 Pounds	90	50	9 / 10	5 / 10
Photometric Measurement	SAE J599	None	80	40	4 / 5	2 / 5
		165 Pounds	100	60	5 / 5	3 / 5
	Vehicle Manufacturer Specification	None	60	20	2 / 5	1 / 5
		165 Pounds	80	20	4 / 5	1 / 5

For the subset of test vehicles for which headlamp aim was measured via both visual and photometric measurement methods, the average magnitude of difference between measurements was 0.12°.

This test effort provided a good initial assessment of the new vehicle lower beam headlamp aim state of current vehicles on the market and a comparison of aiming accuracy attainable via visual and photometric methods.

1. Introduction

Correct vehicle headlamp aim is important to the performance quality of a vehicle's headlamp system and driving safety. A low headlamp aim can result in diminished visibility for the driver. High headlamp aim can result in an abundance of glare for drivers of oncoming and preceding vehicles. There are currently no requirements in Federal Motor Vehicle Safety Standard (FMVSS) No. 108, Lamps, reflective devices, and associated equipment (49 CFR § 571.108, 2011), for aiming headlamps on a vehicle. However, SAE J599, Lighting Inspection Code (2015), provides guidance on the inspection and aiming of headlamps.

Headlamps can be aimed by mechanical means or using Visual Optical Aim (VOA), with most current headlamps designed for the latter. The aim location for a VOA-aimed headlamp is defined by the cutoff, which is the point of highest transition from dark to light at the top of the beam pattern. VOA aim is subdivided into two types: visually optically aligned left (VOL) and visually optically aligned right (VOR). VOR-designed headlamps are aimed by the cutoff in the area located 1° to 3° to the right of the plane that goes through the headlamp's optical center and is parallel to the longitudinal axis of the vehicle. VOL-designed headlamps are aimed by the cutoff in the area of 1.5° to 3.5° to the left of the plane that goes through the lamp's optical center and is parallel to the longitudinal axis of the vehicle.

Headlamp aim is determined based upon these VOA requirements and SAE J599 guidelines. The SAE J599 procedure uses an aiming screen that is perpendicular to the longitudinal axis of the vehicle and located 25 feet away from the front of the vehicle being tested. All headlamp cutoff measurements and adjustments are performed with the headlamps projecting onto this aiming screen. The nominal cutoff location is the lamp height for VOR and 2 inches below the lamp height for VOL. SAE J599 has limits for acceptable aim based on the VOR and VOL nominal cutoff location and the height of the lamp optical center, as shown in Table 2.

Table 2. SAE J599 VOR/VOL Vertical Lower Beam Aim Angle Criteria

Optical Center Height	Vertical Aim Offset	Upper Limit	Lower Limit
22" to 36"	No Offset	2" Up	3" Down
36" to 48"	2" Down	1" Up	4" Down
48" to 54"	4" Down	0.75" Up	4.25" Down

Vehicle manufacturers have their own headlamp aim specifications that may differ from SAE J599. This report evaluated the measured headlamp aim state per both SAE J599 and the vehicle manufacturers' specifications. Some manufacturers use SAE J599 as their in-house specification and some manufacturers do not publicly disclose their aim target and tolerance information. Any information that is not publicly disclosed is listed as Confidential Business Information (CBI) in this report.

1.1. Objective and Scope

The objective of this assessment was to characterize the vehicle lower beam headlamp aim state for several new model year 2022–2023 light vehicles. The aim was judged by determining the cutoff visually for all vehicles. A subset of 5 of the 15 test vehicles' headlamps were also measured photometrically to confirm the visual measurements. Test vehicles' headlamp aim state measurements were assessed per both SAE J599 and the vehicle manufacturers' aiming criteria. Measurement results were summarized and values obtained for visual and photometric methods were compared.

2. Method

This section describes the specified test procedures, equipment used, and test approach.

2.1. Test Environment and Surface

Testing was conducted in an indoor laboratory with a generally level floor. Ambient light was kept to a minimum to ensure that the headlamps' beam patterns were sufficiently visible.

2.2. Vehicle Preparation

For testing, a test vehicle was positioned at the proper distance from the measurement screen using a floor grid having a pattern of 1-foot squares on the test surface and plumb bobs attached to the center of the front and rear of the vehicle. The vehicle was aligned such that the plumb bobs were both on the center line of the grid layout. The vehicle was placed 25 feet away from the aiming screen, such that the plane of the screen and plane through which the plumb bobs hang were normal to each other. Per the SAE J599 procedure, each vehicle was prepared for testing by ensuring the test vehicle's tires were set to the manufacturers' recommended cold inflation pressures, the headlamp lenses were cleaned, and the suspension was stabilized by rocking the vehicle back and forth. Mileage and fuel level were recorded, with the fuel level maintained at a minimum of 3/4 full.

