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Adaptive Driving Beam Headlighting Systems Rulemaking Support Testing

DISCLAIMER

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16. Abstract

This report describes work conducted to support resolution of NPRM comments regarding a compliance test procedure for "adaptive driving beam" (ADB) headlighting systems. The work supports a National Highway Traffic Safety Administration (NHTSA) rulemaking effort initiated by a 2018 Notice of Proposed Rulemaking (NPRM) that proposed to allow ADB headlighting systems on light vehicles in the U.S. The test procedure involving full-vehicle, dynamic test scenarios performed on a test track was carried out to provide needed data to support resolution of comments on NHTSA's proposal. Testing based on SAE's Surface Vehicle Recommended Practice J3069 "Adaptive Driving Beam" test procedure was also conducted.

Work included development of a test to serve as a surrogate for a stimulus vehicle that would provide a stimulus needed to observe the performance of an ADB headlighting system. Testing was conducted to ensure validity of dynamic illuminance measurements through comparison to static measurements; verify the proposed NHTSA test procedure provides accurate results for multiple light source types; evaluate a current vehicle's lower beam headlamp performance against the NHTSA-proposed ADB glare limit criteria; carry out the draft NHTSA test procedure with an ADB-equipped vehicle; carry out the SAE J3069 test procedure with an ADB-equipped vehicle; and assess whether ADB-equipped vehicles respond similarly when tested using the modified NHTSA test procedure with a stimulus test fixture as when using a FMVSS-compliant vehicle.

The test fixture fitted with original equipment lamps was found to serve as a reasonable surrogate for an actual vehicle. The test procedure was observed to be effective, efficient, and observed to be effective and efficient at determining whether an ADB system can limit glare to other motorists to specified criteria levels. In addition, the test procedure adequately accounted for test surface conditions and other sources of test variability. Through the evaluations and verifications performed, it was determined that a full-vehicle performance test for ADB headlighting systems was suitable for FMVSS use and effective in determining whether an ADB headlighting system limits glare to other motorists to specified criteria levels.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ADB	Adaptive Driving Beam is a type of advanced headlighting system in which the headlamps automatically adjust the headlamp beam pattern to improve long-range visibility for the driver without causing discomfort, distraction, or glare to other road users.
DAS	Data Acquisition System is a generic term for data collection systems.
IRI	International Roughness Index is a measurement of the variation in the test surface, typically measured in meters per kilometer.
LED	A Light-Emitting Diode, as used in this document, is a source of vehicle lighting for certain types of headlamps and other lamps on the vehicle.
RH	This refers to the sensors used to measure illuminance data, Receptor Heads, that were connected to an illuminance meter.
TRC	Transportation Research Center is the proving grounds where testing occurred.
VCDAS	This refers to Video CAN Data Acquisition System, an in-house data system developed for collecting video data in synchronization with any form of CAN data, that was used for collecting data for this research.
VDA	This refers to the name of the facility in which testing occurred, the Vehicle Dynamics Area on the proving grounds of the Transportation Research Center.
VOR	Visually Optically Aligned Right is a term used for a method of adjusting vehicle headlamps.

EXECUTIVE SUMMARY

This report describes work supporting a rulemaking effort associated with a type of advanced headlighting system called "adaptive driving beam," or ADB. ADB headlighting systems use advanced technology that actively modifies the headlamp beam pattern to improve long-range visibility for the driver without causing discomfort, distraction, or glare to other road users. ADB does this by casting more illumination in areas of the roadway not occupied by other vehicles, while limiting illumination to lower beam levels in the direction of other vehicles. The automatic adaptation of the beam pattern may not only serve as a convenience feature for drivers, but could result in increased, safety-beneficial upper beam use.

The National Highway Traffic Safety Administration (NHTSA) published a 2018 Notice of Proposed Rulemaking (NPRM) (FR 83, No. 198) that outlined a proposal to revise Federal Motor Vehicle Safety Standard (FMVSS) No. 108 (49 CFR Sec. 571.108) to allow optional Adaptive Driving Beam (ADB) headlighting systems on light vehicles in the United States. The NPRM proposed compliance criteria and a compliance test procedure using stimulus vehicles to evaluate the performance of an ADB system in preventing glare to other vehicles. The test procedure involves full-vehicle, dynamic test scenarios performed on a test track in dry environmental conditions and dark ambient lighting conditions. Test scenarios include both straight and curved paths of different radii of curvature, both oncoming and same direction orientations, and different vehicle speeds. All test scenarios involve a test vehicle being driven toward a test fixture with light sensors mounted at specific locations.

The work described in this report involved 1) modifying the test procedure proposed in the NPRM to use stimulus test fixtures instead of stimulus vehicles, 2) revising the set of test scenarios to reduce the number of scenarios and revise the radii of curvature for curved-road test scenarios, and 3) carrying out testing to permit evaluation of the test procedure. The modified NHTSA test scenarios and related conditions are shown in the following table.

Modified NHTSA ADB Test Matrix

Test Scenario No.	Test Vehicle Speed (mph)	Orientation (Direction of Test Vehicle and Stimulus)	Radius of Curvature (m)	Curve Direction	Superelevation (Percent)	Measurement Distance Range (m)
1	60-70	Oncoming	Straight	N/A	0-2	15-220
2	60-70	Same Direction	Straight	N/A	0-2	15-100
3	25-30	Oncoming	85-115	Left	0-2	15-59.9
4	40-45	Oncoming	210-250	Left	0-2	15-150
5	40-45	Same Direction	210-250	Left	0-2	15-100
6	40-45	Oncoming	210-250	Right	0-2	15-50
7	50-55	Oncoming	335-400	Left	0-2	15-220
8	50-55	Oncoming	335-400	Right	0-2	15-70

The NPRM proposed a set of maximum allowed illuminance values (glare limits) that an ADB system may produce in the above test scenarios. The glare limits, shown in the table below, are numeric illuminance values that would be the maximum illuminance the ADB system would be permitted to cast on the oncoming or same-direction vehicle in the specified test scenarios.

Separate glare limit illuminance values are indicated for each measurement distance sub-range and for both oncoming and same-direction test scenarios.

Proposed Maximum Illuminance Criteria

Measurement Distance Sub-Range (m)	Maximum Illuminance Oncoming Direction (lux)	Maximum Illuminance Same Direction (lux)
15.0 to 29.9	3.1	18.9
30.0 to 59.9	1.8	18.9
60.0 to 119.9	0.6	4.0
120.0 to 220	0.3	N/A

Testing per the modified NHTSA compliance test procedure was conducted to provide data to support resolution of comments on NHTSA's proposal.

Testing was also conducted based on the SAE's Surface Vehicle Recommended Practice J3069, Adaptive Driving Beam test procedure (2016) for comparison. The SAE J3069 "test drive" conditions are shown below and consist of only straight-path scenarios in which the test vehicle drives toward a test fixture equipped with lamps to simulate another vehicle in a nearby lane and elicit a response from the ADB system. The test procedure uses three fixture positions to represent a vehicle in the lane: two lanes over to the left (position 1), the left adjacent lane (position 2), and second lane to the right (position 3). There is no right adjacent lane fixture position. The procedure involves four stimulus lamp sets: car/truck front lamps, car/truck rear lamps, motorcycle front lamp, and motorcycle rear lamp. Each lamp condition has a specific mounting location on the test fixture. Stimulus lamps are presented as steady burning in most trials and illuminated "suddenly" in six trials involving motorcycle fixtures.

SAE J3069 ADB Test Matrix [3]

Test No.	Direction (of Test Vehicle and Stimulus)	Fixture Position	Vehicle / Fixture Type (Indicates Stimulus Lamps Used)	Lamp Presentation
1	Opposing	1	Car/Truck	Steady
2	Opposing	2	Car/Truck	Steady
3	Opposing	3	Car/Truck	Steady
4	Opposing	1	Motorcycle	Steady
5	Opposing	1	Motorcycle	Sudden
6	Opposing	2	Motorcycle	Steady
7	Opposing	2	Motorcycle	Sudden
8	Opposing	3	Motorcycle	Steady
9	Opposing	3	Motorcycle	Sudden
10	Preceding	1	Car/Truck	Steady
11	Preceding	2	Car/Truck	Steady
12	Preceding	3	Car/Truck	Steady
13	Preceding	1	Motorcycle	Steady
14	Preceding	1	Motorcycle	Sudden
15	Preceding	2	Motorcycle	Steady
16	Preceding	2	Motorcycle	Sudden
17	Preceding	3	Motorcycle	Steady
18	Preceding	3	Motorcycle	Sudden

The SAE J3069 glare limits are shown in the following table.

SAE J3069 Glare Limits [3]

Distance: ADB Vehicle to Opposing Vehicle Driver/Rider's Eye (m)	Opposing Vehicle - Maximum Illuminance (lux)	Preceding Vehicle - Maximum Illuminance (lux)
155	0.3	4.0
120	0.3	4.0
60	0.7	8.9
30	1.8	18.9

The objectives of the test effort described in this report included:

1. Design, build, and assess a test fixture that could serve as a surrogate for a stationary stimulus vehicle in ADB testing.
2. Develop detailed modified ADB compliance test procedure documentation.
3. Evaluate the stability of illuminance meter measurements over time without a test run to check for noise in the system that is not dependent on the tested vehicle.
4. Ensure validity of dynamic-scenario illuminance measurements through comparison to statically performed measurements.
5. Verify that the modified NHTSA test procedure provides accurate results for multiple light source types.
6. Evaluate a late-model vehicle's lower beam performance with respect to NHTSA-proposed ADB glare limit criteria.
7. Carry out the draft NHTSA test procedure with an ADB-equipped vehicle.
8. Carry out the SAE J3069 test procedure with an ADB-equipped vehicle.
9. Assess whether ADB-equipped vehicles respond similarly when tested using the modified NHTSA test procedure with a stimulus test fixture as when using a FMVSS-compliant vehicle.
10. Characterize NHTSA ADB test procedure repeatability and reproducibility.
11. Characterize SAE J3069 test procedure repeatability.

This report describes testing and analyses related to the first nine points above, while the repeatability and reproducibility efforts are documented in a separate NHTSA report titled, "Adaptive Driving Beam (ADB) Headlamps Test Repeatability Assessment" [8]. Testing sought to assess both the viability of the test fixture and the viability/need for SAE J3069-style stimulus lamps.

The NHTSA and SAE ADB test procedures were run with each of three test vehicles one or more times depending on the analyses the testing of each vehicle was assigned to support. The three test vehicles are listed below.

- 2019 Ford Fusion (halogen headlamps, FMVSS certified)
- 2018 Lexus NX300 (European mass production model), ADB-equipped (LED headlamps)
  - FMVSS No. 108 compliant lower and upper beams; all other lighting aspects were ECE-compliant
- 2016 Volvo XC90 (LED headlamps, FMVSS certified)

Test procedure implementation information, testing performed, and analysis results are summarized below according to the previously listed numbered objectives.

1. **Design, build, and assess a test fixture that could serve as a surrogate stationary stimulus in place of an actual vehicle for use in ADB testing.**

   A test fixture was designed and built to accommodate both the NHTSA and SAE test procedures. The test fixture layout included a vertical array of illuminance meter light sensors (i.e., receptor heads) positioned to correspond to an oncoming or preceding vehicle driver's eye location or outside mirror locations (for a preceding vehicle). The fixture also provided a structure on which to mount stimulus lamps for accurate positioning of the various NHTSA and SAE lamp conditions that included: Toyota Camry headlamps and taillamps, Ford F-150 headlamps and taillamps, a Harley Davidson motorcycle headlamp and taillamp, and SAE headlamps and taillamps (custom lamps built by a vendor to meet the SAE J3069 specifications). Testing was conducted using the developed fixture to assess both the viability of test fixture use and viability/need for SAE-style stimulus lamps.

2. **Develop detailed ADB modified compliance test procedure documentation.**

   A detailed test procedure document was written that outlines dynamic test procedure details, test fixture characteristics, example instrumentation, test vehicle preparations, test execution, data processing, and test result determination. Testing conducted in support of this effort allowed for further assessment of the test procedure to determine if there were any problems or additional needed detail in the NHTSA test procedure and related documentation. No problems or gaps were found in any of the test procedures, with the results of each test procedure showing illuminance data to have mixed results for adherence to the glare limits.

3. **Evaluate the stability of illuminance meter outputs over time without a test run (checking for any noise in the measurement system that is not dependent on the tested vehicle).**

   Testing was performed to evaluate the stability of the measured illuminance values, without a test vehicle present, to determine if there was any noise in the measurement system that was not dependent on the vehicle being tested or some aspect of the test procedure. This was performed to confirm that the measurement system would provide consistent and stable data before beginning any vehicle testing. For each stimulus lamp condition, illuminance data were recorded for a period of 30 seconds in typical test conditions. The results indicated that both the analog and digital data measured value standard deviations were low for each of the receptor heads for each of the ten stimulus lamp conditions, suggesting very little system noise or fluctuation. In fact, each lamp condition had at least two receptor heads that exhibited no variability (standard deviation = 0) in the digital data. Thus, the illuminance data as measured were found to be stable and the measurement system could be ruled out as a source of any data noise or variability in measured values.

4. **Ensure validity of dynamic illuminance measurements through comparison to stationary measurements.**

Tests were performed to assess whether test scenarios could be executed with sufficiently steady vehicle dynamics such that, in lower beam mode, headlamp illumination measured during dynamic test scenario performance would match that measured in the same location with the vehicle stationary. Measured illuminance and pitch angle data values were extracted for both dynamic and static test trials at specific scenario path points corresponding to an end of a glare limit distance range. Illuminance results indicated dynamic and static measurements were comparable in most scenarios; however, there were some receptor head locations in some scenarios in which the dynamic and static measurements were not similar. Pitch angle results indicated dynamic and static measurements were comparable in most scenarios.[1] Overall, analysis of vehicle pitch data showed that pitch could be monitored and controlled as part of the test procedure conditions.

5. **Verify that the modified NHTSA test procedure provides accurate results for multiple light source types.**

   Tests were performed using the three vehicle models with headlighting systems operating in lower beam mode. Results demonstrated that the headlamp types tested, halogen and LED, were compatible with the test procedure.

6. **Evaluate a late-model vehicle's lower beam performance with respect to NHTSA-proposed ADB glare limit criteria.**

   Three test vehicles with headlighting systems operating in lower beam mode were subjected to the NHTSA ADB modified compliance test procedure. The vehicles included a 2019 Ford Fusion with halogen headlamps, a 2018 Lexus NX300 European mass production model with LED headlamps and modified to have FMVSS No. 108 compliant lower and upper beams, and a 2016 Volvo XC90 with LED headlamps. Measured illuminance values were evaluated with respect to the glare limit criteria. The Ford Fusion lower beam headlamps produced illuminance values that met glare limit criteria in all test scenarios, while the modified European-market Lexus NX300 lower beam headlamps produced measured illuminance values that exceeded glare limit criteria in several of the test scenarios. The Volvo XC90's lower beam headlamps were found to meet the glare limit criteria in most of the test scenarios.

7. **Test an ADB-equipped vehicle per the NHTSA modified test procedure.**

   An ADB-equipped, European-market 2018 Lexus NX300 with LED headlamps and modified to have FMVSS No. 108 compliant lower and upper beams was subjected to the draft NHTSA ADB compliance test procedure. As noted above, this vehicle's lower beam headlamps exceeded glare limits for several of the test scenarios. As ADB reduces headlighting system illuminance to lower beam levels where another vehicle is detected,

[1] Section 6.2 of this report discusses vehicle pitch data findings.

this vehicle's results for testing in ADB mode also showed a mix of test scenario outcomes varying by radius of curvature and measurement distance sub-range.

8. **Test an ADB-equipped vehicle per the SAE J3069 test procedure.**

   The objective of this effort was to gather information on the SAE J3069 (2016) test procedure and to aid discussion of differences between the NHTSA and SAE J3069 ADB test procedures. Data and information were needed to be able to effectively discuss the trade-offs between realism of test scenarios versus repeatability and efficiency of testing. Test results for the ADB-equipped Lexus test vehicle for both lower beam and ADB modes showed a mix of test outcomes varying by fixture location, test vehicle speed, and measurement distance. Two aspects of the SAE test procedure, the open-ended test vehicle speed selection and variable stimulus lamp sudden appearance distance, were identified as possible contributors to test outcome variability.

9. **Assess whether ADB-equipped vehicles respond similarly to a stimulus consisting of a test fixture as they do to a FMVSS-compliant vehicle.**

   The Lexus NX300 with headlighting system operating in ADB mode was subjected to both the NHTSA and SAE ADB test procedures once with the specified stimulus test fixture and again with a 2018 Ford F-150 production vehicle serving as a stimulus vehicle in place of the test fixture. Measured values and system performance outcomes for the stimulus vehicle versus the test fixture were compared for both test procedures. The results showed that the Lexus NX300's ADB system generally responded similarly to the test fixture as it did to the full stimulus vehicle. Results for the Lexus NX300 operated in lower beam mode showed complete agreement for oncoming NHTSA test scenarios test outcomes between the F-150 stimulus vehicle and the test fixture for all test scenarios except the 400-m right curve and complete agreement for all same direction test scenarios. For the Lexus NX300 operated in ADB mode, test outcomes agreed for most oncoming test scenarios and approximately half of the same direction test scenarios. For the SAE J3069 test procedure, there was test outcome agreement between the test fixture and stimulus vehicle results for most test scenarios for both lower beam and ADB trials. For both test procedures, any differences in test outcomes between the test fixture and stimulus vehicle were likely due both to differences in headlamp mounting heights and the measurement point between the test fixture and the stimulus vehicle.

In summary, to assess the objectives above, a test fixture was designed and constructed to provide a stimulus needed to observe the performance of an ADB headlighting system. The test fixture was found to serve as a reasonable surrogate for an actual vehicle. Through the evaluations and verifications performed, it was determined that a full-vehicle performance test for ADB headlighting systems was suitable for FMVSS use and effective in determining whether an ADB headlighting system limits glare to other motorists to specified criteria levels. In addition, the test procedure adequately accounted for test surface conditions and other sources of test variability.

1.0 INTRODUCTION

This report describes work focused on a type of advanced headlighting system called "adaptive driving beam," or ADB. ADB headlighting systems use advanced technology that actively modifies the headlamp beam pattern to improve long-range visibility for the driver by casting more illumination in areas of the roadway not occupied by other vehicles, while limiting illumination to lower beam levels in the direction of other vehicles to minimize discomfort, distraction, or glare to other road users. The automatic adaptation of the beam pattern may not only serve as a convenience feature for drivers, but could result in increased, safety-beneficial upper beam use.

The efforts documented herein support a National Highway Traffic Safety Administration (NHTSA) rulemaking effort initiated by a 2018 Notice of Proposed Rulemaking (NPRM) [1] that outlined a proposal to revise Federal Motor Vehicle Safety Standard (FMVSS) No. 108 [2] to allow optional Adaptive Driving Beam (ADB) headlighting systems on light vehicles in the United States. The NPRM [1] proposed compliance criteria and a compliance test procedure using stimulus vehicles to evaluate the performance of an ADB system in preventing glare to other vehicles. The compliance test procedure involves full-vehicle, dynamic test scenarios performed on a test track in dry environmental conditions and dark ambient lighting conditions. Test scenarios include both straight and curved paths of different radii of curvature, both oncoming and same direction orientations, and different vehicle speeds. While the proposed test procedure involved the use of stimulus vehicles that would elicit an ADB response from test vehicles, most of the testing described herein involved use of a test fixture in place of a stimulus vehicle. The test fixture was equipped with vehicle lamps and light sensors mounted at specific locations.

The work described in this report involved 1) modifying the test procedure proposed in the NPRM to use stimulus test fixtures instead of stimulus vehicles, 2) revising the set of test scenarios to reduce the number of scenarios and revise the radii of curvature for curved-road test scenarios, and 3) carrying out testing to permit evaluation of the modified test procedure.

Testing per that test procedure was conducted to provide data to support resolution of comments on NHTSA's proposal. Testing based on SAE's Surface Vehicle Recommended Practice J3069 "Adaptive Driving Beam" test procedure [3] was also conducted.

1.1 Objective and Scope

Testing was conducted to obtain data that would facilitate addressing several objectives. Those objectives included:

1. Design, build, and assess a test fixture that could serve as a stationary surrogate for an actual vehicle providing a stimulus for the ADB system to respond to in compliance test scenarios.
2. Develop detailed ADB modified compliance test procedure documentation.
3. Evaluate the stability of illuminance meter measurements over time without a test run to check for noise in the measurement system that is not dependent on the tested vehicle.
4. Verify that the modified NHTSA test procedure provides accurate results for multiple light source types.

5. Ensure validity of dynamic-scenario illuminance measurements through comparison to statically performed measurements.
6. Evaluate a late-model vehicle's lower beam performance with respect to NHTSA-proposed ADB glare limit criteria.
7. Carry out the modified NHTSA test procedure with an ADB-equipped vehicle.
8. Carry out the SAE J3069 test procedure with an ADB-equipped vehicle.
9. Assess whether ADB-equipped vehicles respond similarly when tested using the modified NHTSA test procedure with a stimulus test fixture as when using a FMVSS-compliant vehicle.
10. Characterize NHTSA ADB test procedure repeatability and reproducibility.
11. Characterize SAE J3069 test procedure repeatability.

This report describes testing and analyses related to the first nine points above, while the repeatability and reproducibility efforts are documented in a separate NHTSA report titled, "Adaptive Driving Beam (ADB) Headlamps Test Repeatability Assessment."

2.0 NHTSA NPRM-PROPOSED AND SAE J3069 ADB TEST PROCEDURES

This section describes the SAE J3069 and NHTSA-proposed ADB test procedures.

2.1 SAE J3069 Test Procedure

In June 2016, SAE International (SAE) published SAE J3069 JUN2016 [3], Surface Vehicle Recommended Practice; Adaptive Driving Beam (SAE J3069).[2] The recommended practice, which is based, in part, on NHTSA's research [4], includes (among other requirements) a track test to evaluate ADB system performance in avoiding excessive glare to other vehicles. It specifies a straight test path with a single lane, on either side of which it specifies the placement of test fixtures simulating an opposing or preceding vehicle, as shown in Figure 1. The test fixtures are fitted with lamps having a specified luminous intensity, color, and size intended to simulate the taillamps and headlamps on a typical car, truck, or motorcycle. Four different test fixtures are specified: an opposing (*i.e.*, oncoming) car/truck; an opposing motorcycle; a preceding car/truck; and a preceding motorcycle. In addition to simulated vehicle lighting, the test fixtures are fitted with light measurement sensors (also known as photometers or receptor heads) to measure the illumination from the ADB headlamps. Although the test does not specify any scenarios with a curved test path, the placement of the fixtures relative to the straight test path, along with a sudden appearance test, are intended to simulate curves.