Test vehicles' lower beam headlamp angles were measured in both loaded and unloaded conditions. For the initial measurement, the test vehicle was unloaded. For the second measurement, a 165-pound load (75 kg) was placed in the driver's seat for the next measurement as per the SAE J599 test procedure.

2.3. Measurement Equipment and Procedures

2.3.1. Visual Measurement

A white screen having a matte finish and landmarks to mark headlamp locations was used as specified in SAE J599 (see Figure 1). The main deviation from the SAE J599 test setup was the absence of the vertical and horizontal tapes to denote acceptable regions. For ease of transferring the headlamp optical center height value from the lamp to the aiming screen, a self-leveling 360-degree horizontal laser was used to mark the horizontal axes of each headlamp and the vertical axes were marked by vertical paper markers. The laser was placed away from the beam pattern and adjusted to the height of the optical center, which resulted in a laser line at the height of the optical center being projected onto the aiming screen. A separate self-leveling vertical laser was placed in front of the driver-side headlamp and intersected the low beam optical center. The headlamp width was then measured between the laser and the center of the front end of the vehicle. The laser was then removed, and a vertical marker was then placed on the aiming screen at the headlamp width and intersecting the horizontal laser to mark the center point of measurement. The headlamp not being measured was covered to ensure only light from the measured headlamp shined on the aiming screen. Pictures were taken with the Fujifilm FinePix S100 FS digital camera of the aiming screen with the headlamps on, the horizontal laser on, and the vertical marker in place. The same procedure was done for the other headlamp on the vehicle, in which the laser was adjusted as needed for referencing the headlamp height. The process was then repeated with a driver load present. The horizontal laser and vertical marker were adjusted as needed.

Figure 1. Aiming Screen

2.3.2. Photometric Measurement

An imaging photometer was acquired during the course of this work, which allowed for some vehicles' lower beam headlamp aim angles to be measured using both visual and photometric methods.

For photometric measurements, the test setup and equipment were largely the same, and the same vehicle loading and preparation conditions were used. The only difference was instead of a digital camera, an imaging photometer was used to capture photometric measurements. The photometer used was a Radiant Vision Systems ProMetric Y imaging photometer[2] (see Figure 2) with corresponding ProMetric software for analysis. The photometer captured and analyzed a measurement of the headlamp beam pattern. In the software a gradient measurement was made vertically at a location on the aiming screen 2° right of the center of the headlamp from 1.5° up the 1.5° down at a pitch of 0.02°. The gradient was calculated at each point by the formula:

$$G_a = \log (E_a) - \log (E_{a+0.1^\circ})$$

G_a is the gradient, E_a is the luminance intensity of the point, and $E_{a+0.1^\circ}$ is the luminous intensity of the point 0.1° above.

The max gradient and its corresponding location were found and logged as the headlamp aim location.

[2] Radiant Vision Systems, Redmond, WA.

Figure 2. ProMetric Y Imaging Photometer made by Radiant Vision Systems

2.4. Analysis Methods

2.4.1. Visual Measurement

Headlamp aim angle measurements were determined by visually defining a cutoff location in the image taken. Once a cutoff location was determined, the inch markings on the aiming screen were used to determine the location of the cutoff relative to the headlamp height, represented by the laser line. This aim value was then calculated as an angle based on the aim measurement and the distance to the screen. Figure 3 provides an example of visual aim angle measurement using an aiming screen.