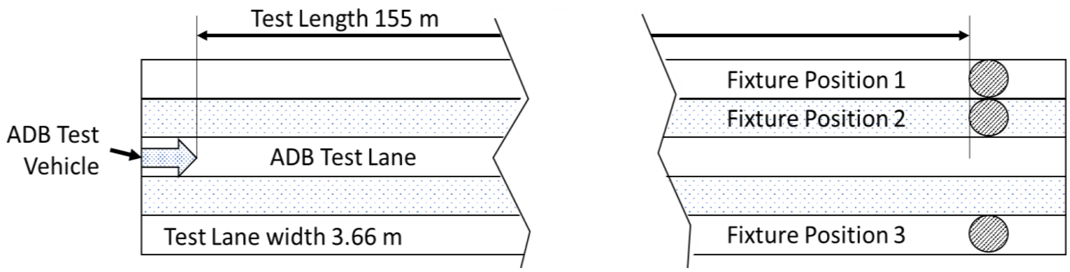

Figure 1. *SAE Test Fixture Positions*

In addition to the dynamic track test, SAE J3069 contains other system requirements, such as a physical test (*e.g.*, a corrosion test) and telltale requirements. It also requires the system to comply with a limited set of component-level laboratory-based photometry requirements.

2.1.1 SAE J3069 Test Drives

The SAE J3069 ADB test procedure specifies six "test drives" that are run three times with different stimulus headlamp types and either steady or "sudden reveal" presentation style, resulting in a total of eighteen different test drive scenarios. The scenarios vary the test fixture, the placement of the fixture, and whether the lamps on the test fixture are illuminated for the entire test drive or

[2] SAE has recently published a revised version of this recommended practice (SAE J3069 MAR2021). Testing described in this report was conducted based on the 2016 version of SAE J3069.

are instead suddenly illuminated when the ADB vehicle reaches a specified distance from the test fixture.

The six test drives are specified in SAE J3069 [3] as indicated below.

> "5.5.6.3 For each of the six test drive events described below, the fixture representing an opposing or preceding vehicle shall be placed in one of the three positions as shown in Figure 5 (eighteen total test drives). Prior to each test drive, the illuminance meters shall be zero-calibrated. The fixture shall function as specified for each of the conditions below:
>
> 5.5.6.3.1 An opposing vehicle, according to Figure 1, with the fixture lamps exposed for the entire test drive.
>
> 5.5.6.3.2 An opposing vehicle, according to Figure 2, with the fixture lamps exposed for the entire test drive.
>
> 5.5.6.3.3 An opposing vehicle, according to Figure 2, where the fixture lamp is suddenly exposed when the ADB equipped vehicle is between 155 m and 100 m from the fixture simulating the sudden appearance of an opposing vehicle.
>
> 5.5.6.3.4 A preceding vehicle, according to Figure 3, with the fixture lamps exposed for the entire test drive.
>
> 5.5.6.3.5 A preceding vehicle, according to Figure 4, with the fixture lamps exposed for the entire test drive.
>
> 5.5.6.3.6 A preceding vehicle, according to Figure 4, where the fixture lamp is suddenly exposed when the ADB equipped vehicle is between 155 m and 100 m from the fixture simulating the sudden appearance of a preceding vehicle.
>
> 5.5.6.4 During each test drive, record the lux levels at the illuminance meter(s) along with the distance between the ADB equipped vehicle's headlamp optical center and the illuminance meter(s) when lux levels are measured. The distance measured shall be accurate to within 2 m. The illuminance meter shall be accurate to within 6 percent. Interpolation may be used to determine the illuminance corresponding to those distances provided that the illuminance values are measured at a rate of at least 10 Hz during the entire test drive."

The content of the noted figures are as follows:

- Figure 1 - Opposing vehicle fixture (car/truck)
- Figure 2 - Opposing vehicle fixture (motorcycle)
- Figure 3 - Preceding vehicle fixture (car/truck)
- Figure 4 - Preceding vehicle fixture (motorcycle)

Figures 1 - 4 in SAE J3069 indicate the mounting position of stimulus headlamps and light measurement sensors on the test fixture.

The three test fixture positions are shown in the figure above (which depicts the test fixture positions described in SAE J3069 [3] Figure 5). For the adjacent lane SAE J3069 test drives

(Fixture Position 2), the test vehicle passes to the right of the test fixture, having a lane width separation of 12 feet (3.66 meters), which is measured from the center of the test fixture to the center of the test vehicle's path of travel when it is at its nearest adjacent lane location. For the two non-adjacent lane scenarios, the test vehicle passes to the right (Fixture Position 1) and to the left (Fixture Position 3) of the test fixture, having a lane width separation of 24 feet (7.32 meters) center to center.

The test surface requirements describe a uniform, straight, and flat area having at least one lane and a "linear extent of at least 155 m that is flat and level over this extent with adjoining areas sufficient to allow the acceleration of a test vehicle to the test speed and its deceleration after completing a test drive."

2.1.2 SAE J3069 Maximum Allowed Illuminance

During each of the 18 test drive scenarios, the illuminance[3] recorded at 30 m, 60 m, 120 m, and 155 m must not exceed the maximum allowed illuminance specified for each distance, listed in Table 1 below. These illuminance maxima are based on and similar (but not identical) to the maximum illuminance limits developed in NHTSA's published research and proposed in the NPRM. If there is no recorded illuminance value at any of these distances, SAE J3069 states that interpolation is to be used to estimate the illuminance at that distance. For sudden appearance tests, the system is given a maximum of 2.5 seconds to react and adjust the beam to reduce illumination to a level within the applicable maximum. If any recorded (or interpolated) illuminance value exceeds the applicable maximum illuminance, SAE J3069 provides for an allowance: the same test drive scenario is run with the lower beam activated. The ADB system can still be deemed to have passed the test if any of the ADB exceedances do not exceed 125 percent (or 1.25 times) of the measured (or interpolated) illuminance value(s) for the lower beam.

Table 1. *SAE J3069 Glare Limits [3]*

Distance: ADB Vehicle to Opposing Vehicle Driver/Rider's Eye (m)	Maximum Illuminance Opposing Vehicle Driver/Rider's Eye (lux)	Maximum Illuminance Preceding Vehicle Rearview Mirror, Driver-Side Mirror, and Passenger-Side Mirror (lux)
155	0.3	4.0
120	0.3	4.0
60	0.7	8.9
30	1.8	18.9

2.1.3 SAE J3069 Lamp Specifications

SAE J3069 provides lamp specifications for opposing vehicle and preceding vehicle stimuli separately. The opposing vehicle lamps "shall project 300 cd ± 5 percent of white light per SAE

[3] Illuminance is the amount of light falling on a surface. The unit of measurement for illuminance is lux.

J578 in a uniform manner over a conical angle greater than ± 15 degrees and shall have an illuminated area of 80 cm2 ± 10 cm^2. No other vehicle lighting devices shall be activated or any retro-reflective material present and care should be taken to avoid other sources of light, reflected or otherwise." The preceding vehicle lamps each "shall emit no more than 7 cd of red light per SAE J578 in a uniform manner over a conical angle greater than ± 25 degrees with an illuminated area of 50 cm^2 ± 10 cm^2. No other vehicle lighting devices shall be activated or any retro-reflective material present and care should be taken to avoid other sources of light, reflected or otherwise."

In carrying out the SAE J3069 test procedure as part of this research effort, the lamps used were the Sapphire Technical Solutions Model No. LS-301-1. This calibrated light source kit, shown in Figure 2, was designed specifically to meet the SAE J3069 stimulus lamp specifications, and included two identical lamps, two identical red lenses, a remote trigger, a power source, and cables. The taillamp conditions were implemented by inserting a red lens at the face of the lamp(s). A remote trigger was used to turn a single lamp on for the sudden appearance test condition.

Figure 2. *Sapphire Technical Solutions Model No. LS-301-1 Lamp Kit*

<u>2.1.4</u> ***SAE J3069 Lamp and Illuminance Measurement Point Specifications***

Specifications for the locations of stimulus lamps and measurement points, as indicated in SAE J3069, are depicted in Figures 3 and 4. In these figures, circles represent receptor head locations, ovals represent headlamp locations, and rectangles represent taillamp locations.

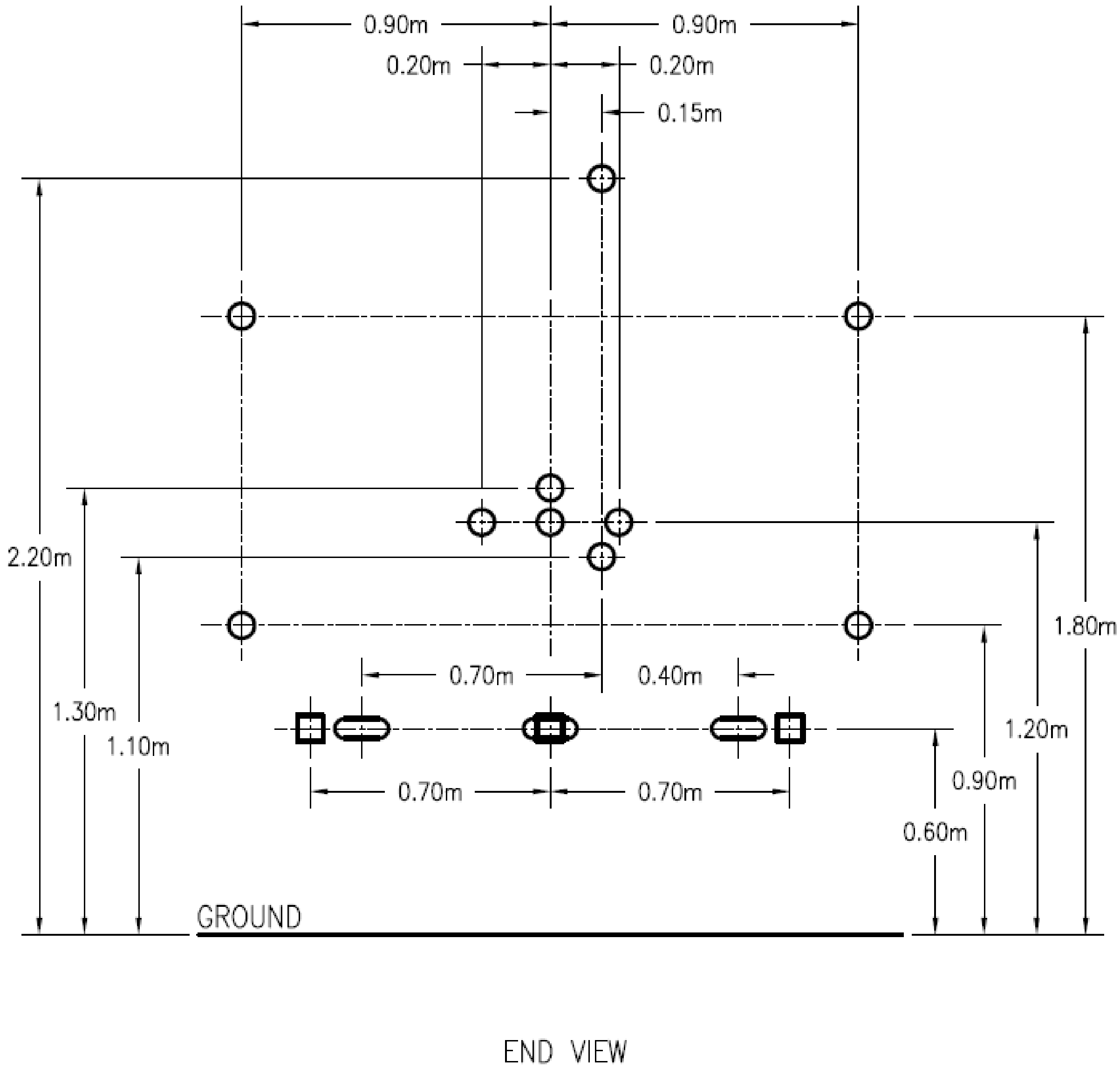

Figure 3. *Stimulus Lamp Locations and Light Measurement Points, End View*

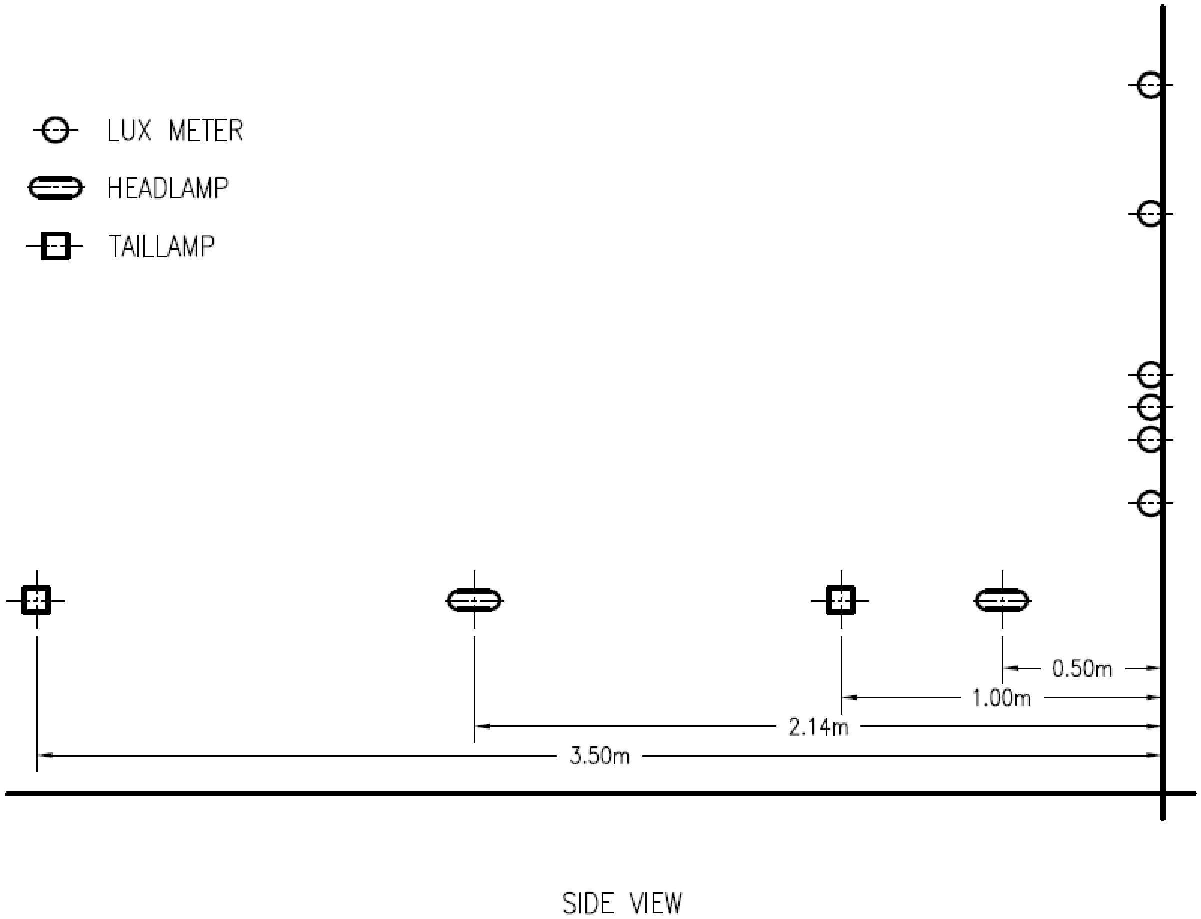

Figure 4. *Stimulus Lamp Locations and Light Measurement Points, Side View*

2.2 Proposed NHTSA ADB Test Procedure

The NPRM [1] proposed amending FMVSS No. 108 to include full-vehicle, track-test requirements specifically tailored to evaluate whether an ADB system functions safely and limits glare for other motorists. NHTSA proposed evaluating the performance of an ADB-equipped vehicle (test vehicle) in a variety of different types of interactions with either an oncoming or preceding vehicle (referred to as a "stimulus" vehicle because it stimulates a response from the ADB system). The stimulus vehicle would be equipped with sensors near the driver's eyes (or rearview mirrors) to measure the illuminance from the ADB headlamps. The illuminance falling on the stimulus vehicle would be measured and recorded throughout the test run.

2.2.1 NHTSA NPRM-Proposed Test Scenarios

The NPRM described a proposed set of test scenarios designed to dynamically assess ADB system performance. The scenario set included three basic vehicle orientation scenarios for testing compliance: oncoming (where the test and stimulus vehicles approach each other traveling in opposite directions); same direction/same lane (where the stimulus vehicle precedes the test vehicle in the same lane); and same direction/passing with one vehicle (either the stimulus or test vehicle) travelling faster than and overtaking the other vehicle. The NPRM also proposed scenarios in which the stimulus vehicle was stationary.

The proposed test procedure involved performing each test scenario at various test and stimulus vehicle speeds (from 0 to 70 mph) on both a straight test path and on left and right curves of varying radii: a "short" curve (with radii from 98 m to 116 m), a "medium" curve (223 m to 241 m), and a "large" curve (335 m to 396 m). The proposal also included a variety of related test procedures and conditions, such as adjusting for ambient light, the condition of the road surface, and the number of lanes. Each test scenario's path was comprised of a specified measurement distance range over which illuminance data was to be measured for comparison to applicable glare limits. The measurement distance range is the distance from each illuminance sensor receptor head to a midpoint between the test vehicle headlamps over which illuminance data are evaluated. Each measurement distance range was composed of multiple measurement distance sub-ranges having associated glare limit criteria as specified in the next section.

The specific conditions of the test scenarios as proposed in the NPRM are described in Tables 2 and 3.

Table 2. *NHTSA ADB Test Scenarios as Proposed in the NPRM [1]*

Test No.	Stimulus Vehicle Speed	Test Vehicle Speed	Radius of Curvature	Superelevation (%)
1	60-70 mph (96.6-112.7 kph)	60-70 mph (96.6-112.7 kph)	Straight	0-2
2	0	60-70 mph (96.6-112.7 kph)	Straight	0-2
3	40-45 mph (64.4-72.4 kph)	60-70 mph (96.6-112.7 kph)	Straight	0-2
4	60-70 mph (96.6-112.7 kph)	40-45 mph (64.4-72.4 kph)	Straight	0-2
5	25-30 mph (40.2-48.3 kph)	25-30 mph (40.2-48.3 kph)	320-380 ft (97.5-115.8 m)	0-2
6	0	25-30 mph (40.2-48.3 kph)	320-380 ft (97.5-115.8 m)	0-2
7	40-45 mph (64.4-72.4 kph)	40-45 mph (64.4-72.4 kph)	730-790 ft (222.5-240.8 m)	0-2
8	0	40-45 mph (64.4-72.4 kph)	730-790 ft (222.5-240.8 m)	0-2
9	30-35 mph (48.3- 56.3 kph)	40-45 mph (64.4-72.4 kph)	730-790 ft (222.5-240.8 m)	0-2
10	40-45 mph (64.4-72.4 kph)	30-35 mph (48.3- 56.3 kph)	730-790 ft (222.5-240.8 m)	0-2
11	50-55 mph (80.5-88.5 kph)	50-55 mph (80.5-88.5 kph)	1,100-1,300 ft (335-396 m)	0-2
12	50-55 mph (80.5-88.5 kph)	40-45 mph (64.4-72.4 kph)	1,100-1,300 ft (335-396 m)	0-2
13	40-45 mph (64.4-72.4 kph)	50-55 mph (80.5-88.5 kph)	1,100-1,300 ft (335-396 m)	0-2

Table 3. *ADB Test Orientation [1]*

Orientation	Lane Orientation/Maneuver	Test Scenario No.	Measurement Distance Range
Oncoming	Adjacent	1, 2, 5, 6, 7, 8, 11	49.2-721.8 ft (15-220 m)
Same Direction	Same Lane	1, 5, 7, 11	98.4-393.4 ft (30-119.9 m)
Same Direction	Adjacent/Passing	2, 3, 6, 8, 9, 13	49.2-393.4 ft (15-119.9 m)
Same Direction	Adjacent/Passing	4, 10, 12	98.4-393.4 ft (30-119.9 m)

2.2.2 *Proposed NHTSA Glare Limit Criteria*

The NPRM [1] proposed a set of maximum allowed illuminance values (glare limits) derived from information provided in FMVSS No. 108 [2]. These are numeric illuminance values that would be the maximum illuminance the ADB system would be permitted to cast on a stimulus vehicle (i.e., a vehicle that provides a stimulus for the ADB system to respond to) in the specified test scenarios. The proposed glare limits and test procedures were based on extensive agency research and testing [4] and are listed in Table 4. The NPRM proposed sampling illuminance values throughout the proposed measurement ranges (also referred to in this document as measurement distances). The proposed compliance criteria consisted of a set of glare limits that, if any recorded illuminance value exceeded, would be considered a test failure, except that values above the applicable glare limit lasting no longer than 0.1 second (s) or over a distance of no longer than 1 meter (m) would not be considered test failures. This adjustment was intended to allow for electric noise in the illuminance measurement components (*i.e.*, any electrical signal whose source is not a result of changes in illuminance) as well as momentary changes in vehicle pitch angle.

Table 4. *NHTSA Glare Limits, Derived From FMVSS No. 108*

Measurement Distance Sub-Range (m)	Oncoming Scenarios - Illuminance (lux)	Same Direction Scenarios - Illuminance (lux)
15.0 - 29.9	3.1	18.9
30.0 - 59.9	1.8	18.9
60.0 - 119.9	0.6	4.0
120.0 - 239.9	0.3	N/A

2.2.3 *NHTSA NPRM-Proposed ADB Stimulus Specifications*

The proposal specified a broad set of potential stimulus vehicles. The NPRM proposed using any FMVSS-certified vehicle from the five model years preceding the model year of the test vehicle, subject to a specified height constraint intended to exclude unusually high- or low-riding vehicles.