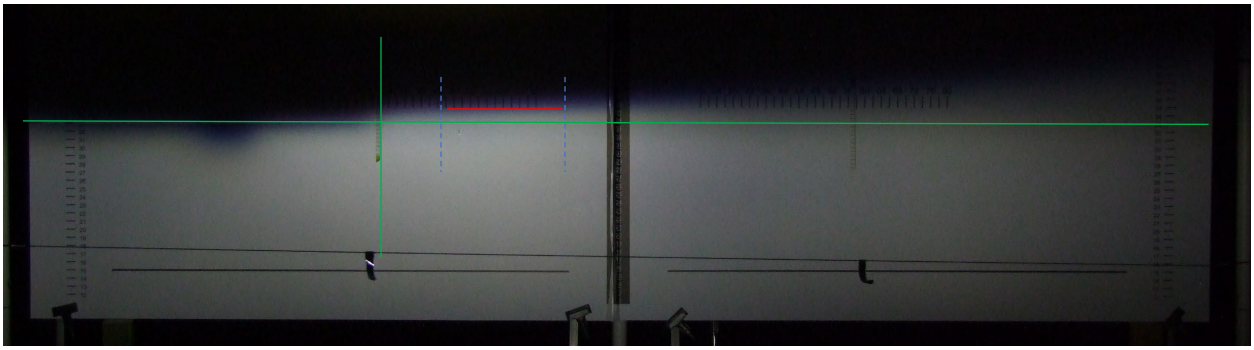

Figure 3. Analysis Screen Example

2.4.2. Photometric Measurement

Aim angle measurements were determined by the location of maximum gradient on the line defined as 2° to the center of the headlamp from 1.5° up to 1.5° down. Figure 4 presents a gradient analysis example.

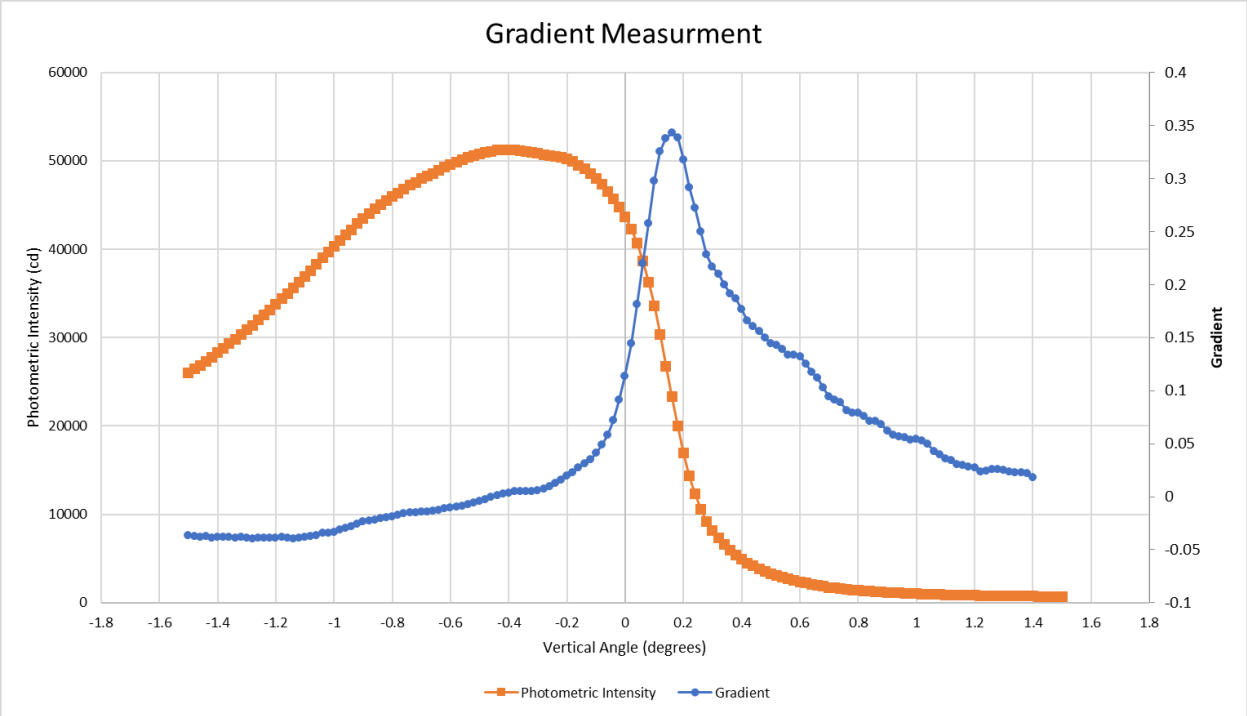

Figure 4. Gradient Analysis Example

3. Vehicles Tested

Vehicles measured in this effort were test vehicles purchased for research projects to be conducted at NHTSA's Vehicle Research and Test Center. All measurements were performed soon after delivery of the vehicles and prior to any other sort of testing performed using the vehicles. Table 3 lists the test vehicles used in this assessment.

Table 3. Vehicle Information

Vehicle #	Model Year	Make	Model	Trim
1	2022	Cadillac	XT4	Premium Luxury
2	2022	Chevrolet	Equinox	Premier AWD
3	2022	Ford	F-150	XLT Crew Cab
4	2023	Ford	F-150	4x4 Super Crew
5	2022	Ford	Mach-e	Premium
6	2022	Honda	Civic	EX sedan
7	2022	Honda	CRV	EX
8	2022	Honda	Odyssey	Touring
9	2022	Hyundai	Tucson	Limited
10	2022	Jeep	Grand Cherokee	L Limited 4X4
11	2022	Mercedes	S580	4 Matic
12	2022	Subaru	Outback	Touring
13	2022	Tesla	Model 3	N/A
14	2022	Tesla	Model Y	N/A
15	2022	Toyota	Camry	SE

Table 4 lists the characteristics of the headlamps on each of the vehicles used in this assessment.

Table 4. Headlamp Characteristics

Vehicle #	Lower Beam Optic Type	VOA Type	SAE J599 Aim, Height Offset	Vehicle Manufacturer Headlamp Aim Angle Specification and Tolerance
1	LED Projector	VOL	No Offset	-0.4° + 0.38°, -0.57° (SAE J599)
2	LED Projector	VOR	No Offset	0° + 0.38°, -0.57° (SAE J599)
3	LED Reflector	VOR	2" Down	0° +/- 0.29°
4	LED Projector	VOR	No Offset	-0.29° +/- 0.29°
5	LED Projector	VOR	No Offset	0° +/- 0.29°
6	LED Reflector	VOR	No Offset	CBI
7	Halogen Projector	VOR	No Offset	CBI
8	LED Reflector	VOR	No Offset	CBI
9	LED Projector	VOR	No Offset	0° +0.11°, -0°
10	LED Reflector	VOR	2" Down	-0.05° +/-0.1°

Vehicle #	Lower Beam Optic Type	VOA Type	SAE J599 Aim, Height Offset	Vehicle Manufacturer Headlamp Aim Angle Specification and Tolerance
11	LED Projector	VOR	No Offset	CBI
12	LED Projector	VOR	No Offset	CBI
13	LED Projector	VOR	No Offset	0° +/-0.2°
14	LED Reflector	VOR	No Offset	0° +/-0.2°
15	LED Projector	VOR	No Offset	0° +0.38°, -0.57° (SAE J599)

4. Results

The following analysis characterizes the data collected to assess new vehicle headlamp aim state.

4.1. Headlamp Aim – Visual Measurements

Tables 5 to 9 show the visually measured headlamp aim state of the 15 new vehicles examined in this effort. A positive aim value means the headlamp was aimed above the headlamp height, and a negative value means the headlamp was aimed below the headlamp height. Headlamp aim was measured in distance, specifically inches, on the aiming screen and later converted to an angle. The aim was then judged if it did or did not meet the given criteria.

Table 5. Visually Measured Headlamp Aim Without Driver Load Judged Against SAE J599

Vehicle #	DRIVER-SIDE Aim (°)	PASS.-SIDE Aim (°)	Aim Target (°)	SAE J599 Upper Limit (°)	SAE J599 Lower Limit (°)	DRIVER SIDE (Met/Did Not Meet)	PASSENGER SIDE (Met/Did Not Meet)
1	0.00	0.10	-0.40	0.00	-0.95	Met	Did Not Meet
2	0.24	0.14	0.00	0.38	-0.57	Met	Met
3	-0.19	-0.19	-0.38	0.19	-0.76	Met	Met
4	0.00	0.19	0.00	0.38	-0.57	Met	Met
5	-0.10	-0.10	0.00	0.38	-0.57	Met	Met
6	0.00	0.00	0.00	0.38	-0.57	Met	Met
7	-0.19	-0.14	0.00	0.38	-0.57	Met	Met
8	-0.24	-0.19	0.00	0.38	-0.57	Met	Met
9	0.24	0.24	0.00	0.38	-0.57	Met	Met
10	0.10	0.10	-0.38	0.19	-0.76	Met	Met
11	-0.24	-0.14	0.00	0.38	-0.57	Met	Met
12	0.24	0.00	0.00	0.38	-0.57	Met	Met
13	0.38	0.29	0.00	0.38	-0.57	Met	Met
14	0.00	-0.76	0.00	0.38	-0.57	Met	Did Not Meet
15	-0.33	0.00	0.00	0.38	-0.57	Met	Met