2.2.4 NHTSA NPRM-Proposed Lamp and Illuminance Measurement Point Specifications

In the NPRM, NHTSA proposed to locate illuminance receptor heads at measurement points on the windshield and outside rearview mirrors of the stimulus vehicle.

Lamp locations were dictated by the specification of U.S. market vehicles in test scenarios to elicit a response from the ADB-equipped vehicle. As such, lamp locations would be the as-equipped lamp locations on the stimulus vehicle.

3.0 METHOD

This section describes post-NPRM modifications to the NHTSA ADB dynamic test procedure, the equipment used, and details regarding how testing was conducted.

3.1 NHTSA Test Procedure Modifications Implemented in This Testing

Some aspects of the testing described in this report differed from the NPRM-proposed test procedure specifications to allow for investigation of comments relating to certain aspects of the test procedure. This section notes those differences.

3.1.1 Test Scenarios

In response to comments received on the NPRM, a modified and reduced set of test scenarios was developed and implemented in this testing. The radii of curvature were revised for curved-road test scenarios and the smallest radius of curvature right-curve scenario was eliminated. The measurement distances were truncated for all but the large left curve scenario. The measurement distances were also modified for the preceding scenarios. Table 5 summarizes the test scenarios.

Table 5. *NHTSA ADB Test Scenarios as Implemented in This Testing*

Orientation	Curve Direction	Radius of Curvature (m)	Measurement Distance Range	Test Vehicle Speed
Oncoming	Straight	N/A	49.2-721.8 ft (15-220 m)	60-70 mph (96.6-112.7 kph)
Oncoming	Left	85-115	49.2-196.5 ft (15-59.9 m)	25-30 mph (40.2-48.3 kph)
Oncoming	Left	210-250	49.2-492.1 ft (15-150 m)	40-45 mph (64.4-72.4 kph)
Oncoming	Left	335-400	49.2-721.8 ft (15-220 m)	50-55 mph (80.5-88.5 kph)
Oncoming	Right	210-250	49.2-164.0 ft (15-50 m)	40-45 mph (64.4-72.4 kph)
Oncoming	Right	335-400	49.2-229.7 ft (15-70 m)	50-55 mph (80.5-88.5 kph)
Same Direction	Straight	N/A	49.2-721.8 ft (15-220 m)	60-70 mph (96.6-112.7 kph)
Same Direction	Left	85-115	49.2-196.5 ft (15-59.9 m)	25-30 mph (40.2-48.3 kph)
Same Direction	Left	210-250	49.2-328.1 ft (15-100 m)	40-45 mph (64.4-72.4 kph)
Same Direction	Left	335-400	49.2-721.8 ft (15-220 m)	50-55 mph (80.5-88.5 kph)
Same Direction	Right	210-250	49.2-164.0 ft (15-50 m)	40-45 mph (64.4-72.4 kph)
Same Direction	Right	335-400	49.2-229.7 ft (15-70 m)	50-55 mph (80.5-88.5 kph)

For the NHTSA tests described in this report, the test vehicle passed to the right of the ADB stimulus in an adjacent lane scenario, having a lane width separation of 10 feet (3.048 meters), which is measured from the center of the test fixture to the center of the test vehicle's path of travel when it is at its nearest adjacent lane location.

3.1.2 **Stimulus Test Fixture (In Lieu of Stimulus Vehicle)**

In response to NPRM commenters' concerns[4] regarding the use of stimulus vehicles as opposed to test fixtures, the agency decided to gather data to examine the performance of the NHTSA test procedure implemented with a test fixture serving as the ADB stimulus rather than a stimulus vehicle. A test fixture was designed and constructed to achieve the SAE J3069 measurement points and lamp mounting positions. The test fixture was designed and constructed to accommodate both the oncoming and preceding vehicle scenario orientations of both the NHTSA and SAE test procedures. This single fixture could be used to properly position all the needed illuminance meter receptor heads and each of the stimulus lamps at the correct heights and distances with respect to the receptor heads.

The fixture was constructed from 80/20 T-slot aluminum framing, brackets, and associated fasteners. The aluminum had a matte black finish to minimize light reflection.

For ease of assembly and transport, the test fixture was designed to have three sections that could be easily connected. The main section and rearmost section consisted of a tall vertical structure on which a vertical array of illuminance meter receptor heads was mounted with a low, horizontally-oriented structure on which stimulus lamps could be mounted. The second, center section was a rectangular piece that laid directly on the ground and connected the first section to the third section while maintaining proper alignment and distance between them. The third section consisted of a low, horizontal assembly on which taillamps could be positioned. The three fixture sections could be transported and stored in a small trailer and quickly assembled at the test site.

The first and third sections of the fixture were designed to hold stimulus lamp "trays" that would allow for stimulus lamps to be placed on and taken off the fixture quickly and precisely. Each tray was composed of a black matte steel pegboard panel on which 80/20 aluminum framing and fasteners were used to support the lamps securely.

The following figure contains a drawing showing the structure of the fixture with receptor heads in the appropriate measurement point locations and stimulus lamp mounting locations (from an end-view perspective).

[4] Commenters were concerned that the NPRM proposal involving use of stimulus vehicles would result in an impracticably large set of potential vehicles and high associated test burden.

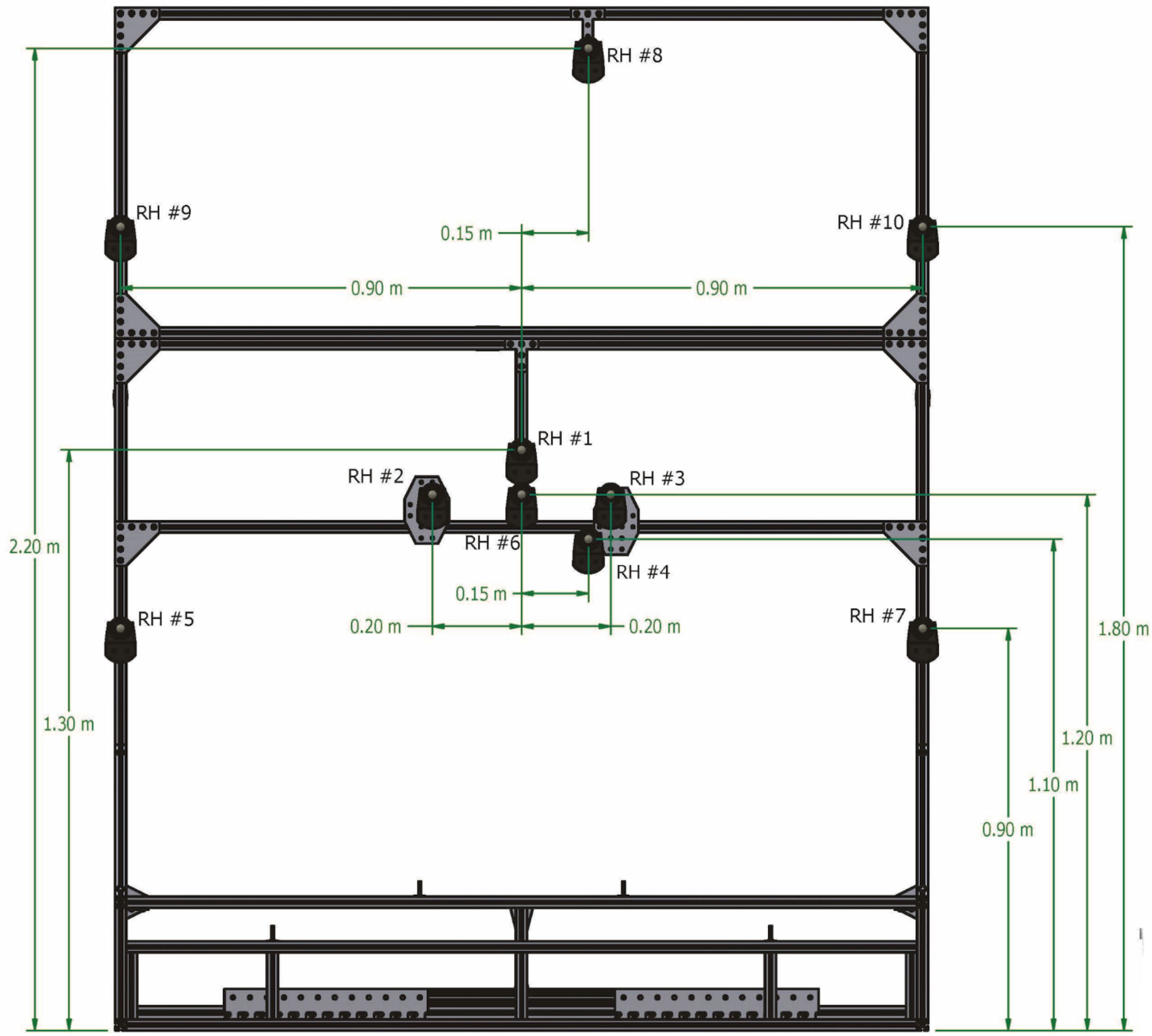

Figure 5. *Test Fixture Drawing Showing Mounted Illuminance Receptor Heads*

Illuminance meter receptor heads were mounted on the NHTSA test fixture to represent the locations listed in the following table.

Table 6. *Illuminance Meter Receptor Head Locations on the Stimulus Test Fixture*

Stimulus	Scenario	Receptor Head (RH) Number	Location
NHTSA Test Fixture	Oncoming	4	Car driver eye point
		1	Motorcycle eye point
		8	Truck driver eye point
	Same Direction	5	Car driver-side rearview mirror
		7	Car passenger-side rearview mirror
		6	Car inside rearview mirror
		2	Motorcycle left rearview mirror
		3	Motorcycle right rearview mirror
		9	Truck driver-side rearview mirror
		10	Truck passenger-side rearview mirror

Several of the following figures contain photographs of the constructed fixture and its components.

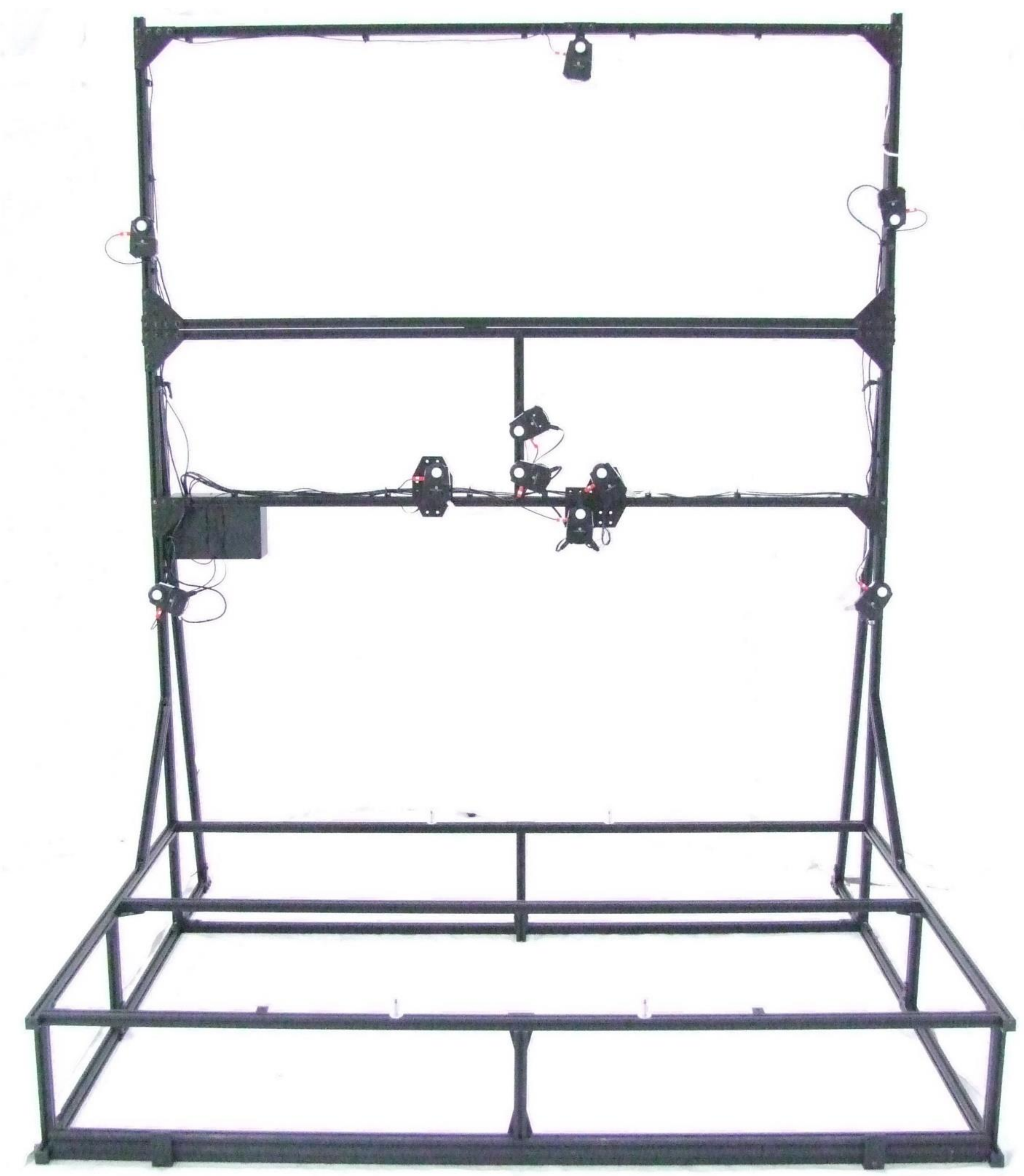

Figure 6. *Main Fixture Section With Receptor Heads and Related Wiring, End View*

The next figure shows the proper longitudinal positioning of stimulus lamps.

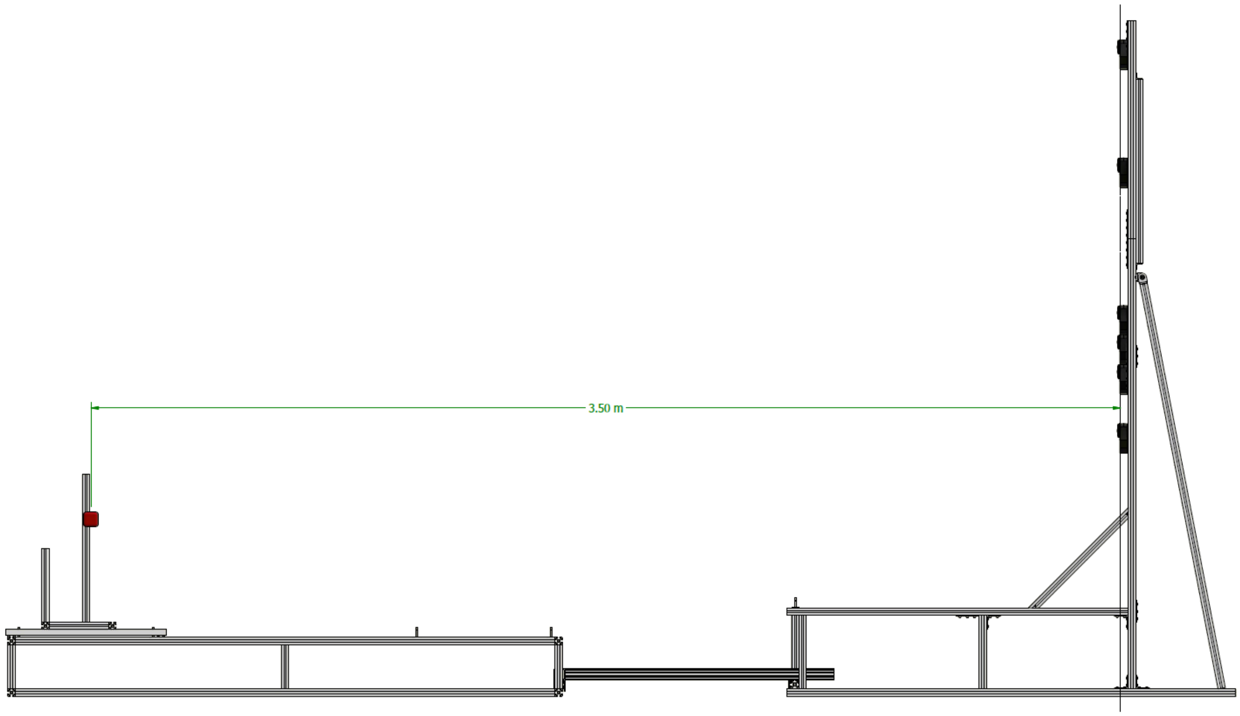

Figure 7. *Complete Test Fixture With Receptor Heads and Stimulus Lamp Locations Shown, Side View*

3.1.3 Stimulus Lamps for NHTSA ADB Test Procedure

To assess the ability of a test fixture to simulate an actual vehicle using actual vehicle headlamps and taillamps, original manufacturer replacement equipment vehicle headlamps and taillamps were used in testing the NHTSA test procedure. The lamps used were from a model year (MY) 2018 Ford F-150 pickup truck (headlamps and taillamps), MY 2018 Toyota Camry (headlamps and taillamps), and a Harley Davidson motorcycle halogen headlamp and LED taillamp.

The following table indicates, for each test scenario type and test fixture condition, the details of the stimulus lamps used in the NHTSA test procedure. Lamp part numbers for the vehicle original equipment lamps used in the NHTSA test procedure were taken from identification stickers found on the lamp assemblies or, in the absence of such a sticker, the part number as listed on the lamp assembly's box. Each lamp's light source technology is also noted.

Table 7. NHTSA Fixture and Stimulus Lamp Descriptions by Test Scenario Type

Scenario Type and Test Fixture	Lamps	Description (Part/Model Numbers)
Oncoming Test Fixture	Camry Headlamp (LED)	Left/Driver-side (part no. 8115006C40)
		Right/Passenger-side (part no. 8111006C40)
	F-150 Headlamp (Halogen)	Left/Driver-side (part no. JL3Z-13008-E)
		Right/Passenger-side (part no. JL3Z-13008-C)
Oncoming Test Fixture (Motorcycle)	Harley Davidson Headlamp (Halogen)	2018 Roadster headlamp (part no. 68593-06; using an HB2 replaceable light source)
Same Direction Test Fixture	Camry Taillamp (LED)	Left/Driver-side (part no. 81560-06730)
		Right/Passenger-side (part no. 81550-06730)
	F-150 Taillamp (Incandescent)	Left/Driver-side (part no. JL3Z-13405-E)
		Right/Passenger-side (part no. JL3Z-13404-E)
Same Direction Test Fixture (Motorcycle)	Harley Davidson Taillamp (LED)	Roadster Layback LED taillamp assembly (part no. 67800355)

Each pair of lamps, or single motorcycle lamp, was mounted securely on a removable steel tray. The following figures show photos of each of the NHTSA stimulus lamps as mounted on the trays.

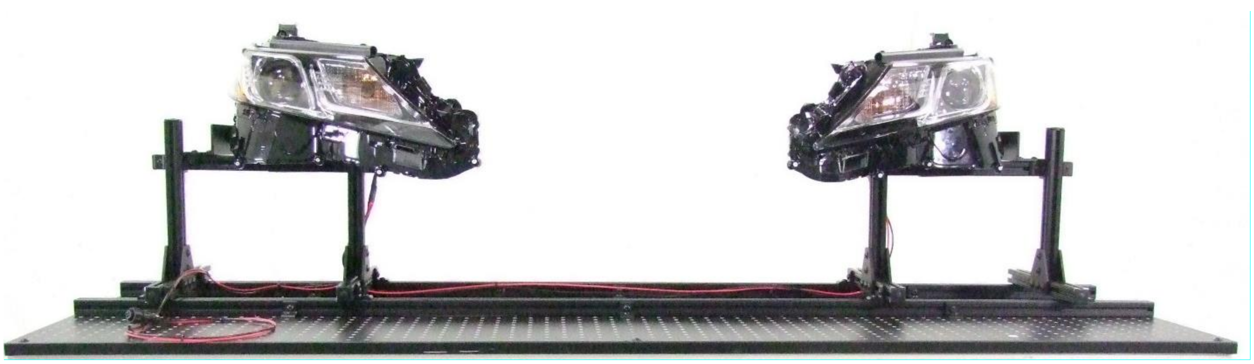

Figure 8. *NHTSA-Specified Stimulus Lamps, Oncoming Camry Headlamps*

Figure 9. *NHTSA-Specified Stimulus Lamps, Same Direction Camry Taillamps*

Figure 10. *NHTSA-Specified Stimulus Lamps, Oncoming F-150 Truck Headlamps*

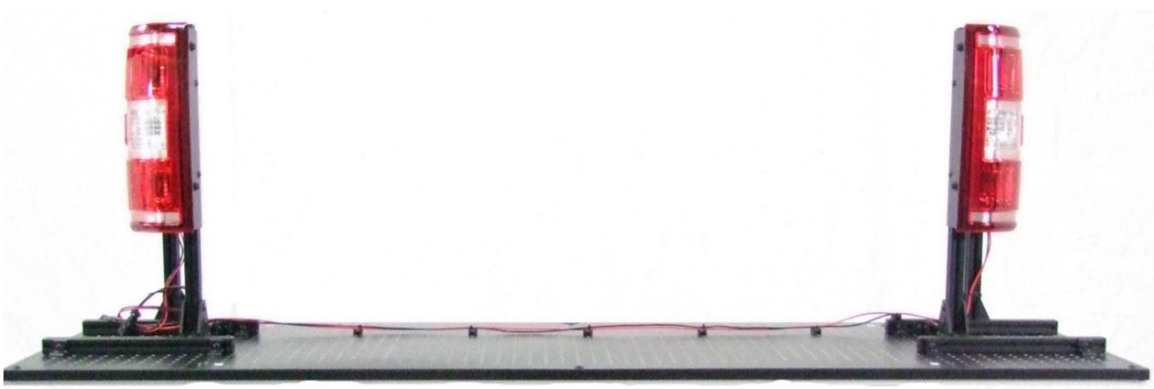

Figure 11. *NHTSA-Specified Stimulus Lamps, Same Direction F-150 Truck Taillamps*

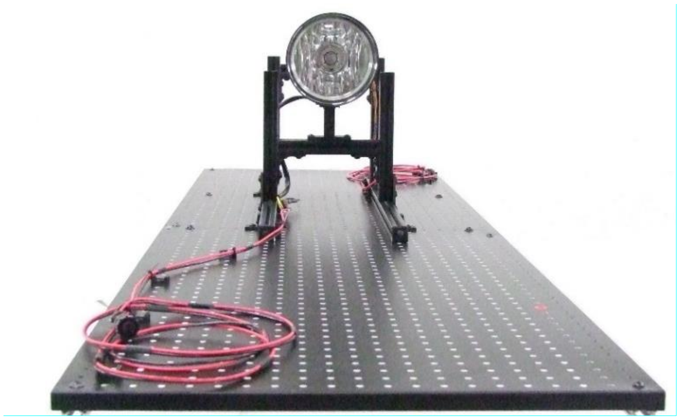

Figure 12. *NHTSA-Specified Stimulus Lamps, Oncoming Harley Davidson Motorcycle Headlamp*

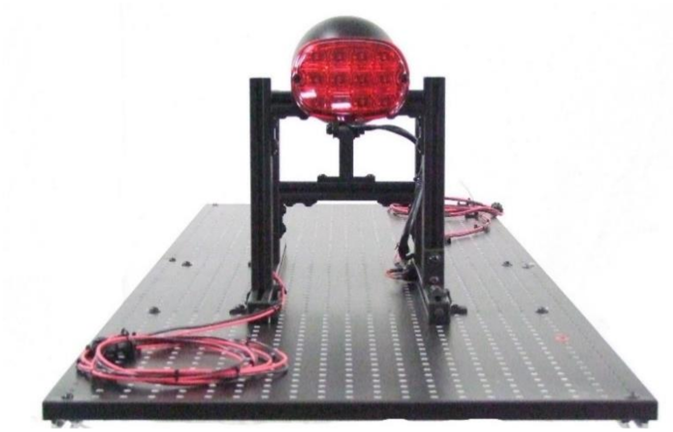

Figure 13. *NHTSA-Specified Stimulus Lamps, Same Direction Harley Davidson Motorcycle Taillamp*

The following are photo examples of each of the NHTSA stimulus lamps mounted on the fixture.

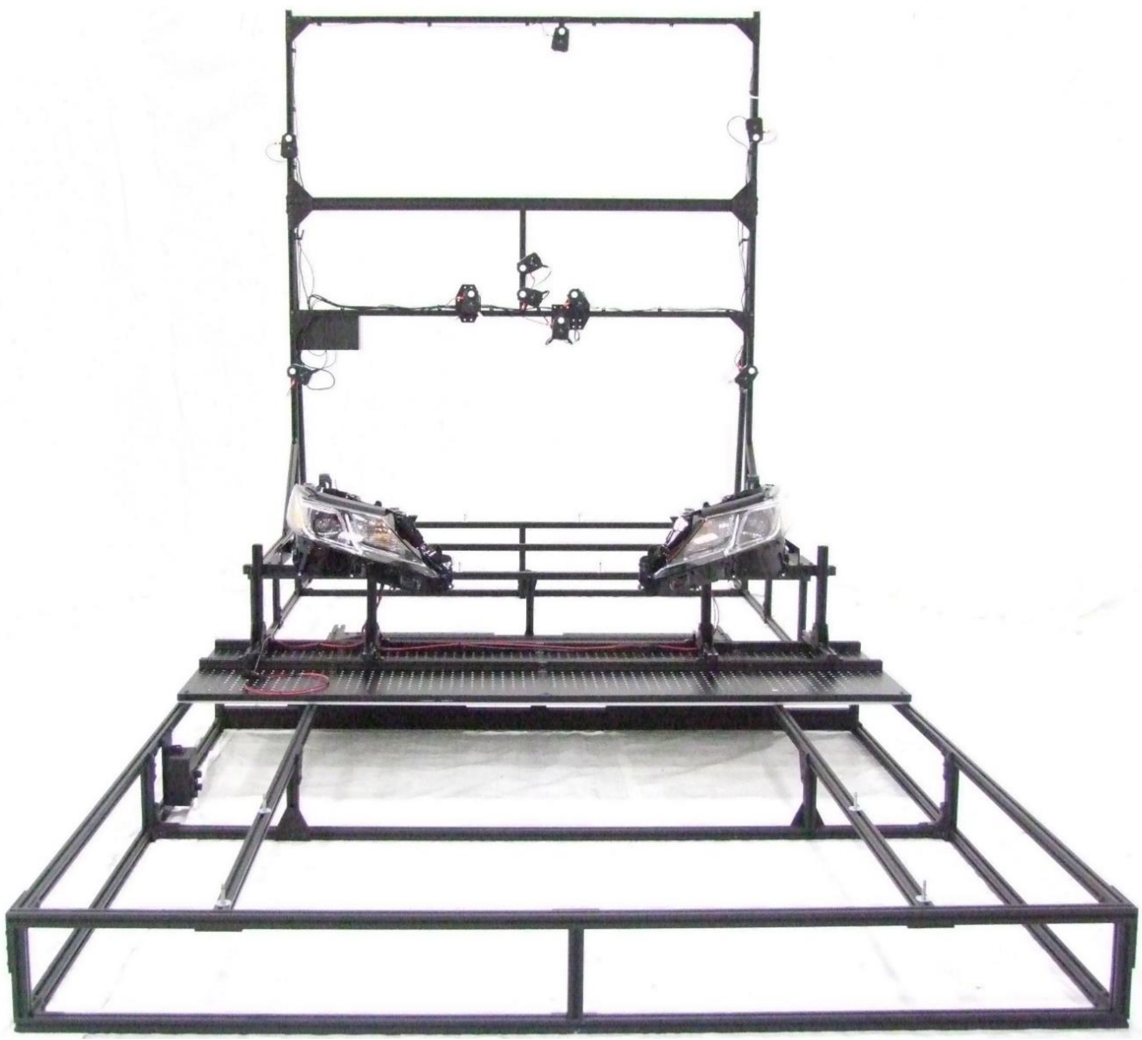

Figure 14. *NHTSA Test Fixture Photo, Camry Headlamp Stimulus Lamps*

Figure 15. *NHTSA Test Fixture Photo, Camry Taillamp Stimulus Lamps*

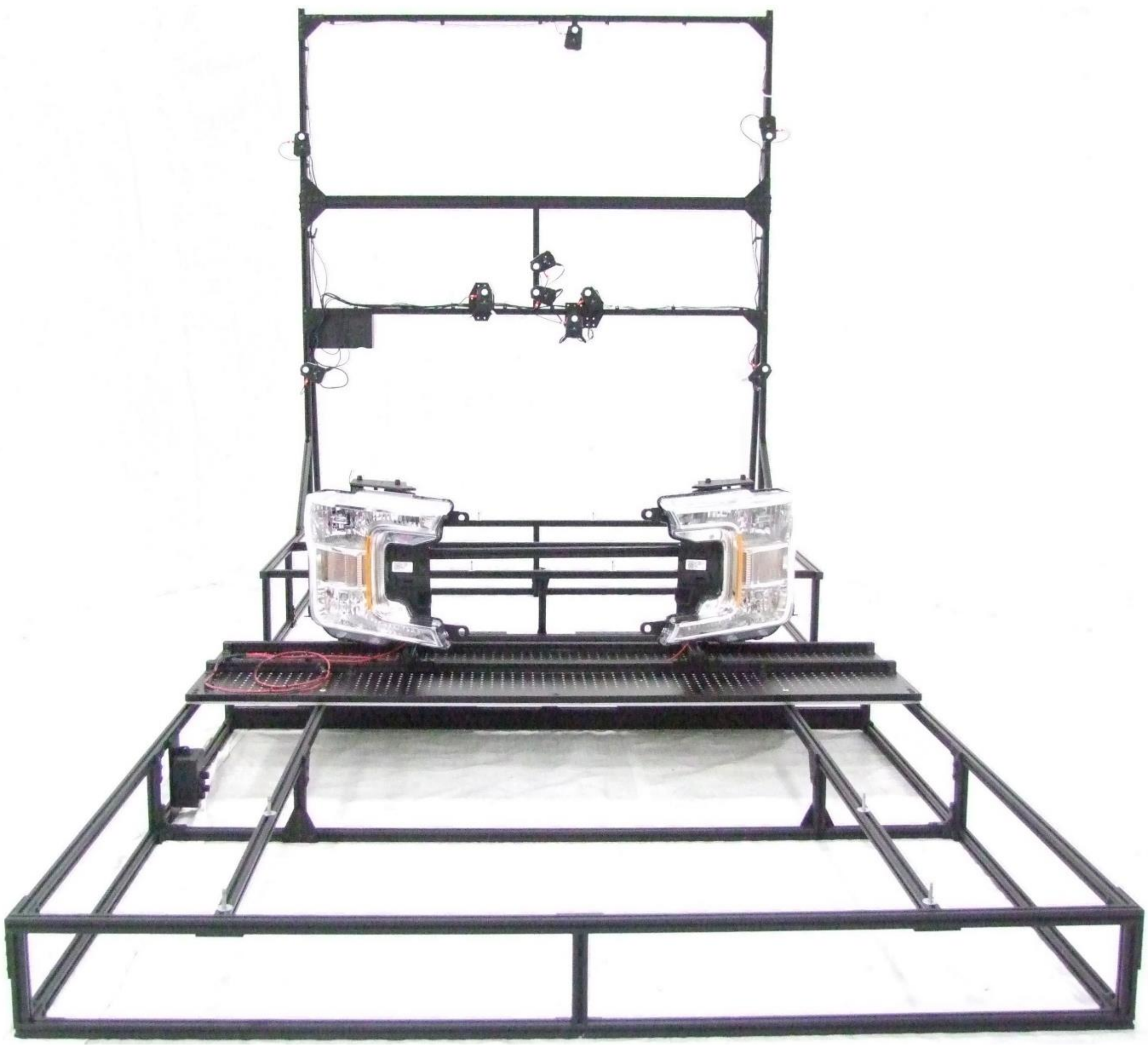

Figure 16. *NHTSA Test Fixture Photo, F-150 Truck Headlamp Stimulus Lamps*

Figure 17. *NHTSA Test Fixture Photo, F-150 Truck Taillamp Stimulus Lamps*

Figure 18. *NHTSA Test Fixture Photo, Harley Davidson Motorcycle Headlamp Stimulus Lamp*

Figure 19. *NHTSA Test Fixture Photo, Harley Davidson Motorcycle Taillamp Stimulus Lamp*

3.2 Stimulus Lamps Used With SAE J3069 Test Procedure

Lamps meeting the stimulus lamp specifications of SAE J3069 were obtained from Sapphire Technical Solutions. Lamp model information is provided in the table below.

Table 8. *SAE J3069 Fixture and Stimulus Lamp Descriptions by Test Scenario Type*

Scenario Type and Test Fixture (or Test Vehicle)	Lamps	Description (Part/Model Numbers)
Oncoming Test Fixture (Car/Truck)	2 SAE Front Lamps	Sapphire Technical Solutions, Model No. LS-301-1
Oncoming Test Fixture (Motorcycle)	SAE Front Lamp	Sapphire Technical Solutions, Model No. LS-301-1
Same Direction Test Fixture (Car/Truck)	2 SAE Taillamps	Sapphire Technical Solutions, Model No. LS-301-1 with appropriate filter
Same Direction Test Fixture (Motorcycle)	SAE Taillamp	Sapphire Technical Solutions, Model No. LS-301-1 with appropriate filter

The following figures show photos of each of the SAE stimulus lamps as mounted for testing.

Figure 20. *SAE Test Fixture Photo, Car/Truck Headlamp Stimulus Lamps*

Figure 21. *SAE Test Fixture Photo, Car/Truck Taillamp Stimulus Lamps*

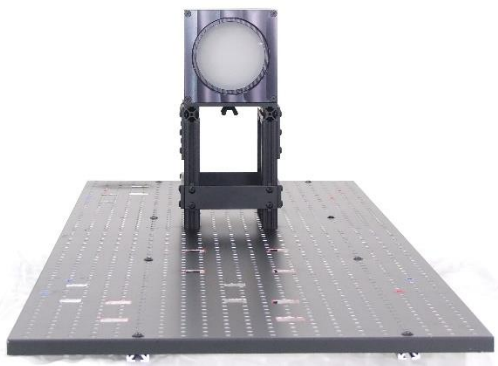

Figure 22. *SAE Test Fixture Photo, Motorcycle Headlamp Stimulus Lamps*

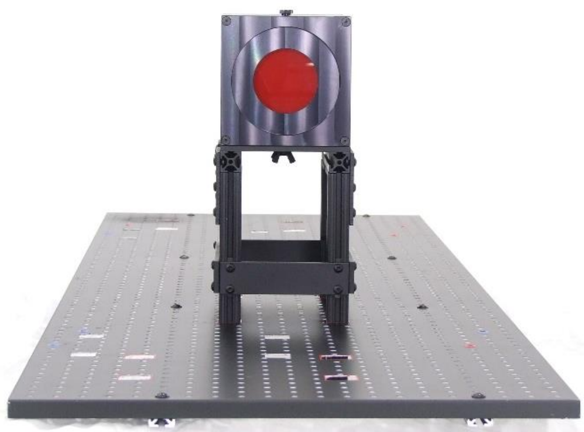

Figure 23. *SAE Test Fixture Photo, Motorcycle Taillamp Stimulus Lamps*

3.2.1 Stimulus Lamp Voltage Measurement

Stimulus lamp voltage was measured and adjusted to the correct voltage for each of the NHTSA stimulus lamps at the onset of each lamp's usage in a set of tests. To access stimulus lamp voltage, test pins were added to the power wires at connectors supplied on the lamp assemblies (assemblies were not opened or compromised, and thus were not measured directly at the bulb). A digital voltmeter was attached to the pins to acquire the voltage level. The power supply was manually adjusted for each condition to set the lamp assembly voltage to 12.8 volts (+/- 20 mV).

The SAE lamps had their own built-in voltage regulators designed to meet the specifications of the test procedures if the battery power source was maintained above the specified minimum voltage level. The SAE lamps were sealed in a housing that had no accessible voltage measurement location. The battery was charged to full capacity prior to each night of testing and observed throughout testing to ensure it stayed above the specified minimum voltage level.

3.3 Test Surface

The course on which the NHTSA test was performed met the following proposed specifications outlined in the October 2018 NPRM, except for the proposed International Roughness Index (IRI) of less than 1.5 m/km:

- "S14.9.3.12.4.1 *Test Scenario Geometry*. Test scenarios shall involve straight roads and curved roads."
- "S14.9.3.12.4.2 The curves shall be of a constant radius within the range listed in the ADB test matrix table."
- "S14.9.3.12.4.3 The test road shall have a longitudinal grade (slope) that does not exceed 2%."
  - o The test surface used in this testing had a 1% slope downward in the south-southeast direction to facilitate drainage.
- "S14.9.3.12.4.4 The lane width shall be from 3.05 m (10 ft.) to 3.66 m (12 ft.)"
  - o A lane width of 10 feet was used for NHTSA test procedure trials.
- "S14.9.3.12.4.6 The lanes shall be adjacent, but may have a median of up to 6.1 m (20 ft.) wide, and shall not have any barrier taller than 0.3 m (12 in.) less than the mounting height of the stimulus vehicle's headlamps."
  - o No median or barriers were used.
- "S14.9.3.12.4.7 The tests are conducted on a dry, uniform, solid paved surface. The road surface shall have an International Roughness Index (IRI) of less than 1.5 m/km."
  - o The test surface met all the proposed specifications outlined in the NPRM [1] except surface roughness. The IRI values for the area traversed in the various test scenario paths ranged from 1.43 to 1.86 m/km.
- "S14.9.3.12.4.8 The road surface may be concrete or asphalt, and shall not be bright white."
  - o The surface used in testing was asphalt.
- "S14.9.3.12.4.9 The test road surface may have pavement markings, and shall be free of retroreflective material or elements that affect the outcome of the test."
  - o No lane markings were used to delineate test scenario paths. A programmable steering robot was used to control the vehicle path (see Section 3.5.1).

The Vehicle Dynamics Area (VDA) facility at the Transportation Research Center (TRC) was the surface on which both the draft NHTSA ADB test procedure and the SAE J3069 test procedure were carried out. The test surface is a large, asphalt pad with a 1 percent slope downward in the south-southeast direction to facilitate drainage. The surface has some non-reflective pavement markings but is free of any reflectors or reflective lane markings. The area in which testing was conducted was free of post-mounted or other signs.

Since the VDA is a large surface without specific lanes for this testing, the specific International Roughness Index (IRI) associated with each straight and curved path was not known. The following table shows the general IRI measurements recorded of four courses that are delineated on the VDA.

Table 9. *VDA International Roughness Index (IRI) Measurements (July 2019)*

Vehicle Dynamics Area	Course	IRI (m/km)
Main Surface	Winding Course East	1.86
Main Surface	Winding Course West	1.43
Main Surface	Diagonal EW	1.46
Main Surface	Diagonal NS	1.61

The following figure shows the locations of the straight and curved paths overlaid on an image of the VDA, with the IRI measurements listed on the four delineated courses, for reference.

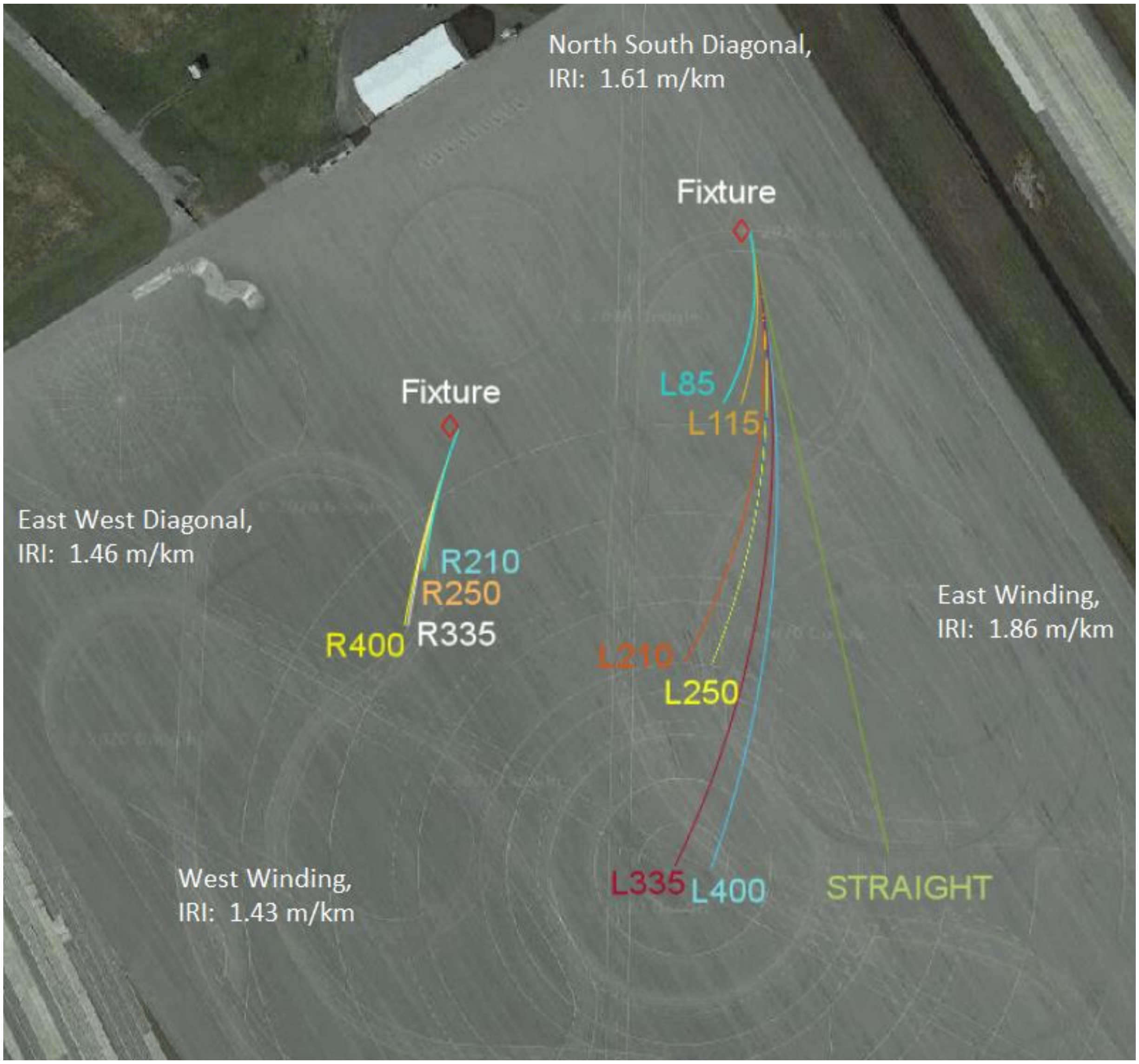

Figure 24. *VDA, IRI Measurements and Straight / Curved Paths Overlay [5]*

3.4 Test Fixture Positioning

Testing was conducted with the test fixture positioned in one of two specific locations (and orientations) on the TRC VDA to achieve all test trials. Fixture locations were selected to allow the most scenarios to be able to be performed without needing to move the fixture. One location accommodated straight (both NHTSA and SAE J3069) and left curve test scenarios while the other location was used for right curve scenarios. As described previously, all NHTSA test scenarios ended with the test vehicle passing the fixture on the right in an adjacent lane orientation, and the SAE test scenarios ended with the test vehicle passing the fixture on either the left or the right in adjacent lane and non-adjacent lane scenarios. The test fixture was centered in its lane and oriented such that the longitudinal centerlines of the text fixture and receptor heads, as well as the fixture lamps' optical axes, were parallel with the vehicle path centerline at the point that the vehicle passed the fixture.

3.5 Test Procedure Equipment

3.5.1 Test Vehicle Path Control Equipment

Test vehicle path guidance was controlled using an AB Dynamics SR15 Orbit Steering Robot and controller installed in each of the test vehicles. Steering controlled programs were created to define the GPS-based path a test vehicle should travel in each test scenario. Per the equipment manufacturer, "Using AB Dynamics' path-following and differential GPS, absolute lateral position accuracy in a straight line is 2 cm or better" and in curves "lateral positional accuracy is typically 10 cm or better, with absolute repeatability of approximately 2 cm" [6]. Additional information is provided in Appendix B.

3.6 Measurement System and Related Equipment

This section contains a summary of the measurement system components and power-related equipment used in this test effort. A list of all measurement system components and related equipment is provided in Appendix B.