Table 6. Visually Measured Headlamp Aim With Driver Load Judged Against SAE J599

Vehicle #	DRIVER-SIDE Aim (°)	PASS.-SIDE Aim (°)	Aim Target (°)	SAE J599 Upper Limit (°)	SAE J599 Lower Limit (°)	DRIVER SIDE (Met/Did Not Meet)	PASSENGER SIDE (Met/Did Not Meet)
1	0.00	0.10	-0.40	0.00	-0.95	Met	Did Not Meet
2	0.00	0.14	0.00	0.38	-0.57	Met	Met
3	-0.14	-0.19	-0.38	0.19	-0.76	Met	Met
4	0.00	0.19	0.00	0.38	-0.57	Met	Met
5	-0.14	-0.19	0.00	0.38	-0.57	Met	Met
6	-0.10	-0.19	0.00	0.38	-0.57	Met	Met
7	-0.19	-0.14	0.00	0.38	-0.57	Met	Met
8	-0.38	-0.38	0.00	0.38	-0.57	Met	Met
9	0.00	0.24	0.00	0.38	-0.57	Met	Met
10	0.05	0.00	-0.38	0.19	-0.76	Met	Met
11	-0.24	-0.14	0.00	0.38	-0.57	Met	Met
12	0.19	-0.10	0.00	0.38	-0.57	Met	Met
13	0.33	0.38	0.00	0.38	-0.57	Met	Did Not Meet
14	0.00	-0.76	0.00	0.38	-0.57	Met	Did Not Meet
15	-0.33	-0.19	0.00	0.38	-0.57	Met	Met

Table 7. Visually Measured Headlamp Aim Without Driver Load Judged Against Manufacturer Targets

Vehicle #	DRIVER-SIDE Aim (°)	PASS.-SIDE Aim (°)	Aim Target (°)	Aim Tolerance Max (°)	Aim Tolerance Min (°)	DRIVER SIDE (Met/Did Not Meet)	PASSENGER SIDE (Met/Did Not Meet)
1	0.00	0.10	-0.40	0.00	-0.97	Met	Did Not Meet
2	0.24	0.14	0.00	0.38	-0.57	Met	Met
3	-0.19	-0.19	0.00	0.29	-0.29	Met	Met
4	0.00	0.19	-0.29	0.00	-0.58	Met	Did Not Meet
5	-0.10	-0.10	0.00	0.29	-0.29	Met	Met
6	0.00	0.00	CBI			N/A	N/A
7	-0.19	-0.14	CBI			N/A	N/A
8	-0.24	-0.19	CBI			N/A	N/A
9	0.24	0.24	0.00	0.11	0.00	Did Not Meet	Did Not Meet
10	0.10	0.10	-0.05	0.05	-0.15	Did Not Meet	Did Not Meet
11	-0.24	-0.14	CBI			N/A	N/A
12	0.24	0.00	CBI			N/A	N/A
13	0.38	0.29	0.00	0.20	-0.20	Did Not Meet	Did Not Meet
14	0.00	-0.76	0.00	0.20	-0.20	Met	Did Not Meet
15	-0.33	0.00	0.00	0.38	-0.57	Met	Met

Table 8. Visually Measured Headlamp Aim With Driver Load Judged Against Manufacturer Targets

Vehicle #	DRIVER-SIDE Aim (°)	PASS.-SIDE Aim (°)	Aim Target (°)	Aim Tolerance Max (°)	Aim Tolerance Min (°)	DRIVER SIDE (Met/Did Not Meet)	PASSENGER SIDE (Met/Did Not Meet)
1	0.00	0.10	-0.40	0.00	-0.95	Met	Did Not Meet
2	0.00	0.14	0.00	0.38	-0.57	Met	Met
3	-0.14	-0.19	0.00	0.29	-0.29	Met	Met
4	0.00	0.19	-0.29	0.00	-0.58	Met	Did Not Meet
5	-0.14	-0.19	0.00	0.29	-0.29	Met	Met
6	-0.10	-0.19	CBI			N/A	N/A
7	-0.19	-0.14	CBI			N/A	N/A
8	-0.38	-0.38	CBI			N/A	N/A
9	0.00	0.24	0.00	0.11	0.00	Met	Did Not Meet
10	0.05	0.00	-0.05	0.05	-0.15	Met	Met
11	-0.24	-0.14	CBI			N/A	N/A
12	0.19	-0.10	CBI			N/A	N/A
13	0.33	0.38	0.00	0.20	-0.20	Did Not Meet	Did Not Meet
14	0.00	-0.76	0.00	0.20	-0.20	Met	Did Not Meet
15	-0.33	-0.19	0.00	0.38	-0.57	Met	Met

Table 9. Visually Measured Headlamp Aim Deviation (Degrees) from Manufacturers' Lower Beam Aim Angle Targets