3.6.1 Data Acquisition System (DAS)

An in-house developed data collection system called VCDAS (Video CAN Data Acquisition System) was the main component of the data collection system. VCDAS is a NUC-based[5] system with 16 analog inputs, 7 CAN ports, 8 digital inputs, and 4 digital outputs. The VCDAS was designed to receive data in CAN format and could also convert data to CAN format internally. For ease of transport and setup, the VCDAS was housed in a stationary data collection vehicle (Ford F-150 pickup). During testing, this vehicle was positioned a distance away from the test fixture and covered with a non-reflective fabric car cover to prevent reflections.

3.6.2 Illuminance Meter

The illuminance data were collected with a Konica Minolta T-10A illuminance meter. The meter was a multi-function illuminance meter with a detachable receptor head that allowed multiple receptor heads (RH) to be connected in series for simultaneous measurement of illuminance at multiple points. The illuminance meter was configured with 10 receptor heads mounted on the NHTSA test fixture for most of the testing described herein.

The T-10A meter had an operating temperature range of 14 to 104 degrees Fahrenheit (-10 to 40 degrees Celsius) and specified operating conditions of 85 percent or less relative humidity (at 35°C/95°F) with no condensation.

The separate illuminance data channels were recorded to the data acquisition system (DAS) at a frequency of 200 Hz. The analog output of the ten receptor heads located on the test fixture were converted to CAN with the use of two Peak Systems PCAN-MicroMod Analog 2s. Both the analog and USB outputs of the illuminance meter were recorded. These data were compared for select

[5] NUC stands for Next Unit of Computing and is a small form factor PC.

trials as a means of determining appropriate filtering to address possible noise, and/or to assess the possible effects of light sources, such as LEDs, having pulse width modulation.

3.6.3 Range Measurement Equipment

To permit determination of the relative locations of the receptor heads on the test fixture and test vehicle, RT-Range monitoring systems (Oxford Technical Solutions (OxTS)) were installed in the test vehicles and in the stationary data collection vehicle. These systems were used to obtain the relative positions of the test vehicle, the data collection vehicle, the test fixture, and the illuminance receptor heads.

The data collection vehicle contained a RT3003 unit that served to provide location data for the test fixture and illuminance receptor heads in relation to the data collection vehicle. Housing both the RT3003 and RT-Range units in the data collection vehicle provided a means for carrying out the dynamic calibration steps easily. The data collection vehicle's dynamics data were collected by VCDAS from a RT3003 unit and a NovAtel GPS antenna that were installed on the data collection vehicle, with corrections sent by a Freewave wireless data transceiver. In the stationary data collection vehicle, the relative measurements were made using a RT-Range unit receiving data from the two RT3003 units through the XLAN. An AB Dynamics Syncro system was used to provide real-time vehicle-to-vehicle data received thru a TrackFI antenna, providing wireless telemetry.

A test vehicle's measurement devices consisted of an RT 3003 unit with a NovAtel GPS antenna. Vehicle dynamics data (e.g., speed, pitch angle) and relative position measurements were transmitted to the data collection system in the stationary data collection vehicle through an XLAN (long range wireless local area network (LAN)), with corrections coming from a Freewave wireless data transceiver. The real-time vehicle-to-vehicle telemetry was transmitted by a TrackFI antenna.

3.6.4 Measurement System Diagram

The following figure contains a measurement system diagram, showing an overview of the instrumentation, equipment, and vehicle setup, with the various connections between devices.

As shown in the figure, the DAS was housed in the data collection vehicle (Ford F-150 pickup truck) for ease of transporting the equipment as well as to permit calibration of the RT Range system, which requires a series of dynamic maneuvers.

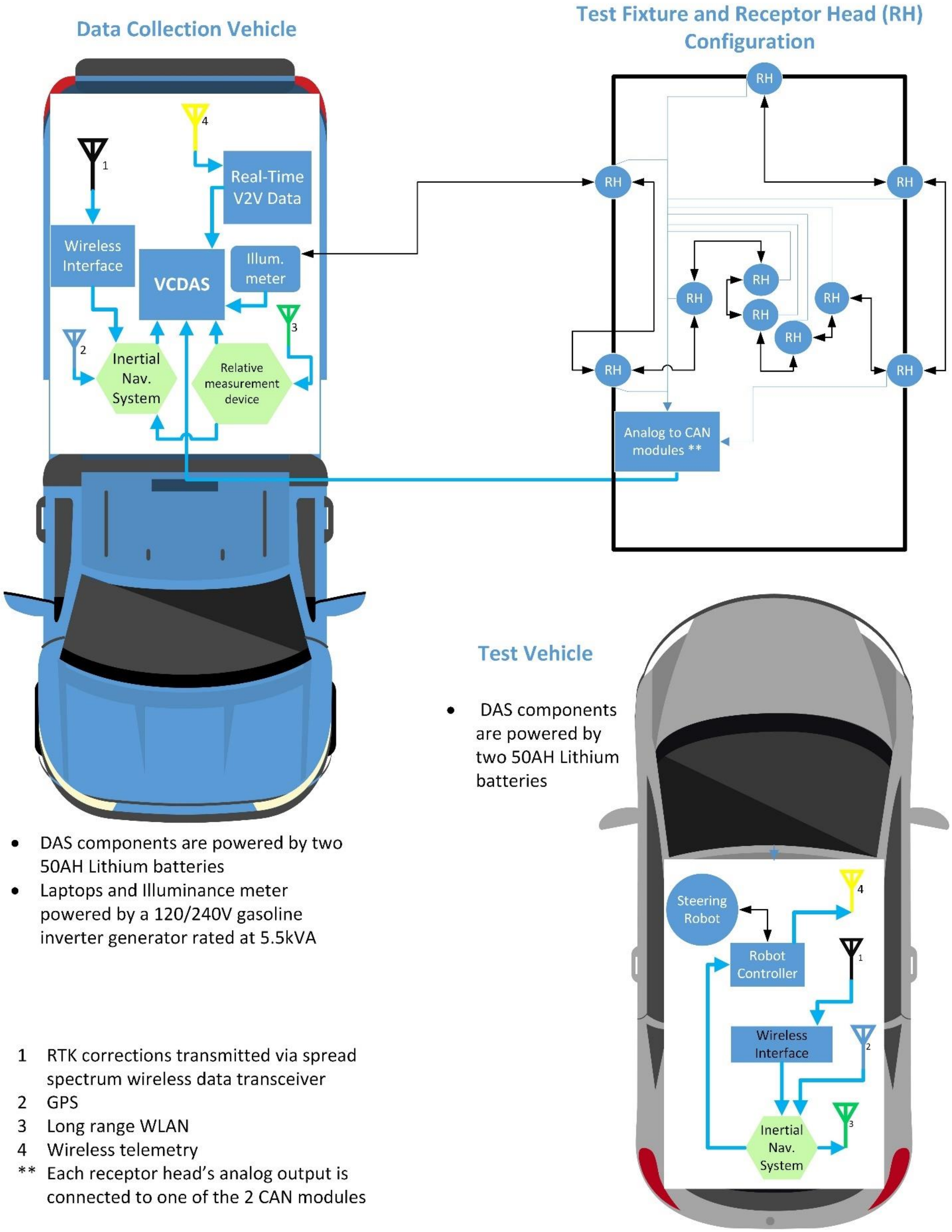

Figure 25. *Measurement System Diagram*

<u>3.6.5</u> *Power-Related Equipment*

All laptops and the illuminance meter were powered by a gas-powered inverter generator providing a conditioned sine wave power source, and by each device's original manufacturer-provided power supply. Most of the data acquisition equipment in the stationary data collection vehicle was powered by two Lithium batteries (12V, 50Ah). The data collection equipment in the test vehicles was powered by two Lithium Batteries (12V, 50Ah), isolated from the vehicle electrical system.

3.7 Test Preparation

<u>3.7.1</u> *Stimulus and Test Vehicle Lamp Preparation*

All NHTSA stimulus lamps and test vehicle lamps were aimed per the SAE J599 procedure prior to initiating any testing. Each test vehicle or stimulus lamp set was positioned on a level surface 25 feet away from a headlamp aiming screen, as shown in the following figure.

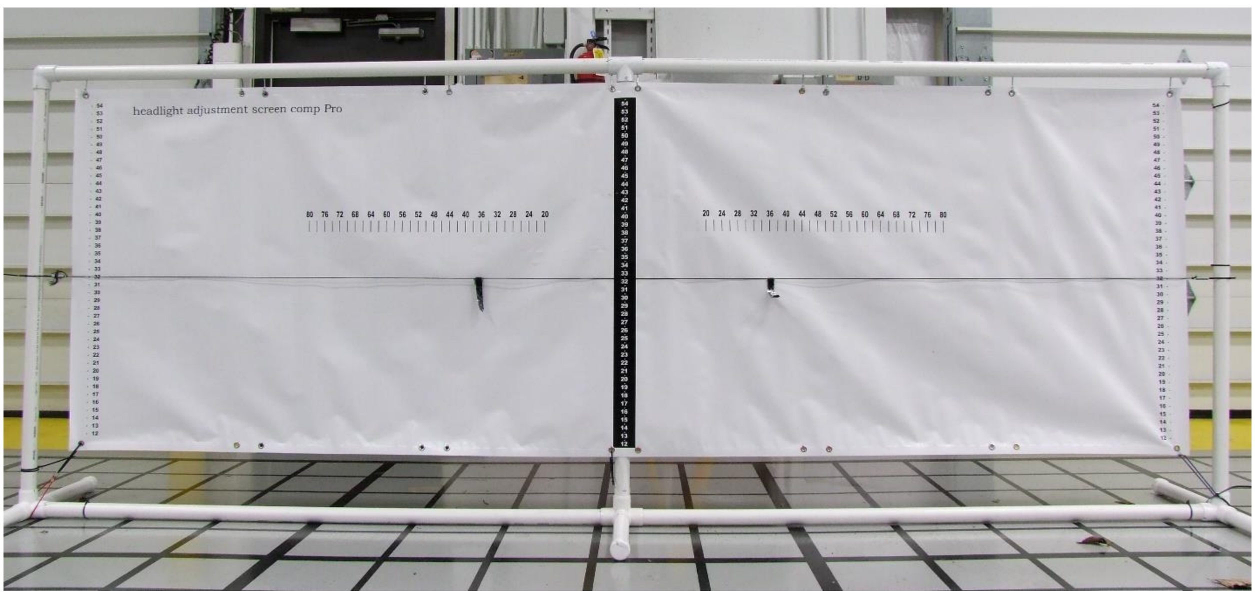

Figure 26. *Headlamp Aiming Screen*

During test vehicle headlamp aiming, each test vehicle was fully instrumented and the test driver was seated in the vehicle. Test fixture stimulus lamps were aimed as mounted on their corresponding lamp trays and installed on the appropriate test fixture section to achieve the necessary height above the ground. Stimulus headlamp aim was adjusted and then the projected beam pattern was photographed and measurements made for documentation (see Appendix C).

SAE J3069 stimulus lamps had no aiming adjustment capability.

All stimulus lamps and test vehicle headlamps went through a warm-up period of at least 5 minutes before being used in a test scenario trial.

3.7.2 Test Vehicle Preparation

Test vehicles' headlamps were aimed or confirmed to be already aimed before they were used in any testing (see Appendix C). At the start of each night of testing, each test vehicle's headlamp lenses were wiped clean to ensure they were free of dirt and other substances that might impact performance. ADB system sensors were wiped to ensure they were free of dirt and other substances. The test vehicle's battery level was confirmed to be within normal operating range before beginning each test session (i.e., night), but was not monitored or recorded throughout the test session. Vehicle fluids were checked to ensure they were at appropriate levels. Each test vehicle's tires were set to the pressure value(s) recommended by the vehicle manufacturer. The fuel tank was filled and fuel level was monitored throughout each test session and maintained to always be at least three-fourths full. Maintaining a consistent fuel level helped to ensure consistent test vehicle weight distribution across test sessions. During testing, all test vehicle doors, hatches, hood, and trunk lid (as appropriate) were closed.

3.8 Test Environment Conditions

Testing was conducted in darkness as indicated by measured ambient illuminance of 0.2 lux or less. Testing was not conducted when precipitation, fog, or other vehicles were present in the test area. As stated previously, the T-10A illuminance meter has an operating temperature range of 14 to 104 degrees Fahrenheit (-10 to 40 degrees Celsius) and specified operating conditions of 85 percent or less relative humidity (at 35°C/95°F) with no condensation. Ambient temperature and humidity values were monitored to ensure test conditions complied with the operating conditions of the illuminance meter. Weather condition data were based on proving grounds condition information maintained by the facility manager (Transportation Research Center Inc.).

3.9 Additional Information About Carrying Out the Test Procedures

3.9.1 Research Staff Roles

Typically, three to four team members were needed to perform the test procedure. At least two individuals were needed to set up the test fixture, with additional help making the setup go faster. At least two individuals were needed to connect test equipment data and power cables. During testing, one individual (same individual for all test trials) operated the test vehicle and two others handled running the data acquisition system, coordinating the test matrix details, and monitoring environmental conditions (as provided by the proving ground staff). A fourth team member made sure fixture changes and operation went smoothly while watching for traffic or other environmental factors that might affect a test run. The person running the data acquisition system also ran a quick check of data channels after each test trial to ensure that the trial met validity criteria (e.g., speed was properly maintained) and that there were no data drop-outs that warranted re-running the test trial.

During each evening's test session, research staff cleaned headlamp lenses, illuminance meter receptor heads, and vehicle windshields before testing commenced. During testing, research staff performed the series of test scenarios following a test trials list and made notes to document any noteworthy observed headlighting system behavior, such as flicker and activation conditions.

3.9.2 *Test Vehicle Operation in Test Scenarios*

The test vehicle driver manually controlled the vehicle's speed, while steering was controlled via a previously described robotic steering machine. Vehicle speed was achieved and maintained by application of the accelerator pedal, which was deemed more feasible than cruise control during pre-testing (in some vehicles, the steering controller blocked the driver's ability to effectively engage the cruise control features). To perform each test trial, the test driver prompted operation of the steering machine to perform a pre-programmed GPS-coordinate-based path routine based on the test scenario being performed. The steering controller program paths for each NHTSA test scenario ended with the test vehicle passing the fixture on the right in an adjacent lane orientation with 10 feet between the center of the test vehicle and the center of the test fixture. The steering controller program paths for SAE test scenarios ended with the test vehicle passing the fixture on either the left or the right in adjacent lane and non-adjacent lane scenarios depending on the test drive being carried out.

3.9.3 *Test Trial Validity Checking*

Test data validity was checked twice: first, during testing after the completion of each test trial and a second time during data processing. After each test trial, a member of the research staff accessed recorded test data using a laptop connected to the DAS and performed a quick test trial data quality check. Data channels including vehicle speed, range, pitch angle, and illuminance were plotted and reviewed to ensure that the trial data appeared reasonable. Test vehicle speed was checked to ensure that it was maintained within 1 mph of the target speed throughout the measurement distance. Pitch data were visually scanned to ensure there were no obvious pitch angle spikes. Range data were checked to make sure no measurement drop-outs were observed in the data. Illuminance data were checked to make sure that recorded values appeared reasonable. Trials were repeated as needed based on this review of data. Later during data processing, illuminance data were further reviewed to ensure that the allowance for momentary glare exceedances (or "spikes") of magnitude not greater than 0.1 second in duration or spanning 1 meter of vehicle travel was not exceeded.

4.0 DATA, DATA PROCESSING, AND DATA ANALYSIS

4.1 DAS Logged Channels

The following channels were collected from the test vehicle using an Oxford RT Range system:

Forward_Vel_T2[6]	Vehicle velocity (meters per second)
Lat_T2	GNSS[7] Latitude in decimal format
Long_T2	GNSS Longitude in decimal format
Pitch_T2	Vehicle pitch angle (degrees)

The following channels were collected from the ABD Steering Robot using an ABD Sync-Omni for telemetry to record them via the DAS on CAN:

OthRefXPos	Vehicle X position on steering robot path (meters)
OthRefYPos	Vehicle Y position on steering robot path (meters)

The following channels were recorded by the DAS from the analog output channels of the illuminance meter receptor heads:

Car_DS_mirror	Car driver-side rearview mirror (lux)
Car_PS_mirror	Car passenger-side rearview mirror (lux)
Car_eye_pt	Car driver eye point (lux)
Car_inside_mirror	Car rearview mirror point (lux)
Cycle_eye_pt	Motorcycle driver eye point (lux)
Cycle_left_mirror	Motorcycle left rearview mirror (lux)
Cycle_right_mirror	Motorcycle right rearview mirror (lux)
Truck_DS_mirror	Truck driver-side rearview mirror (lux)
Truck_PS_mirror	Truck passenger-side rearview mirror (lux)
Truck_eye_pt	Truck driver eye point (lux)

4.2 Data Channels and Associated Processing (As Appropriate)

The following channels were recorded. Channels for derived data used the DAS logged channels with the appropriate equations or scripts applied, as indicated.

[6] "T2" here means "Target 2," in terms of the RT Range Hunter and Target scheme. "T1" refers to "Target 1," which was the RT unit used to help determine relative location of the test fixture.

[7] GNSS stands for "global navigation satellite system."

Table 10. Data Channels Example, Car and Truck Eye Point Illuminance

Channel Name	Description	Source
CEPZSample	Car eye point 2-second data sample for zero-calibrating illuminance (where CEPZ is car eye point zeroed)	Derived
CEPZValue	Car eye point average value of the 2-second sample for zero-calibrating illuminance	Derived
Car_eye_pt	Illuminance at car eye point on fixture, in lux	Meter
Car_eye_pt_zrd	(CEPZ) Illuminance at car eye point on fixture, in lux, zero value set using CEPZValue	Konica Minolta T-10A illuminance meter; Adjusted
Car_eye_pt_zrd_fltd	Illuminance at car eye point on fixture, in lux, zero value set using CEPZValue and filtered	Konica Minolta T-10A illuminance meter; Adjusted, Filtered
Forward_Vel_T2	Test vehicle speed, in meters per second	Oxford RT
Lat_T2	Lateral position of the test vehicle, GPS coordinates	Oxford RT
Long_T2	Longitudinal position of the test vehicle, GPS	Oxford RT
OthRefXPos	Vehicle X position on Steering Robot path, in meters	ABD Sync-Omni Steering Robot
OthRefYPos	Vehicle Y position on Steering Robot path, in meters	ABD Sync-Omni Steering Robot
Pitch_T2	Pitch angle of the test vehicle; Not accurately zeroed	Oxford RT
Range_Car_eye_pt	Range from test vehicle to receptor head at car eye point	Derived
Range_Truck_eye_pt	Range from test vehicle to receptor head at truck eye point	Derived
TEPZSample	Truck eye point 2-second data sample for zero-calibrating illuminance (where TEPZ is truck eye point	Derived
TEPZValue	Truck eye point average value of the 2-second sample for zero-calibrating illuminance	Derived
Truck_eye_pt	Illuminance at truck eye point on fixture, in lux	Konica Minolta T-10A illuminance meter
Truck_eye_pt_zrd	(TEPZ) Illuminance at truck eye point on fixture, in lux, zero value set using TEPZValue	Konica Minolta T-10A illuminance meter; Adjusted
Truck_eye_pt_zrd_fltd	Illuminance at truck eye point on fixture, in lux, zero value set using TEPZValue and filtered	Konica Minolta T-10A illuminance meter; Adjusted, Filtered
Vmph	Test vehicle speed, in mph	RT, Converted
distance	Distance to fixture point, in meters	RT, Converted

4.3 Data Processing

4.3.1 Test Vehicle Speed

Velocity was recorded by the DAS in m/s units. For analysis, velocity data were converted into mph using the following formula:

V(mph) = V(m/s) * (3600 s/hr)/(1609.34 m/mile)

Or

V(mph) = V(m/s) * 2.234694(mph/(m/s))

Test vehicle speed throughout each test trial fell within +/- 1mph of the designated speed of the scenario or the trial was re-run.

4.3.2 Range Calculation

For calculating range (i.e., distance) for use in evaluating illuminance data with respect to glare limits, the linear distance from each illuminance receptor head on the test fixture or stimulus vehicle to the test vehicle's headlighting system midpoint had to be determined by translating the range data from known reference points on the test vehicle, the facility, and the test fixture.

Range was calculated using the Pythagorean distance formula. The base coordinate system used the Anthony Best Dynamics Steering Robot path maps, which placed the origin (0,0) at the end of the path (adjacent to the test fixture) and measured to the location of the test vehicle reference point. The test vehicle reference point is located at "the intersection of a horizontal plane through the headlamp light sources, a vertical plane through the headlamp light sources and a vertical plane through the vehicle's centerline to the forward most point of the relevant photometric receptor head mounted on the test fixture" [2]. This reference point was found using FARO arm measurements.

To find the range from the test vehicle to the fixture, the origin had to be translated to a FARO arm measured center point on the test fixture. For the NHTSA test procedure, the fixture was offset from the origin by 10 feet (3.048 meters). Therefore, the range measurements were calculated using an origin of (0, -3.048).

OthRefYPosAdj = OthRefYPos – 3.048;

Range to Fixture = sqrt((OthRefXPos)^2 + (OthRefYPosAdj)^2)

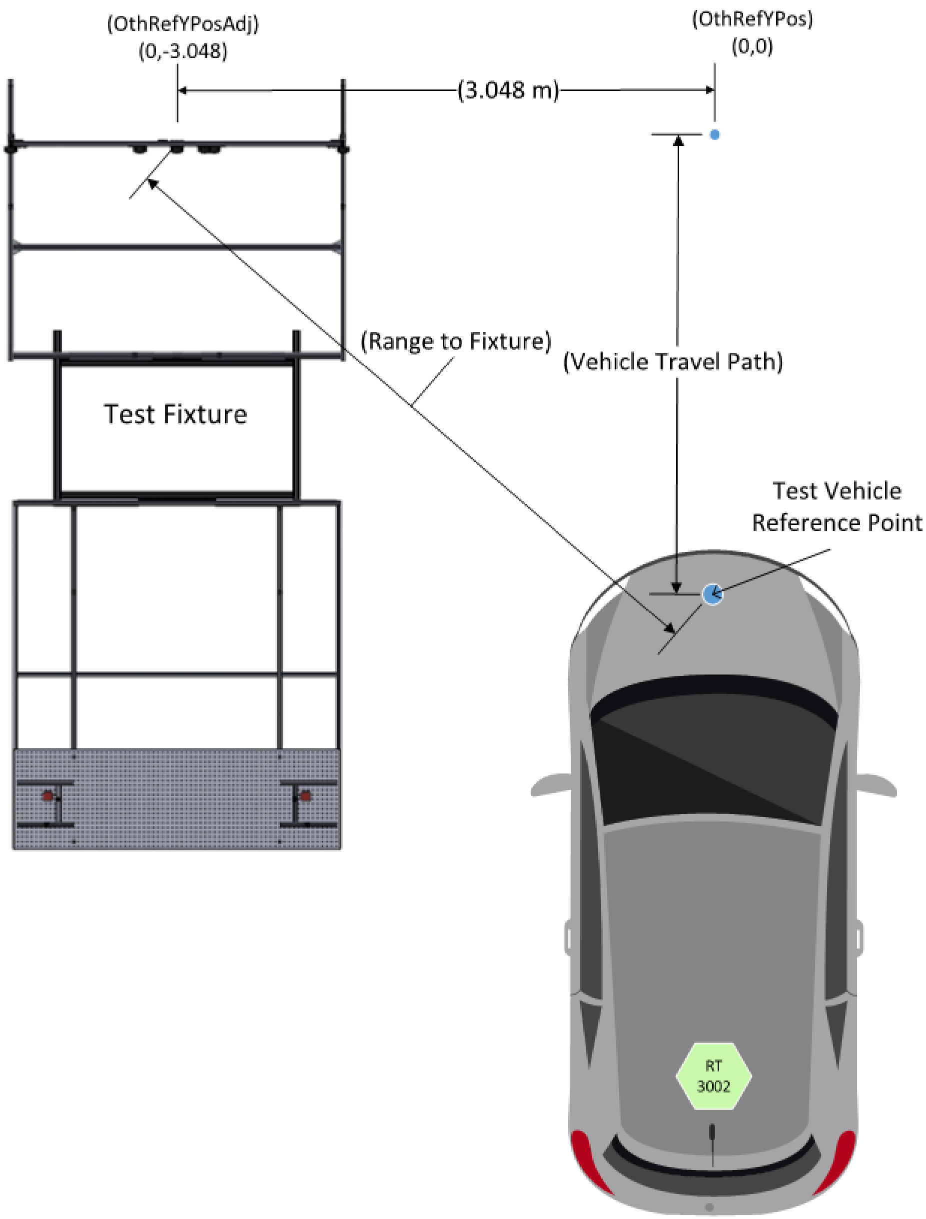

Figure 27. *Illustration of Range From Fixture to Test Vehicle*

For each individual receptor head range, the origin was again translated by the lateral distance between the receptor head and the fixture center point, as measured by a FARO arm.

As an example, the car passenger-side mirror receptor head was offset from the center of the fixture by 0.1484 meters, therefore

Car Eye Point Y (CEPY) = OthRefYPosAdj + 0.1484 m, and

Range to Car Eye Point receptor head = sqrt((OthRefXPos)^2 + (CEPY)^2)

For the SAE test procedure range data calculations, the FARO arm measured center point on the test fixture was offset from the adjacent path origin (Fixture Position 2) by 12 feet (3.7 meters). Test fixture offsets of 24 feet (7.3 meters) in each direction were utilized to calculate the ranges for the other two SAE test fixture positions (Fixture Position 1 and Fixture Position 3).

To trim the collected data to fit within the designated measurement range, a find function was used that locates the first value less than the maximum measurement range.

4.3.3 Illuminance Data Zero Calibration

The impact of ambient illumination and fixture lamps on measured illuminance values was removed before evaluating illuminance data compliance with glare limit values. Zero calibrating the illuminance meter was performed to isolate illuminance produced by test vehicle headlighting systems from any ambient illumination present in the test area.

Since the meter used in this testing did not have a zero-calibration function, an alternative method was used to isolate the illuminance produced by the test vehicle's headlighting system from any ambient illumination. Data recording for each test trial run continued through a few to several seconds after the test vehicle had passed the test fixture. A 2-second sample of illuminance data were extracted from the portion of recorded data after the test fixture was passed. The 2-second sample began 3 seconds after the vehicle had passed the fixture. If 5 seconds of data were not available for the period after the test vehicle had passed the test fixture, the sampling period was shifted from the nominal 3 to 5 seconds past the fixture up to 0.5 to 2.5 seconds past the fixture. Any run that did not have at least 2.5 seconds of post-fixture data from which to draw a zero value was rejected and re-run.

An average illuminance value was calculated from the 2-second sample of data. This average value was then subtracted from the test trial's illuminance data from each receptor head.

4.3.4 Illuminance Data Filtering

All illuminance meter data was filtered by passing it through a low-pass Butterworth filter. Filtering was performed in Matlab using a ButterFilter function with 12 poles and a cutoff frequency of 35 hertz (allowing for accurate measurements of pulse width modulated light sources, such as an LED), at the DAS sampling rate of 200 hertz.

Example:

> Motor Cycle Eye Point Filtered (Cycle_eye_pt_fltd) = ButterFilter (Cycle_eye_pt_zrd,12,35,200)

4.3.5 Identification of Illuminance Data Momentary Glare Exceedances

The NPRM proposed an allowance for momentary glare exceedances of magnitude not greater than 0.1 second in duration or spanning 1 meter of vehicle travel. This was intended to account for variations in illumination due to uncontrolled testing variables, such as minor imperfections in the road surface. Minor imperfections in the road surface can cause glare exceedances by affecting vehicle pitch angle. Thus, during data processing, data were "flagged" if a glare limit exceedance either had a duration under 0.1 second or lasted over a vehicle movement range of 1 meter or less. A flag did not necessarily indicate an exceedance event caused by external factors that can be excluded, it only served to draw attention to that exceedance event for further investigation.

4.4 Data Analysis

Data analysis steps for each analysis are described in this report briefly at the beginning of each results section.

4.4.1 Illuminance as a Function of Range

The data required to assess glare exposure are illuminance and range. Range was measured from a point between the ADB test vehicle's headlamps to the eyes of the driver of another vehicle, which in this testing context are represented by illuminance receptor heads positioned at measurement points corresponding to a driver's eye mid-point (for oncoming scenarios) or the oncoming or preceding vehicle's outside mirrors. Maximum illuminance values occurring in each range were extracted for comparison to the corresponding glare limits.

4.4.2 Assessment of Illuminance Data Conformance to Glare Limits

During each test run, the measured illuminance at each receptor head measurement point was recorded. Measured illuminance values were evaluated with respect to the proposed glare limits.

4.4.3 Vehicle Pitch Angle

Vehicle pitch angle was recorded and examined as part of this effort to assess whether it could be adequately controlled in a dynamic lighting test such that repeatable test outcomes could be achieved. The NPRM did not propose any adjustments to correct directly for or take vehicle pitch into account as part of the track-based compliance testing, although it did seek comment on whether pitch correction should be addressed directly. Ford recommended NHTSA adopt the IIHS pitch correction protocol. Ford commented that pitch correction is essential to produce results that are independent of differences in vehicle suspensions and are repeatable at different test tracks and different locations on the test tracks themselves. Ford noted that dynamic testing makes illuminance more difficult to measure because throughout the driving event, the vehicle pitch changes and effects from instrumentation inaccuracies increase proportionately. On the other hand, Intertek claimed that pitch correction would not be necessary unless there is a sustained change in pitch longer than 0.1 seconds.

Pitch refers to rotation of a vehicle about its transverse axis appearing as an opposing vertical motion of the front and rear ends of a vehicle. When vehicle pitch increases (negative pitch) or decreases (positive pitch) from a horizontal plane, it correspondingly increases or reduces the angle of headlamp beam projection depending on its upward or downward rotation. When a vehicle's pitch angle increases, the vehicle's front end, and therefore the angle of its headlamps, will raise in an upward direction away from the road surface. Conversely, when pitch angle decreases, the vehicle's front end will lower, and the headlamps' light will be cast downward towards the road surface.

The amount of glare perceived by other roadway users may be more pronounced when a vehicle (and its headlamps) is pitched upward. Pitch changes occur with dynamic vehicle motions due to dynamic interaction between the wheels and road surface (governed by vehicle speed, road surface conditions, and dynamic characteristics of vehicle system). Some other common causes of changes in vehicle pitch angle include vehicle loading condition or weight distribution, vehicle suspension characteristics, tire inflation that deviates from specifications, and vehicle acceleration. The test procedures control for these vehicle-based factors that could affect pitch as follows:

1) Vehicle loading and suspension - The headlamps were aimed with the vehicle loaded as it would be during testing, including the test driver. The gas tank (if the vehicle is equipped with one) was maintained at lease three-quarters full.

2) Tire pressure - Before beginning testing each day, the pressure of each tire was checked and adjusted as needed to be within 1 psi of recommended cold pressure.

3) Vehicle acceleration - The vehicle speed was maintained within 1 mph of the target test scenario speed throughout the test run.

The test procedures control for test surface factors that could affect pitch as follows:

4) Road surface - The road surface must have an IRI measurement of less than 1.5 m / km. Imperfections in the roadway are also addressed by the 0.1-second momentary glare allowance, which is intended to account for variations in illumination due to uncontrolled testing variables, including minor imperfections in the road surface that can cause glare exceedances by affecting vehicle pitch.

Analyses of vehicle pitch were performed to assess the degree to which vehicle pitch may affect measured illuminance values. Three pitch metrics were focused on:

1) **Average pitch** across each test scenario's full measurement distance: This is the average of vehicle pitch values measured throughout the performance of a test scenario. This value gives an indication of the slope of the test surface area traversed over a test scenario's full measurement distance range.

2) **Maximum pitch** over each test scenario's measurement distance sub-ranges: This is the maximum of vehicle pitch values measured over each test scenario measurement distance sub-range. This represents the combined effects of test surface slope and dynamic vehicle pitch during performance of a test trial.

3) **Pitch Difference, or Relative pitch** (maximum pitch - average pitch): The difference between these two pitch values is taken to give an indication of how much the vehicle pitched independent of the pavement's overall slope. This difference highlights how well the vehicle dynamics were able to be maintained at an essentially constant level throughout a scenario to limit the effect of vehicle dynamics on the illuminance measurements.

The RT equipment used measures vehicle pitch with respect to gravity [7]. The RT Range system has a means of zero-calibrating pitch angle. The RT system in each test vehicle was zero-calibrated, but not on a perfectly level surface. As a result, a small difference in pitch exists in the data across test vehicles. However, the relative pitch calculation is not impacted by this zero inconsistency.

Pitch information is not presented for the SAE J3069 test procedure since it only measures illuminance at specific distances and does not consider test vehicle pitch angle nor specify any means to control its variability.

5.0 TESTING PERFORMED

The testing performed had some aspects that go beyond what is specified in the test procedures (e.g., additional trials, or variations of test scenarios) in order to permit gathering of data needed to address research questions.

5.1 Stationary Illuminance Measurements Without a Test Vehicle

To evaluate the stability of the illuminance meter outputs, stationary illuminance measurements were made for each stimulus lamp or lamp set outside of the context of a test scenario, so no test vehicle was involved. A lamp or lamp set was installed on the fixture and illuminance data were recorded for a period of 30 seconds, equivalent to the duration of a long test trial.

5.2 Stationary and Low-Speed Testing to Support Vehicle Pitch Angle and Illuminance Analysis

Testing was performed to assess whether test scenarios could be executed with sufficiently steady vehicle dynamics such that, in lower beam mode, headlamp illuminance and vehicle pitch angle measured during dynamic test scenario trials would be consistent with that measured in the same location with the vehicle stationary or traveling at a slow speed (5 mph). Stationary illuminance measurements were recorded with the test vehicle stopped at specific points within the test scenario paths. To do this, instead of running test scenarios at speed, the test vehicle traversed the test scenario paths under the control of the steering robot and was stopped at specified distances corresponding as closely as possible to the end of measurement distance sub-ranges. Illuminance data were then recorded at each stopping distance to obtain a data sample of 10 seconds in both analog and digital modes.

5.3 Testing of NHTSA Test Procedure With Test Fixture

The conditions of the NHTSA ADB test procedure test matrix implemented in testing with the developed test fixture are shown in the following table, except for superelevation of the test surface, which is always to be within 0 to 2 percent for every test scenario. Additional test conditions beyond those listed in Table 2 or Table 4 were included to allow gathering of data for confirming decisions about the final scenario conditions set; these test scenarios are listed in the table but do not have test scenario numbers. Each NHTSA test scenario was run at the minimum and maximum of each ROC range end value to ensure that the full range of scenario specifications were reasonable. For each scenario, two target speeds were selected: one value 1 mph above the lower end of the speed range and one value 1 mph below the upper end of the specified speed range.

Table 11. NHTSA ADB Test Scenarios Performed in This Effort

Orientation	Curve Direction	Radius of Curvature (m)	Test Vehicle Speed	Measurement Distance Range
Oncoming	Straight	N/A	61 mph (98.2 kph)	49.2-721.8 ft (15-220 m)
		N/A	69 mph (111.0 kph)	
	Left	85	26 mph (41.8 kph)	49.2-196.5 ft (15-59.9 m)
		85	29 mph (46.7 kph)	
		115	26 mph (41.8 kph)	
		115	29 mph (46.7 kph)	
	Left	210	41 mph (66.0 kph)	49.2-492.1 ft (15-150 m)
		210	44 mph (70.8 kph)	
		250	41 mph (66.0 kph)	
		250	44 mph (70.8 kph)	
	Left	335	51 mph (82.1 kph)	49.2-721.8 ft (15-220 m)
		335	54 mph (86.9 kph)	
		400	51 mph (82.1 kph)	
		400	54 mph (86.9 kph)	
	Right	210	41 mph (66.0 kph)	49.2-164.0 ft (15-50 m)
		210	44 mph (70.8 kph)	
		250	41 mph (66.0 kph)	
		250	44 mph (70.8 kph)	
	Right	335	51 mph (82.1 kph)	49.2-229.7 ft (15-70 m)
		335	54 mph (86.9 kph)	
		400	51 mph (82.1 kph)	
		400	54 mph (86.9 kph)	
Same Direction	Straight	N/A	61 mph (98.2 kph)	49.2-721.8 ft (15-220 m)
		N/A	69 mph (111.0 kph)	
	Left	85	26 mph (41.8 kph)	49.2-196.5 ft (15-59.9 m)
		85	29 mph (46.7 kph)	
		115	26 mph (41.8 kph)	
		115	29 mph (46.7 kph)	
	Left	210	41 mph (66.0 kph)	49.2-328.1 ft (15-100 m)
		210	44 mph (70.8 kph)	
		250	41 mph (66.0 kph)	
		250	44 mph (70.8 kph)	
	Left	335	51 mph (82.1 kph)	49.2-721.8 ft (15-220 m)
		335	54 mph (86.9 kph)	
		400	51 mph (82.1 kph)	
		400	54 mph (86.9 kph)	
	Right	210	41 mph (66.0 kph)	49.2-164.0 ft (15-50 m)
		210	44 mph (70.8 kph)	
		250	41 mph (66.0 kph)	
		250	44 mph (70.8 kph)	
	Right	335	51 mph (82.1 kph)	49.2-229.7 ft (15-70 m)
		335	54 mph (86.9 kph)	
		400	51 mph (82.1 kph)	
		400	54 mph (86.9 kph)	

5.4 Testing of NHTSA Test Procedure With Stimulus Vehicle

Limited testing with a stimulus vehicle was performed for comparison to testing performed with test fixtures. A United States market 2018 Ford F-150 pickup truck served as a stimulus vehicle. The vehicle was outfitted with light sensor receptor heads at the relevant measurement points. Testing was conducted and illuminance values recorded with the stimulus vehicle were compared to corresponding receptor heads on the test fixture. The conditions of the NHTSA ADB test procedure test matrix as implemented for testing with the Ford F-150 stimulus vehicle are the same as those indicated in Table 11.

5.5 Testing of SAE J3069 Test Procedure

In testing the SAE J3069 test procedure, for the purposes of creating a test matrix and related datasheet, the six test drive events and three fixture positions were listed as eighteen total test drives as shown in Table 12. Table 12 lists the trial conditions run for the ADB mode tests and includes both steady and sudden lamp presentation modes for observing ADB response to the stimuli. Table 13 lists the trial conditions run for lower beam mode for which no sudden-presentation trials were needed.

The SAE test procedure scenarios were carried out using a 12-ft lane width.

Table 12. *SAE J3069 ADB Test Procedure Test Matrix as Implemented in This Testing For Testing of a Vehicle With Headlighting System in ADB Mode*

Test Drive No.	Direction	Stimulus Lamp(s)	Fixture Position	Lamp Presentation	Speed	Measurement Distances
1	Opposing	Car/Truck	1 (2 lanes left of ADB test lane)	Steady	28 mph (45.1 kph)	30, 60, 120, 155 m
					61 mph (98.2 kph)	
2	Opposing	Car/Truck	2 (1 lane left of ADB test lane)	Steady	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
3	Opposing	Car/Truck	3 (2 lanes right of ADB test lane)	Steady	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
4	Opposing	Motorcycle	1 (2 lanes left of ADB test lane)	Steady	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
5	Opposing	Motorcycle	1 (2 lanes left of ADB test lane)	Sudden	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
6	Opposing	Motorcycle	2 (1 lane left of ADB test lane)	Steady	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
7	Opposing	Motorcycle	2 (1 lane left of ADB test lane)	Sudden	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
8	Opposing	Motorcycle	3 (2 lanes right of ADB test lane)	Steady	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
9	Opposing	Motorcycle	3 (2 lanes right of ADB test lane)	Sudden	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
10	Preceding	Car/Truck	1 (2 lanes left of ADB test lane)	Steady	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
11	Preceding	Car/Truck	2 (1 lane left of ADB test lane)	Steady	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
12	Preceding	Car/Truck	3 (2 lanes right of ADB test lane)	Steady	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
13	Preceding	Motorcycle	1 (2 lanes left of ADB test lane)	Steady	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
14	Preceding	Motorcycle	1 (2 lanes left of ADB test lane)	Sudden	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
15	Preceding	Motorcycle	2 (1 lane left of ADB test lane)	Steady	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
16	Preceding	Motorcycle	2 (1 lane left of ADB test lane)	Sudden	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
17	Preceding	Motorcycle	3 (2 lanes right of ADB test lane)	Steady	28 mph (45.1 kph)	
					61 mph (98.2 kph)	
18	Preceding	Motorcycle	3 (2 lanes right of ADB test lane)	Sudden	28 mph (45.1 kph)	
					61 mph (98.2 kph)	

*Note: Test lane width is 3.66 m.

Table 13. *SAE J3069 ADB Test Procedure Test Matrix as Implemented in This Testing For Testing of a Vehicle With Headlighting System in Lower Beam Mode*

Test Drive No.	Direction	Stimulus Lamp(s)	Fixture Position*	Lamp Presentation	Speed	Measurement Distances
1	Opposing	Car/Truck	1 (2 lanes left of ADB test lane)	Steady	61 mph (98.2 kph)	30, 60, 120, 155 m
2	Opposing	Car/Truck	2 (1 lane left of ADB test lane)			
3	Opposing	Car/Truck	3 (2 lanes right of ADB test lane)			
4	Opposing	Motorcycle	1 (2 lanes left of ADB test lane)			
6	Opposing	Motorcycle	2 (1 lane left of ADB test lane)			
8	Opposing	Motorcycle	3 (2 lanes right of ADB test lane)			
10	Preceding	Car/Truck	1 (2 lanes left of ADB test lane)			
11	Preceding	Car/Truck	2 (1 lane left of ADB test lane)			
12	Preceding	Car/Truck	3 (2 lanes right of ADB test lane)			
13	Preceding	Motorcycle	1 (2 lanes left of ADB test lane)			
15	Preceding	Motorcycle	2 (1 lane left of ADB test lane)			
17	Preceding	Motorcycle	3 (2 lanes right of ADB test lane)			

*Note: Test lane width is 3.66 m.

5.6 Testing of SAE J3069 Test Procedure With Stimulus Vehicle

Testing per the SAE J3069 test procedure was also performed with the stimulus vehicle in place of the test fixture.

5.7 Test Vehicles / Headlighting Systems

Three test vehicles were used in this research. Each vehicle's lower beam headlamps were used for assessing the NHTSA test procedure. In addition, one vehicle was equipped with an ADB headlighting system for a full assessment of the test procedures. The following shows the naming convention that will be used throughout this report to label the test vehicles.

- Ford Fusion: 2019 Ford Fusion (halogen headlamps)
- Lexus NX300: 2018 Lexus NX300 European mass production model, ADB-equipped (LED headlamps; modified to United States VOR (visually optically aligned right) standards and to have lower and upper beam patterns compliant with FMVSS No. 108[8])
- Volvo XC90: 2016 Volvo XC90 (LED headlamps)

[8] Based on communication from Toyota. NHTSA did not test this vehicle's lower beam photometry to confirm FMVSS No. 108 compliance.

6.0 RESULTS

This section summarizes the results of testing according to the objectives listed in Section 1.1. Results presented focus on illuminance and pitch data (and glare limit compliance outcomes when appropriate). Test vehicle speed is not presented in the analyses since the only test trials considered valid and retained for analysis were trials for which speed was successfully maintained within +/- 1 mph of the specified test speed.

6.1 Evaluation of Illuminance Meter Output Stability (System Noise)

The objective of this test was to evaluate the stability of the illuminance meter outputs, without a test vehicle present, to determine if there was any noise in the data that was not dependent on the vehicle being tested, but perhaps caused by some component in the measurement system or the stimulus lamps. For example, one noise source might be the use of real automotive component stimulus lamps with high gradients for which emitted light cast onto the road, trees, grass, or other objects in the surrounding environment, could bounce back to the receptor heads and fluctuate over time (e.g., a breeze causing a roadside sign to flap which changes the magnitude of reflected light). This assessment also allowed for examination of any differences in illuminance values between analog and digital measurements.

For this testing, the test fixture was positioned on the test surface with no test vehicle present and illuminance data were recorded from each stimulus lamp condition one time for a period of 30 seconds, equivalent to the duration of a long test trial. While analog data were recorded at a 200 Hz sample rate, digital illuminance data were recorded at the 1 Hz rate provided by the illuminance meter. The following table shows the test matrix used for this assessment.