	Deviation (Degrees) from Manufacturers' Aim Angle Targets			
	Without Driver Load		With Driver Load	
Vehicle #	Driver Side (°)	Passenger Side (°)	Driver Side (°)	Passenger Side (°)
1	0.40	0.50	0.40	0.50
2	0.24	0.14	0.00	0.14
3	-0.19	-0.19	-0.14	-0.19
4	0.29	0.48	0.29	0.48
5	-0.10	-0.10	-0.14	-0.19
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A
9	0.24	0.24	0.00	0.24
10	0.15	0.15	0.10	0.05
11	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A
13	0.38	0.29	0.33	0.38
14	0.00	-0.76	0.00	-0.76
15	-0.33	0.00	-0.33	-0.19

4.2. Headlamp Aim – Photometric Measurements

A subset of test vehicles that were not needed for other testing were available for their headlamps' aim angles to be checked using photometric equipment for comparison to the visual measurements. Tables 10 to 14 provide the photometrically measured headlamp aim state of new vehicles measured as part of this effort. A positive aim value means the headlamp is aimed above the headlamp height and a negative value means the headlamp is aimed below the headlamp height. Headlamp aim was measured in terms of angle. The aim for each headlamp was then judged in terms of whether it did or did not meet the given criteria.

Table 10. Photometrically Measured Headlamp Aim Without Driver Load Judged Against SAE J599 Manufacturers' Lower Beam Aim Angle Target Values

Vehicle #	DRIVER-SIDE Aim (°)	PASS.-SIDE Aim (°)	Aim Target (°)	SAE J599 Upper Limit (°)	SAE J599 Lower Limit (°)	DRIVER SIDE (Met/Did Not Meet)	PASSENGER SIDE (Met/Did Not Meet)
1	0.12	0.32	-0.4	0	-0.95	Did Not Meet	Did Not Meet
4	-0.14	0.12	0	0.38	-0.57	Met	Met
9	0.24	0.40	0	0.38	-0.57	Met	Did Not Meet
14	-0.08	-0.68	0	0.38	-0.57	Met	Did Not Meet
15	-0.12	0.26	0	0.38	-0.57	Met	Met

Table 11. Photometrically Measured Headlamp Aim With Driver Load Judged Against SAE J599 Manufacturers' Lower Beam Aim Angle Target Values

Vehicle #	DRIVER-SIDE Aim (°)	PASS.-SIDE Aim (°)	Aim Target (°)	SAE J599 Upper Limit (°)	SAE J599 Lower Limit (°)	DRIVER SIDE (Met/Did Not Meet)	PASSENGER SIDE (Met/Did Not Meet)
1	-0.01	0.21	-0.4	0	-0.95	Met	Did Not Meet
4	-0.23	0.10	0	0.38	-0.57	Met	Met
9	0.12	0.34	0	0.38	-0.57	Met	Met
14	-0.19	-0.77	0	0.38	-0.57	Met	Did Not Meet
15	-0.34	0.04	0	0.38	-0.57	Met	Met

Table 12. Photometrically Measured Headlamp Aim Without Driver Load Judged Against Manufacturers' Lower Beam Aim Angle Target Values

Vehicle #	DRIVER-SIDE Aim (°)	PASS.-SIDE Aim (°)	Aim Target (°)	Aim Tolerance Max (°)	Aim Tolerance Min (°)	DRIVER SIDE (Met/Did Not Meet)	PASSENGER SIDE (Met/Did Not Meet)
1	0.12	0.32	-0.4	0	-0.97	Did Not Meet	Did Not Meet
4	-0.14	0.12	-0.29	0.00	-0.58	Met	Did Not Meet
9	0.24	0.40	0	0.114	0	Did Not Meet	Did Not Meet
14	-0.08	-0.68	0	0.2	-0.2	Met	Did Not Meet
15	-0.12	0.26	0.00	0.38	-0.57	Met	Met

Table 13. Photometrically Measured Headlamp Aim With Driver Load Judged Against Manufacturers' Lower Beam Aim Angle Target Values

Vehicle #	DRIVER-SIDE Aim (°)	PASS.-SIDE Aim (°)	Aim Target (°)	Aim Tolerance Max (°)	Aim Tolerance Min (°)	DRIVER SIDE (Met/Did Not Meet)	PASSENGER SIDE (Met/Did Not Meet)
1	-0.01	0.21	-0.40	0.00	-0.97	Met	Did Not Meet
4	-0.23	0.10	-0.29	0.00	-0.58	Met	Did Not Meet
9	0.12	0.34	0.00	0.11	0.00	Did Not Meet	Did Not Meet
14	-0.19	-0.77	0.00	0.20	-0.20	Met	Did Not Meet
15	-0.34	0.04	0.00	0.38	-0.57	Met	Met