Table 14. *Test Matrix, Illuminance Stability / System Noise, NHTSA and SAE Fixtures*

Stimulus Lamp (on Test Fixture)	**Illuminance Data**	**Trial Duration (s)**
NHTSA Car (Camry), Headlamps	Analog (200 Hz) & Digital (1 Hz)	30
NHTSA Car (Camry), Taillamps	Analog (200 Hz) & Digital (1 Hz)	30
NHTSA Truck (F-150), Headlamps	Analog (200 Hz) & Digital (1 Hz)	30
NHTSA Truck (F-150), Taillamps	Analog (200 Hz) & Digital (1 Hz)	30
NHTSA Motorcycle (Harley Davidson), Headlamp	Analog (200 Hz) & Digital (1 Hz)	30
NHTSA Motorcycle (Harley Davidson), Taillamp	Analog (200 Hz) & Digital (1 Hz)	30
SAE Car/Truck Headlamps	Analog (200 Hz) & Digital (1 Hz)	30
SAE Car/Truck Taillamps	Analog (200 Hz) & Digital (1 Hz)	30
SAE Motorcycle Headlamp	Analog (200 Hz) & Digital (1 Hz)	30
SAE Motorcycle Taillamp	Analog (200 Hz) & Digital (1 Hz)	30

For these data comparisons, the analog illuminance data were not zero-calibrated or filtered as was done for other comparisons that involve first removing ambient illuminance and dealing with other factors. The analog data were utilized in raw form. The following tables show the illuminance meter output statistics for each stimulus lamp set of both the NHTSA and SAE test fixtures. In each table, both the analog and digital illuminance data (mean and standard deviations) from each receptor head are provided for comparison.

Table 15. Illuminance Meter Output Stability, NHTSA Fixture: Camry Headlamps

NHTSA Fixture: Camry Headlamps	Cycle Eye Point (RH1)	Cycle Left Mirror (RH2)	Cycle Right Mirror (RH3)	Car Eye Point (RH4)	Car Driver-Side Mirror (RH5)	Car Inside Mirror (RH6)	Car Passenger-Side Mirror (RH7)	Truck Eye Point (RH8)	Truck Driver-Side Mirror (RH9)	Truck Passenger-Side Mirror (RH10)
Analog Mean (lux)	0.565	0.561	0.569	0.548	0.446	0.568	0.455	0.552	0.529	0.531
Analog SD (lux)	0.009	0.009	0.004	0.006	0.012	0.008	0.004	0.004	0.016	0.003
Digital Mean (lux)	0.548	0.542	0.550	0.531	0.423	0.551	0.439	0.530	0.526	0.520
Digital SD (lux)	0.006	0.004	0	0.003	0.007	0.003	0.003	0	0.005	0
Difference in Means (Analog - Digital) (lux)	0.017	0.019	0.019	0.017	0.023	0.017	0.016	0.022	0.003	0.011

Table 16. Illuminance Meter Output Stability, NHTSA Fixture: Camry Taillamps

NHTSA Fixture: Camry Taillamps	Cycle Eye Point (RH1)	Cycle Left Mirror (RH2)	Cycle Right Mirror (RH3)	Car Eye Point (RH4)	Car Driver-Side Mirror (RH5)	Car Inside Mirror (RH6)	Car Passenger-Side Mirror (RH7)	Truck Eye Point (RH8)	Truck Driver-Side Mirror (RH9)	Truck Passenger-Side Mirror (RH10)
Analog Mean (lux)	0.079	0.079	0.080	0.077	0.079	0.079	0.076	0.081	0.071	0.072
Analog SD (lux)	0.009	0.009	0.004	0.006	0.012	0.008	0.004	0.004	0.015	0.003
Digital Mean (lux)	0.063	0.060	0.060	0.061	0.062	0.060	0.060	0.060	0.068	0.060
Digital SD (lux)	0.005	0.005	0	0.003	0.006	0	0	0	0.006	0
Difference in Means (Analog - Digital) (lux)	0.016	0.019	0.020	0.016	0.017	0.019	0.016	0.021	0.003	0.012

Table 17. *Illuminance Meter Output Stability, NHTSA Fixture: F-150 Truck Headlamps*

NHTSA Fixture: F-150 Truck Headlamps	**Cycle Eye Point (RH1)**	**Cycle Left Mirror (RH2)**	**Cycle Right Mirror (RH3)**	**Car Eye Point (RH4)**	**Car Driver-Side Mirror (RH5)**	**Car Inside Mirror (RH6)**	**Car Passenger-Side Mirror (RH7)**	**Truck Eye Point (RH8)**	**Truck Driver-Side Mirror (RH9)**	**Truck Passenger-Side Mirror (RH10)**
Analog Mean (lux)	0.322	0.316	0.318	0.308	0.272	0.318	0.268	0.346	0.316	0.316
Analog SD (lux)	0.009	0.010	0.005	0.006	0.012	0.008	0.004	0.004	0.015	0.004
Digital Mean (lux)	0.352	0.360	0.301	0.320	0.293	0.323	0.250	0.344	0.346	0.310
Digital SD (lux)	0.004	0.005	0.003	0	0.008	0.005	0	0.005	0.007	0
Difference in Means (Analog - Digital) (lux)	-0.030	-0.044	0.017	-0.012	-0.021	-0.005	0.018	0.002	-0.030	0.006

Table 18. *Illuminance Meter Output Stability, NHTSA Fixture: F-150 Truck Taillamps*

NHTSA Fixture: F-150 Truck Taillamps	**Cycle Eye Point (RH1)**	**Cycle Left Mirror (RH2)**	**Cycle Right Mirror (RH3)**	**Car Eye Point (RH4)**	**Car Driver-Side Mirror (RH5)**	**Car Inside Mirror (RH6)**	**Car Passenger-Side Mirror (RH7)**	**Truck Eye Point (RH8)**	**Truck Driver-Side Mirror (RH9)**	**Truck Passenger-Side Mirror (RH10)**
Analog Mean (lux)	0.087	0.086	0.085	0.084	0.085	0.085	0.081	0.088	0.077	0.079
Analog SD (lux)	0.009	0.009	0.004	0.005	0.012	0.008	0.004	0.004	0.015	0.003
Digital Mean (lux)	0.069	0.071	0.070	0.065	0.072	0.070	0.060	0.070	0.078	0.070
Digital SD (lux)	0.003	0.003	0	0.005	0.006	0	0	0	0.006	0
Difference in Means (Analog - Digital) (lux)	0.018	0.015	0.015	0.019	0.013	0.015	0.021	0.018	-0.001	0.009

Table 19. *Illuminance Meter Output Stability, NHTSA Fixture: Harley Davidson Motorcycle Headlamp*

NHTSA Fixture: Harley Davidson Motorcycle Headlamp	Cycle Eye Point (RH1)	Cycle Left Mirror (RH2)	Cycle Right Mirror (RH3)	Car Eye Point (RH4)	Car Driver-Side Mirror (RH5)	Car Inside Mirror (RH6)	Car Passenger-Side Mirror (RH7)	Truck Eye Point (RH8)	Truck Driver-Side Mirror (RH9)	Truck Passenger-Side Mirror (RH10)
Analog Mean (lux)	0.198	0.203	0.204	0.208	0.192	0.204	0.197	0.161	0.157	0.159
Analog SD (lux)	0.009	0.009	0.004	0.006	0.012	0.008	0.004	0.004	0.015	0.004
Digital Mean (lux)	0.183	0.183	0.189	0.190	0.176	0.186	0.180	0.140	0.153	0.149
Digital SD (lux)	0.005	0.005	0.003	0	0.007	0.005	0	0	0.005	0.003
Difference in Means (Analog - Digital) (lux)	0.015	0.020	0.015	0.018	0.016	0.018	0.017	0.021	0.004	0.01

Table 20. *Illuminance Meter Output Stability, NHTSA Fixture: Harley Davidson Motorcycle Taillamp*

NHTSA Fixture: Harley Davidson Motorcycle Taillamp	Cycle Eye Point (RH1)	Cycle Left Mirror (RH2)	Cycle Right Mirror (RH3)	Car Eye Point (RH4)	Car Driver-Side Mirror (RH5)	Car Inside Mirror (RH6)	Car Passenger-Side Mirror (RH7)	Truck Eye Point (RH8)	Truck Driver-Side Mirror (RH9)	Truck Passenger-Side Mirror (RH10)
Analog Mean (lux)	0.081	0.082	0.082	0.080	0.080	0.080	0.078	0.081	0.070	0.071
Analog SD (lux)	0.009	0.009	0.004	0.006	0.012	0.007	0.004	0.004	0.015	0.003
Digital Mean (lux)	0.063	0.065	0.061	0.062	0.064	0.063	0.060	0.060	0.069	0.060
Digital SD (lux)	0.005	0.005	0.003	0.004	0.005	0.005	0	0	0.007	0
Difference in Means (Analog - Digital) (lux)	0.018	0.017	0.021	0.018	0.016	0.017	0.018	0.021	0.001	0.011

Table 21. Illuminance Meter Output Stability, SAE Fixture: Car/Truck Headlamps

SAE Fixture: Car/Truck Headlamps	Cycle Eye Point (RH1)	Cycle Left Mirror (RH2)	Cycle Right Mirror (RH3)	Car Eye Point (RH4)	Car Driver-Side Mirror (RH5)	Car Inside Mirror (RH6)	Car Passenger-Side Mirror (RH7)	Truck Eye Point (RH8)	Truck Driver-Side Mirror (RH9)	Truck Passenger-Side Mirror (RH10)
Analog Mean (lux)	0.712	0.665	0.667	0.615	0.450	0.673	0.560	0.796	0.703	0.710
Analog SD (lux)	0.009	0.009	0.004	0.005	0.012	0.008	0.004	0.004	0.015	0.004
Digital Mean (lux)	0.693	0.649	0.650	0.600	0.433	0.656	0.540	0.780	0.699	0.700
Digital SD (lux)	0.005	0.003	0	0	0.005	0.005	0	0	0.007	0
Difference in Means (Analog - Digital) (lux)	0.019	0.016	0.017	0.015	0.017	0.017	0.020	0.016	0.004	0.010

Table 22. Illuminance Meter Output Stability, SAE Fixture: Car/Truck Taillamps

SAE Fixture: Car/Truck Taillamps	Cycle Eye Point (RH1)	Cycle Left Mirror (RH2)	Cycle Right Mirror (RH3)	Car Eye Point (RH4)	Car Driver-Side Mirror (RH5)	Car Inside Mirror (RH6)	Car Passenger-Side Mirror (RH7)	Truck Eye Point (RH8)	Truck Driver-Side Mirror (RH9)	Truck Passenger-Side Mirror (RH10)
Analog Mean (lux)	0.099	0.127	0.093	0.110	0.094	0.122	0.101	0.096	0.085	0.086
Analog SD (lux)	0.009	0.009	0.004	0.006	0.012	0.007	0.004	0.004	0.015	0.003
Digital Mean (lux)	0.083	0.112	0.075	0.092	0.084	0.106	0.080	0.080	0.084	0.079
Digital SD (lux)	0.005	0.004	0.005	0.004	0.005	0.005	0	0	0.007	0.003
Difference in Means (Analog - Digital) (lux)	0.016	0.015	0.018	0.018	0.010	0.016	0.021	0.016	0.001	0.007

Table 23. *Illuminance Meter Output Stability, SAE Fixture: Motorcycle Headlamp*

SAE Fixture: Motorcycle Headlamp	Cycle Eye Point (RH1)	Cycle Left Mirror (RH2)	Cycle Right Mirror (RH3)	Car Eye Point (RH4)	Car Driver-Side Mirror (RH5)	Car Inside Mirror (RH6)	Car Passenger-Side Mirror (RH7)	Truck Eye Point (RH8)	Truck Driver-Side Mirror (RH9)	Truck Passenger-Side Mirror (RH10)
Analog Mean (lux)	0.877	0.735	0.771	0.641	0.441	0.796	0.484	0.507	0.501	0.538
Analog SD (lux)	0.009	0.009	0.005	0.005	0.012	0.008	0.004	0.004	0.015	0.004
Digital Mean (lux)	0.861	0.716	0.750	0.620	0.424	0.779	0.469	0.490	0.496	0.530
Digital SD (lux)	0.006	0.005	0	0	0.005	0.003	0.003	0	0.007	0
Difference in Means (Analog - Digital) (lux)	0.016	0.019	0.021	0.021	0.017	0.017	0.015	0.017	0.005	0.008

Table 24. *Illuminance Meter Output Stability, SAE Fixture: Motorcycle Taillamp*

SAE Fixture: Motorcycle Taillamp	Cycle Eye Point (RH1)	Cycle Left Mirror (RH2)	Cycle Right Mirror (RH3)	Car Eye Point (RH4)	Car Driver-Side Mirror (RH5)	Car Inside Mirror (RH6)	Car Passenger-Side Mirror (RH7)	Truck Eye Point (RH8)	Truck Driver-Side Mirror (RH9)	Truck Passenger-Side Mirror (RH10)
Analog Mean (lux)	0.100	0.099	0.099	0.098	0.096	0.099	0.095	0.095	0.086	0.088
Analog SD (lux)	0.009	0.009	0.004	0.005	0.012	0.008	0.004	0.004	0.015	0.004
Digital Mean (lux)	0.081	0.081	0.080	0.080	0.080	0.080	0.079	0.080	0.083	0.080
Digital SD (lux)	0.003	0.003	0	0	0.005	0	0.003	0	0.008	0
Difference in Means (Analog - Digital) (lux)	0.019	0.018	0.019	0.018	0.016	0.019	0.016	0.015	0.003	0.008

As could be expected, the illuminance data summarized in the above tables show that headlamps produce more illumination of the surroundings and that results in higher illuminance values than were seen for the single headlamp (motorcycle) and the taillamps. The natural difference in illumination from the headlamps (with gradients) does not have any measurable impact once zero-calibrated. Overall, the SAE lamps produced more illuminance than the comparable NHTSA lamps, as illustrated in Figure 28.

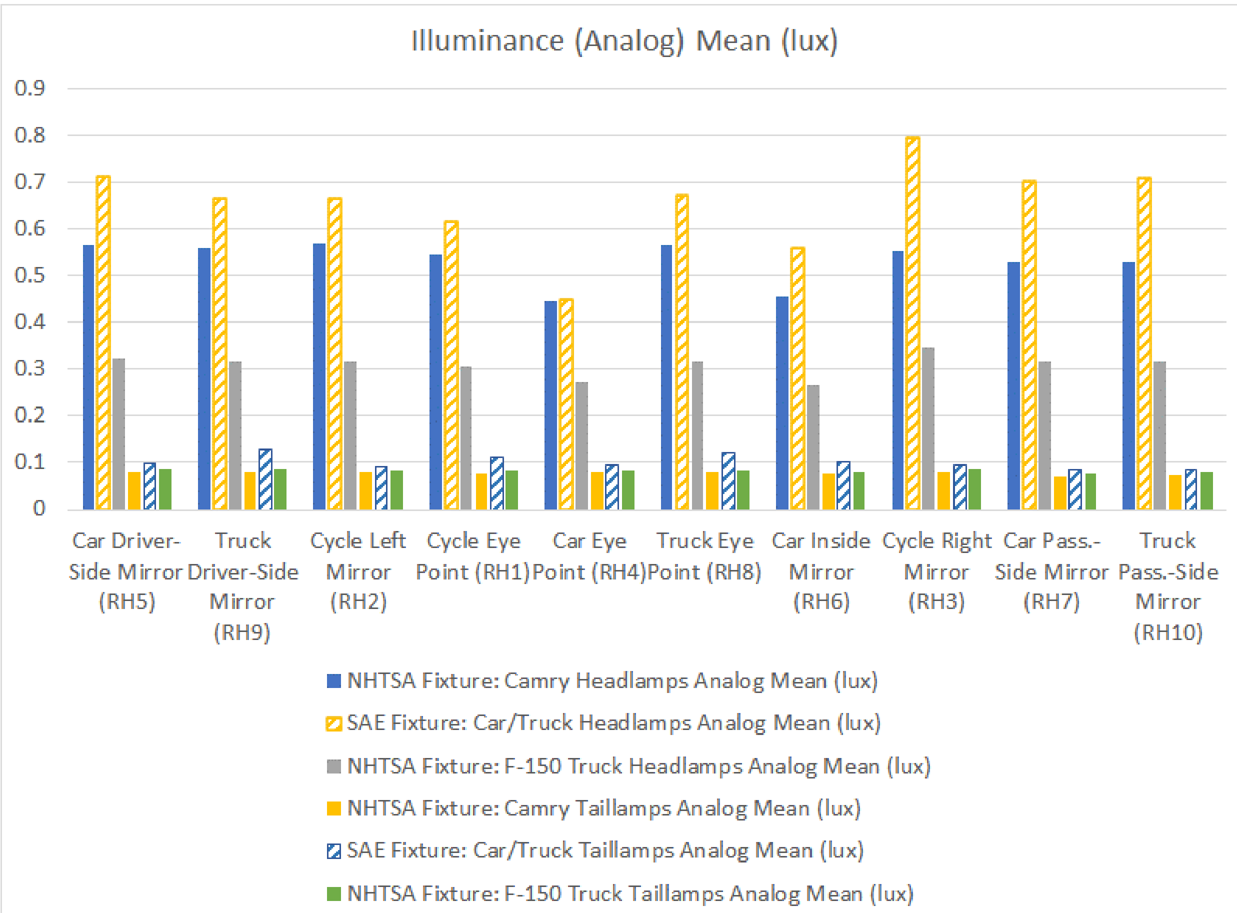

Figure 28. *Mean Illuminance (Analog) for NHTSA and SAE Stimulus Lamps*

The difference in analog versus digital illuminance means was consistently 0.044 lux or less across all lamp sets, with most values being less than or equal to 0.023 lux.

Values in the preceding tables show that both the analog and digital standard deviations were low and similar across all receptor heads and each of the lamp sets, suggesting very little measurement system noise or fluctuation from ambient conditions. In fact, for digital illuminance measurements, each lamp set was found to have at least two receptor heads with standard deviations of 0, indicating no variability. Standard deviations for analog measurements of all NHTSA and SAE motorcycle headlamps and taillamps were 0.016 lux or less. Analog illuminance measurement standard deviation values for NHTSA Camry and F-150 headlamps and the SAE Car/Truck headlamps are summarized in Figure 29. Analog illuminance measurement standard deviation values for the NHTSA and SAE motorcycle headlamps are summarized in Figure 30. These graphs illustrate that standard deviation of measured illuminance values for NHTSA's vehicle component lamp conditions were not higher than those observed for the SAE lamps.

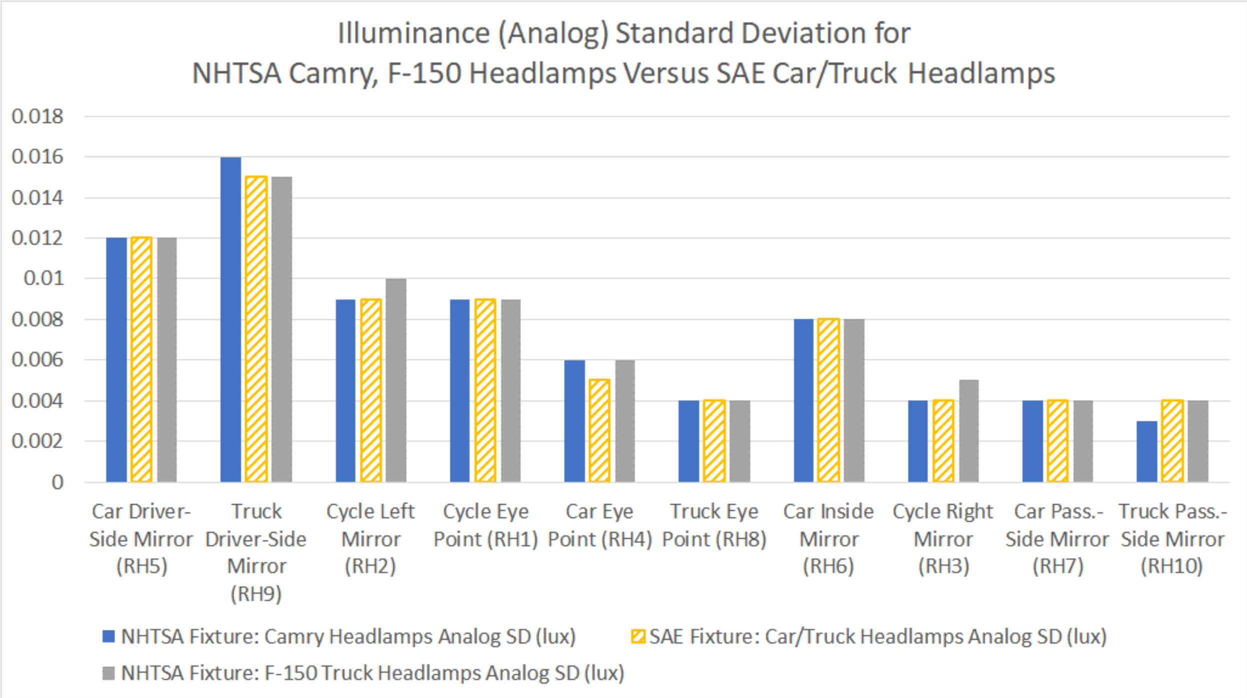

Figure 29. *Illuminance (Analog) Standard Deviation for NHTSA Camry, F-150 Headlamps Versus SAE Car/Truck Headlamps*

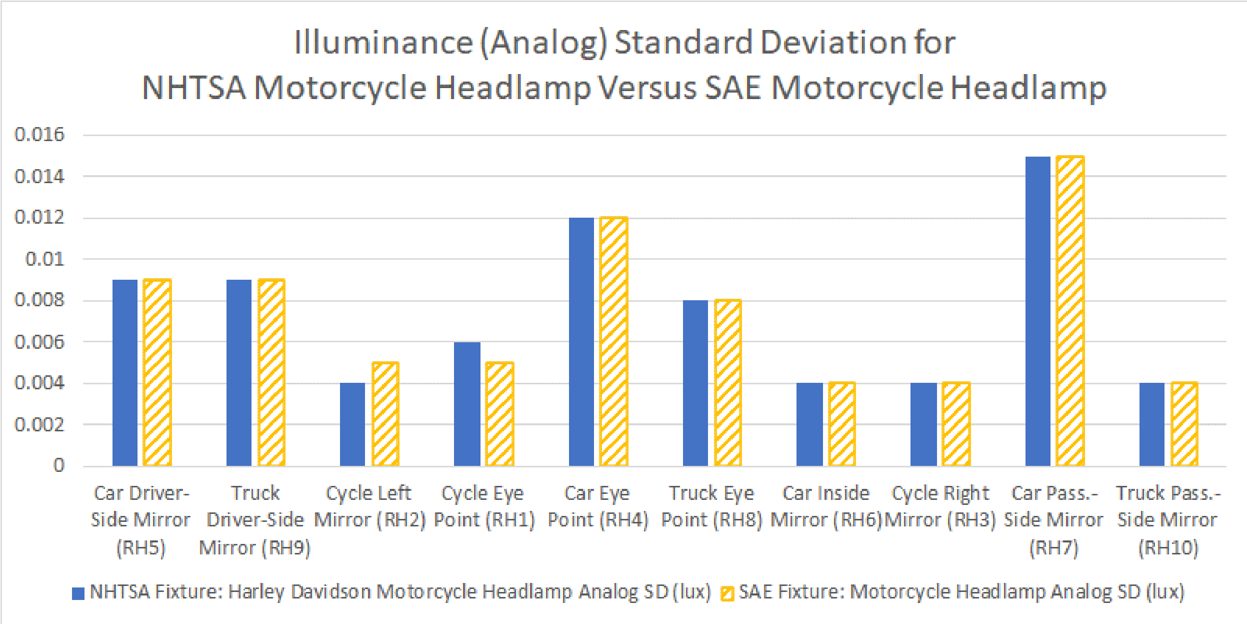

Figure 30. *Illuminance (Analog) Standard Deviation for NHTSA Motorcycle Headlamp Versus SAE Motorcycle Headlamp*

6.2 Assessment of Test Vehicle Motion Effects on Illuminance and Vehicle Pitch Angle for NHTSA ADB Test Scenarios

Tests were performed to assess whether test scenarios could be executed with sufficiently steady vehicle dynamics such that 1) statically measured vehicle pitch angle would be similar to dynamically measured vehicle pitch angle for specified points within a test scenario, and 2) in lower beam mode, headlamp illuminance measured during dynamic test scenario performance would be consistent with that measured in the same location with the vehicle stationary. For these lower beam test trials, stimulus lamps were not needed and each test scenario was performed once rather than in both oncoming and same direction orientations. Both illuminance and vehicle pitch data were examined as part of this analysis.