Table 14. Photometrically Measured Headlamp Aim Deviation From Manufacturers' Lower Beam Aim Angle Targets

	Deviation (Degrees) from Manufacturers' Aim Angle Targets			
	Without Driver Load		With Driver Load	
Vehicle #	Driver Side (°)	Passenger Side (°)	Driver Side (°)	Passenger Side (°)
1	0.52	0.72	0.39	0.61
4	0.15	0.41	0.06	0.39
9	0.24	0.40	0.12	0.34
14	-0.08	-0.68	-0.19	-0.77
15	-0.12	0.26	-0.34	0.04

4.3. Headlamp Aim – Comparison of Visual and Photometric Aim Angle Measurements

Lower beam headlamp aim angle measured by the visual and photometric methods was compared for five vehicles that were still in "new" condition at the time that imaging photometer equipment was acquired. It is assumed that photometric aim angle measurement is more accurate than the visual method. The difference in aim was calculated for both headlamps of each of the five vehicles for both the unloaded and loaded measurement conditions. Tables 15 and 16 show the difference in measured aim between the visual and photometric methods. The average and range of the difference was also calculated for each measurement type.

Table 15. Comparison of Visual and Photometric Aim Angle Measurements Without Driver Load

	Driver Side			**Passenger Side**		
Vehicle #	**Visual Measurement (°)**	**Photometric Measurement (°)**	**Difference (°)**	**Visual Measurement (°)**	**Photometric Measurement (°)**	**Difference (°)**
1	0.00	0.12	-0.12	0.10	0.32	-0.22
4	0.00	-0.14	0.14	0.19	0.12	0.07
9	0.24	0.24	0.00	0.24	0.40	-0.16
14	0.00	-0.08	0.08	-0.76	-0.68	-0.08
15	-0.33	-0.12	-0.21	0.00	0.26	-0.26
AVG	-0.02	0.00	-0.02	-0.05	0.08	-0.13
AVG of Magnitude			0.11			0.16
Max			0.14			0.07
Min			-0.21			-0.26
Range			0.35			0.33

Table 16. Comparison of Visual and Photometric Aim Angle Measurements With Driver Load

	Driver Side			Passenger Side		
Vehicle #	**Visual Measurement (°)**	**Photometric Measurement (°)**	**Difference (°)**	**Visual Measurement (°)**	**Photometric Measurement (°)**	**Difference (°)**
1	0.00	-0.01	0.01	0.10	0.21	-0.12
4	0.00	-0.23	0.23	0.19	0.10	0.09
9	0.00	0.12	-0.12	0.24	0.34	-0.10
14	0.00	-0.19	0.19	-0.76	-0.77	0.01
15	-0.33	-0.34	0.01	-0.19	0.04	-0.23
AVG	-0.07	-0.13	0.06	-0.09	-0.02	-0.07
AVG of Magnitude			0.11			0.11
Max			0.23			0.09
Min			-0.12			-0.23
Range			0.35			0.32

The average magnitude of difference between the visual and photometric aim angle measurements was 0.11° for all scenarios except the passenger side lamps in the unloaded condition, which was 0.16°. A total average of all measurements gives an overall average of difference in magnitude of 0.12°.

5. Discussion

Visually measured headlamp aim angle results showed that a majority of the lower beam headlamps were found to be aimed within the SAE J599 target range for that vehicle. With no load in the vehicle, 15 of 15 of the driver-side headlamps and 13 of 15 of the passenger side headlamps were within the limits set by SAE J599. With a driver load of 165 pounds in the vehicle, all driver-side headlamps met the criteria and 12 of 15 of the passenger side headlamps met the criteria. Of the vehicles that did not meet the limits of SAE J599, two were from the same manufacturer and the other was a VOL lamp that was aimed closer to how a VOR lamp should be aimed.

Visually measured aim angle results were mixed when comparing the headlamp aim angle to the manufacturers' specifications. With no driver load in the vehicle, 7 of the 10 applicable driver-side headlamps and 4 of the 10 applicable passenger side headlamps were within the manufacturer set limits. With a driver load of 165 pounds in the vehicle, 9 of the 10 applicable driver-side headlamps and 5 of the 10 applicable passenger side headlamps were within the manufacturer set limits.

Adding a driver load had a limited effect on headlamp aim judgment for visual aim measurements. At most, only 2 headlamps' outcomes changed when comparing to the manufacturers' specification with the addition of the driver load. In most cases having the test scenario with the driver weight gave more results that met the criteria than the scenario without the driver weight.

All the manufacturers' aim targets were as strict or stricter than SAE J599 aiming criteria. Therefore, any headlamp conditions that did not meet SAE J599 aim criteria also did not meet their manufacturer's specification. There was not a substantial difference in aim angle target conformance when comparing a headlamp's aim to SAE J599 or their manufacturer's specifications. Comparing both sets of aim targets with the driver load condition, only one more headlamp was found to be outside of aim tolerance criteria for both the driver and passenger side headlamps.

The biggest difference observed in visually measured aim angle results was between the driver-side and passenger-side headlamps. In all four test combinations the driver-side headlamps performed better than the passenger side headlamps. With a standard (165 lb) driver load present, 15 of 15 headlamps met the SAE J599 targets and 9 of 10 headlamps met the manufacturers' targets on the driver side, while 12 of 15 headlamps met the SAE J599 targets and 6 of the 10 met the manufacturers' targets on the passenger side.

Photometric measurements of a subset of 5 test vehicles showed lower beam aim angle values that differed from the visual measurements by an average magnitude of 0.12°, but this difference magnitude was not large enough to substantially affect whether the headlamps met aiming criteria. Considering each measurement scenario (with or without driver load and judged against SAE J599 or the manufacturers' aim angle specifications) of both lamps for all five vehicles, the most extreme deviations of the visual measurement from the photometric measurement were +0.23° and -0.26°. However, only one headlamp per side had a difference in whether the headlamp met the aiming criteria between the visual and photometric measurements. This is probably due to the size of the acceptable aim range for SAE J599 and the manufacturers' specifications.

6. Summary

This report describes an assessment of new vehicle lower beam headlamp aim state. The aim state was measured by following the procedure from SAE J599, which involves shining the headlamps of a vehicle onto a white, matte-finish aiming screen and visually determining the cutoff location relative to the target location. The target aim location is based on factors such as headlamp height, aim type, and manufacturer target.

The research team measured the vertical aim angle of 15 vehicles' driver-side and passenger-side lower beam headlamps. Each vehicle was measured with and without a representative driver load of 165 pounds (75 kg). Images used for measurement were taken with a digital camera. All measurements were taken with a laser marker representing the vehicle height. Measurements were then judged against the target criteria and limits of SAE J599 and the vehicle manufacturers' specifications.

Results showed that headlamps were more likely to meet SAE J599 than their manufacturer's aim targets due to the manufacturers' aim targets being as stringent or more stringent than the SAE standard. The presence of a driver load had a limited effect on headlamp performance, but in most cases the aim was better with a driver load present. Headlamps on the driver side of the vehicle were better aimed than headlamps on the passenger side of the vehicle, with aim being outside the specified tolerance in all but one scenario for the driver side coinciding with aim being outside the specified tolerance on the passenger side. Table 17 summarizes the lower beam aim angle results with respect to both SAE J599 and vehicle manufacturer aim angle targets.

Table 17. Lower Beam Aim Angle Deviation Results

			Percentage of Lamps That Meet Aim Target		**Number of Lamps That Met Aim Target Out of Total**	
	Headlamp Aim Target	**Driver Load**	**Driver-Side Lamp (%)**	**Passenger-Side Lamp (%)**	**Driver-Side Lamp**	**Passenger-Side Lamp**
Visual Measurement	SAE J599	None	100	87	15 / 15	13 / 15
		165 Pounds	100	80	15 / 15	12 / 15
	Vehicle Manufacturer Specification	None	70	40	7 / 10	4 / 10
		165 Pounds	90	50	9 / 10	5 / 10
Photometric Measurement	SAE J599	None	80	40	4 / 5	2 / 5
		165 Pounds	100	60	5 / 5	3 / 5
	Vehicle Manufacturer Specification	None	60	20	2 / 5	1 / 5
		165 Pounds	80	20	4 / 5	1 / 5

A comparison of the visual and photometric measurements showed there were differences in the visually measured aim from the photometrically calculated aim, with the average magnitude difference of 0.12°. However, this difference did not substantially affect whether the headlamps met aiming criteria.

This test effort provided a good initial assessment of the new vehicle aim state of current vehicles on the market and a comparison of aiming accuracy attainable via visual and photometric methods.

7. References

49 CFR § 571.108 - Standard No. 108; Lamps, reflective devices, and associated equipment. SAE International. (2015, November 5).

SAE Standard J599-201511, Lighting Inspection Code
www.sae.org/standards/content/j599_201511

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