Table 25. *Test Scenarios Used To Examine Dynamic Versus Statically Measured Data*

Curve Direction	Radius of Curvature (m)	(Dynamic) Vehicle Speed (mph)	Maximum Measurement Distance (m)
Straight	NA	69	220
Left	85	29	59.9
	115	29	59.9
	210	44	50
	250	44	50
	335	54	70
	400	54	70
Right	85	29	59.9
	115	29	59.9
	210	44	150
	250	44	150
	335	54	220
	400	54	220

6.2.1 Comparison of Test Vehicle Pitch Angle for Stationary Versus Dynamically Performed Measurements

Vehicle pitch angle is an important factor affecting measured headlamp illuminance in full-vehicle, dynamic testing. Vehicle pitch angle was recorded during all test scenarios for use in this analysis, with the objective being to quantify how pitch may have affected the results. For the Ford Fusion and Lexus NX300 test vehicles, each test scenario was run an additional time with the test vehicle traveling at 5 mph, for comparison to the higher speed tests. Stationary (0 mph) tests were also run in which the test vehicles were stopped along the test scenario path at the transition distances between measurement distance sub-ranges and data recorded for approximately 10 seconds while the vehicle was stationary. By comparing the stationary and 5 mph trial pitch values to those recorded at test speed, an indicator could be obtained of the degree to which vehicle dynamics were able to be controlled in each test scenario. If the pitch difference, or the value obtained by subtracting the stationary pitch angle value from the dynamic pitch angle value, was small, that would indicate that 1) vehicle dynamics can be controlled to the extent that it is feasible and valid to perform dynamic testing of vehicle headlighting systems, and 2) the vehicle being in motion would have little impact on measured illuminance values.

The following tables show the pitch results for each test scenario, at each of the measurement distance sub-range end points for each speed condition. For the dynamic trials, the pitch data point that occurred closest to the measurement distance sub-range end point listed, is value listed.

Table 26. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 85 m Radius of Curvature, Ford Fusion*

	Pitch (degrees)		
Vehicle Speed (mph)	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
26	0.51	0.43	0.59
5	0.47	0.45	0.66
0	0.42	0.45	0.64
Difference (26 mph Dynamic - Static)	0.09	-0.02	-0.05

Table 27. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 115 m Radius of Curvature, Ford Fusion*

	Pitch (degrees)		
Vehicle Speed (mph)	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
26	0.51	0.51	0.65
5	0.40	0.55	0.64
0	0.35	0.53	0.63
Difference (26 mph Dynamic - Static)	0.16	-0.02	0.02

Table 28. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 210 m Radius of Curvature, Ford Fusion*

	Pitch (degrees)				
Vehicle Speed (mph)	**150 m Measurement Distance**	**119.9 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
41	0.47	0.39	0.59	0.65	0.64
5	0.39	0.45	0.56	0.63	0.66
0	0.41	0.35	0.50	0.60	0.63
Difference (41 mph Dynamic - Static)	0.06	0.04	0.09	0.05	0.01

Table 29. Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 250 m Radius of Curvature, Ford Fusion

	Pitch (degrees)				
Vehicle Speed (mph)	**150 m Measurement Distance**	**119.9 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
41	0.30	0.41	0.50	0.65	0.65
5	0.22	0.48	0.51	0.66	0.66
0	0.17	0.51	0.46	0.63	0.63
Difference (41 mph Dynamic - Static)	0.13	-0.10	0.04	0.02	0.02

Table 30. Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 335 m Radius of Curvature, Ford Fusion

	Pitch (degrees)				
Vehicle Speed (mph)	**220 m Measurement Distance**	**119.9 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
51	0.55	0.47	0.49	0.68	0.68
5	0.31	0.47	0.48	0.66	0.65
0	0.26	0.42	0.48	0.65	0.63
Difference (51 mph Dynamic - Static)	0.29	0.05	0.01	0.03	0.05

The 0.29-degrees difference observed at the 220 m measurement distance for the 335 m radius left curve scenario shown in Table 30 was the largest difference observed between stationary and test-speed trials for any NHTSA test scenario. Given that this pitch difference was seen at the beginning of the measurement distance range, the likely cause of this pitch difference was difficulty in getting the test vehicle up to test speed smoothly by the start of the measurement distance range. The layout of some test scenarios, such as the larger radius curves, on the test surface resulted in less area over which to accelerate, which proved to be a challenge for lower powered vehicles. Adjustment of test scenario layout on the test surface to alleviate this issue should resolve this issue in any future testing.

Table 31. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 400 m Radius of Curvature, Ford Fusion*

	Pitch (degrees)				
Vehicle Speed (mph)	**220 m Measurement Distance**	**119.9 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
51	0.52	0.40	0.51	0.67	0.67
5	0.45	0.45	0.53	0.66	0.67
0	0.43	0.56	0.54	0.67	0.67
Difference (51 mph Dynamic - Static)	0.09	-0.16	-0.03	0	0

Table 32. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Straight, Ford Fusion*

	Pitch (degrees)				
Vehicle Speed (mph)	**220 m Measurement Distance**	**119.9 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
61	0.73	0.66	0.61	0.69	0.68
5	0.66	0.65	0.55	0.66	0.67
0	0.62	0.63	0.59	0.66	0.65
Difference (61 mph Dynamic - Static)	0.11	0.03	0.02	0.03	0.03

Table 33. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Right Curve 210 m Radius of Curvature, Ford Fusion*

	Pitch (degrees)		
Vehicle Speed (mph)	**50 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
41	0.44	0.45	0.41
5	0.49	0.48	0.40
0	0.45	0.42	0.38
Difference (41 mph Dynamic - Static)	-0.01	0.03	0.03

Table 34. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Right Curve 250 m Radius of Curvature, Ford Fusion*

	Pitch (degrees)		
Vehicle Speed (mph)	**50 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
41	0.42	0.50	0.42
5	0.42	0.44	0.42
0	0.38	0.38	0.35
Difference (41 mph Dynamic - Static)	0.04	0.12	0.07

Table 35. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Right Curve 335 m Radius of Curvature, Ford Fusion*

	Pitch (degrees)			
Vehicle Speed (mph)	**70 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
51	0.45	0.45	0.48	0.36
5	0.54	0.43	0.43	0.41
0	0.53	0.42	0.40	0.36
Difference (51 mph Dynamic - Static)	-0.08	0.03	0.08	0

Table 36. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Right Curve 400 m Radius of Curvature, Ford Fusion*

	Pitch (degrees)			
Vehicle Speed (mph)	**70 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
51	0.49	0.57	0.48	0.36
5	0.50	0.36	0.41	0.39
0	0.48	0.34	0.38	0.37
Difference (51 mph Dynamic - Static)	0.01	0.23	0.10	-0.01

For the Ford Fusion, the pitch differences between dynamic trial measurement points and the comparable static measurement points were nominal, not varying by more than 0.29 degrees, with the majority of comparisons being less than a 0.10-degree difference.

Tables 37 - 47 contain vehicle pitch data for the Lexus NX300 for stationary, 5 mph, and scenario-speed trials.

Table 37. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 85 m Radius of Curvature, Lexus NX300*

	Pitch (degrees)		
Vehicle Speed (mph)	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
29	2.02	1.85	1.99
5	1.80	1.83	2.01
0	1.76	1.81	1.99
Difference (29 mph Dynamic - Static)	0.26	0.04	0

Table 38. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 115 m Radius of Curvature, Lexus NX300*

	Pitch (degrees)		
Vehicle Speed (mph)	**50 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
29	1.88	1.95	2.06
5	1.81	1.90	1.99
0	1.69	1.91	1.97
Difference (29 mph Dynamic - Static)	0.19	0.04	0.09

Table 39. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 210 m Radius of Curvature, Lexus NX300*

	Pitch (degrees)				
Vehicle Speed (mph)	**150 m Measurement Distance**	**119.9 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
44	1.73	1.83	2.00	2.06	2.04
5	1.72	1.78	1.88	1.96	1.98
0	1.78	1.71	1.87	1.94	1.97
Difference (44 mph Dynamic - Static)	-0.05	0.12	0.13	0.12	0.07

Table 40. Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 250 m Radius of Curvature, Lexus NX300

	Pitch (degrees)				
Vehicle Speed (mph)	**150 m Measurement Distance**	**119.9 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
44	1.79	1.79	1.90	2.05	2.05
5	1.55	1.81	1.84	1.99	1.99
0	1.52	1.83	1.81	2.01	2.02
Difference (44 mph Dynamic - Static)	0.27	-0.04	0.09	0.04	0.03

Table 41. Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 335 m Radius of Curvature, Lexus NX300

	Pitch (degrees)				
Vehicle Speed (mph)	**220 m Measurement Distance**	**119.9 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
54	1.82	1.83	1.88	2.07	2.05
5	1.65	1.80	1.86	2.03	1.99
0	1.61	1.78	1.85	2.00	1.98
Difference (54 mph Dynamic - Static)	0.21	0.05	0.03	0.07	0.07

Table 42. Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Left Curve 400 m Radius of Curvature, Lexus NX300

	Pitch (degrees)				
Vehicle Speed (mph)	**220 m Measurement Distance**	**119.9 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
54	1.89	1.80	1.90	2.07	2.06
5	1.80	1.85	1.90	2.03	1.98
0	1.78	1.87	1.86	2.00	2.01
Difference (54 mph Dynamic - Static)	0.11	-0.07	0.04	0.07	0.05

Table 43. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Straight, Lexus NX300*

	Pitch (degrees)				
Vehicle Speed (mph)	**220 m Measurement Distance**	**119.9 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
69	2.00	2.06	1.96	2.06	2.10
5	2.04	2.01	1.95	2.02	2.04
0	1.98	1.98	1.91	2.03	2.00
Difference (69 mph Dynamic - Static)	0.02	0.08	0.05	0.03	0.10

Table 44. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Right Curve 210 m Radius of Curvature, Lexus NX300*

	Pitch (degrees)		
Vehicle Speed (mph)	**50 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
44	1.84	1.89	1.87
5	1.83	1.84	1.75
0	1.89	1.84	1.80
Difference (44 mph Dynamic - Static)	-0.05	0.05	0.07

Table 45. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Right Curve 250 m Radius of Curvature, Lexus NX300*

	Pitch (degrees)		
Vehicle Speed (mph)	**50 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
44	1.83	1.92	1.86
5	1.74	1.81	1.75
0	1.81	1.82	1.77
Difference (44 mph Dynamic - Static)	0.02	0.10	0.09

Table 46. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Right Curve 335 m Radius of Curvature, Lexus NX300*

	Pitch (degrees)			
Vehicle Speed (mph)	**70 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
54	1.89	1.87	1.91	1.76
5	1.89	1.78	1.79	1.75
0	1.91	1.76	1.80	1.75
Difference (54 mph Dynamic - Static)	-0.02	0.11	0.11	0.01

Table 47. *Pitch Measurements at Specific Measurement Distances and Test Vehicle Speeds for Right Curve 400 m Radius of Curvature, Lexus NX300*

	Pitch (degrees)			
Vehicle Speed (mph)	**70 m Measurement Distance**	**59.9 m Measurement Distance**	**29.9 m Measurement Distance**	**15 m Measurement Distance**
54	1.88	1.98	1.93	1.77
5	1.86	1.75	1.77	1.73
0	1.89	1.77	1.78	1.76
Difference (54 mph Dynamic - Static)	-0.01	0.21	0.15	0.01

For the Lexus NX300, the pitch differences between dynamic trial measurement points and the comparable stationary measurement points were nominal, not varying by more than 0.27 degrees, with the majority of comparisons being less than a 0.10-degree difference. This finding matches very closely with the Ford Focus results, which showed a 0.29-degree maximum difference and majority of differences being less than 0.10 degrees.

Of all the data presented in the above tables, the largest pitch difference observed in these tests was 0.29 degrees when comparing stationary trial data to 51 mph trial data for the Ford Fusion at the 220 m distance of the 335 m left curve test scenario (Table 30).

These high speed, low speed, and stationary pitch summary data were obtained to assess how pitch may vary based on speed in NHTSA ADB test scenarios. If pitch differences between dynamic and stationary pitch measurements for a particular point within a measurement distance were small, this would demonstrate that the motion of the vehicle did not affect or confound the test results. Differences in pitch between stationary, 5 mph, and test speed comparisons were 0.29 degrees or less for both the Ford Fusion and the Lexus NX300. The magnitudes of vehicle pitch differences between stationary, 5 mph, and scenario-speed trials were similar across test vehicles.

6.2.2 Comparison of Illuminance for Stationary Versus Dynamically Performed Measurements

Stationary and dynamic measurement results of lower beam trials were compared to demonstrate that the illuminance meter components coupled with filtering would record essentially the same value for dynamic scenarios as when they are given time to collect a reading over time (as in a stationary trial). For instance, this comparison can show that the analog readings for dynamic tests are accounting for a pulse width modulation (if the lamps being tested use pulse width modulation) adequately. The static readings can be collected in both analog and digital modes, knowing that the digital mode accounts for modulation internal to the meter. Then, the dynamic reading taken at the exact same point can be compared to see if the selected filter is too aggressive, or not aggressive enough. This analysis would also confirm there was no lag in the data for dynamic test scenario trials that would affect the synchronization of distance and illuminance data.

Stationary illuminance measurements were recorded with the test vehicle stopped at specific points within the test scenario paths. To do this, instead of running test scenarios at speed, the test vehicle traversed the test scenario paths under the control of the steering robot and was stopped at specified distances corresponding as closely as possible to the end of measurement distance sub-ranges. Illuminance data were then recorded at each stopping distance to obtain a data sample of 10 seconds in both analog and digital modes. Static trial (scenarios with stops) illuminance data were taken from the digital illuminance data file. The digital illuminance data files were recorded to a laptop separate from the DAS. The files contained one measurement per second (1 Hz sample rate) and the values were averaged to provide a single value for comparison.

Dynamic test scenario data from trials run at the upper limit target speed for each test scenario were examined to find the point in the path that most closely matched that of the stopped position and the illuminance and pitch data values at that point were extracted for comparison to corresponding static trial values.

Illuminance data for stationary and dynamic test trials were compared for two test vehicles (Ford Fusion and Lexus NX300) with headlighting systems operating in lower beam mode. Only a subset of the data collected for this static versus dynamic comparison is presented here for brevity. The results below show typically just the highest vehicle speed conditions for each curve scenario. In addition, there were not enough data for comparison for the right curves for the Lexus NX300, so only the straight and left curve scenarios are shown for that vehicle.

The following tables show the stationary and the dynamic scenario illuminance and vehicle pitch angle measurements by the specific measurement distances used for each scenario. Note that vehicle pitch angle values presented in this section were obtained from different test trials than those presented in Section 6.2.1 and, as such, the pitch values may be slightly different. Data in the tables, that are not otherwise labeled, represent illuminance values obtained at those distances.

Table 48. *Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Right Curve 210 m Radius of Curvature, at 44 mph, Ford Fusion Lower Beams*

	Speed (mph)	**Distance (m)**	**Pitch (deg)**	**Cycle Eye Pt (RH1) (lux)**	**Cycle Left Mirror (RH2) (lux)**	**Cycle Right Mirror (RH3) (lux)**	**Car Eye Pt (RH4) (lux)**	**Car Driver-Side Mirror (RH5) (lux)**	**Car Inside Mirror (RH6) (lux)**	**Car Passenger-Side Mirror (RH7) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Truck Driver-Side Mirror (RH9) (lux)**	**Truck Passenger-Side Mirror (RH10) (lux)**
Static Means	**Static**	**50.31**	0.45	0.263	0.272	0.260	0.265	0.356	0.265	0.350	0.240	0.284	0.230
	Static	**30.32**	0.38	1.132	1.127	1.182	1.211	1.205	1.161	1.359	0.872	0.815	0.943
	Static	**15.39**	0.35	1.481	1.390	1.790	1.758	3.223	1.528	3.117	1.082	0.951	2.068
Dynamic Means, Unfiltered	**44**	**50.219**	0.41	0.273	0.294	0.271	0.279	0.392	0.271	0.374	0.245	0.297	0.234
	44	**30.260**	0.43	1.079	1.073	1.157	1.180	1.266	1.122	1.575	0.872	0.784	0.959
	44	**15.304**	0.4	1.364	1.315	1.622	1.582	2.849	1.466	3.024	0.983	0.922	1.963
Difference (Dynamic - Static)		***50.0***	-0.042	0.010	0.022	0.011	0.014	0.036	0.006	0.024	0.005	0.013	0.004
		29.9	0.050	-0.053	-0.054	-0.025	-0.031	0.061	-0.039	0.216	0.000	-0.031	0.016
		15.0	0.051	-0.117	-0.075	-0.168	-0.176	-0.374	-0.062	-0.093	-0.099	-0.029	-0.105
Dynamic Means, 35 Hz Filtered	**44**	**50.219**	0.41	0.273	0.289	0.270	0.281	0.397	0.275	0.370	0.251	0.295	0.235
	44	**30.260**	0.43	1.088	1.069	1.159	1.193	1.253	1.119	1.573	0.865	0.776	0.964
	44	**15.304**	0.4	1.394	1.302	1.623	1.610	2.850	1.449	3.009	1.009	0.899	1.991
Difference (35 Hz Dynamic - Static)		***50.0***	-0.042	0.010	0.017	0.010	0.016	0.041	0.010	0.020	0.011	0.011	0.005
		29.9	0.050	-0.044	-0.058	-0.023	-0.018	0.048	-0.042	0.214	-0.007	-0.039	0.021
		15.0	0.051	-0.087	-0.088	-0.167	-0.148	-0.373	-0.079	-0.108	-0.073	-0.052	-0.077

Table 49. *Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Right Curve 250 m Radius of Curvature, at 44 mph, Ford Fusion Lower Beams*

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**50.20**	0.36	0.310	0.328	0.310	0.326	0.455	0.309	0.327	0.290	0.338	0.266
	Static	**30.15**	0.37	1.052	1.009	1.141	1.171	1.147	1.070	1.530	0.850	0.752	1.002
	Static	**15.31**	0.33	1.376	1.327	1.587	1.594	3.362	1.419	3.080	0.990	0.862	2.016
Dynamic Means, Unfiltered	**44**	**50.145**	0.38	0.318	0.336	0.320	0.328	0.506	0.327	0.342	0.289	0.357	0.266
	44	**30.071**	0.46	1.007	0.977	1.110	1.131	1.256	1.040	1.720	0.840	0.745	1.020
	44	**15.248**	0.39	1.342	1.300	1.556	1.548	3.031	1.377	3.005	0.954	0.809	1.957
Difference (Dynamic - Static)		***50.0***	0.018	0.008	0.008	0.010	0.002	0.051	0.018	0.015	-0.001	0.019	0.000
		29.9	0.086	-0.045	-0.032	-0.031	-0.040	0.109	-0.030	0.190	-0.010	-0.007	0.018
		15.0	0.057	-0.034	-0.027	-0.031	-0.046	-0.331	-0.042	-0.075	-0.036	-0.053	-0.059
Dynamic Means, 35 Hz Filtered	**44**	**50.145**	0.38	0.316	0.333	0.315	0.326	0.513	0.324	0.339	0.288	0.351	0.269
	44	**30.071**	0.46	1.006	0.987	1.117	1.139	1.255	1.036	1.722	0.834	0.743	1.018
	44	**15.248**	0.39	1.339	1.291	1.538	1.539	3.027	1.381	3.009	0.962	0.825	1.958
Difference (35 Hz Dynamic - Static)		***50.0***	0.018	0.006	0.005	0.005	0.000	0.058	0.015	0.012	-0.002	0.013	0.003
		29.9	0.086	-0.046	-0.022	-0.024	-0.032	0.108	-0.034	0.192	-0.016	-0.009	0.016
		15.0	0.057	-0.037	-0.036	-0.049	-0.055	-0.335	-0.038	-0.071	-0.028	-0.037	-0.058

Table 50. Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Right Curve 335 m Radius of Curvature, at 54 mph, Ford Fusion Lower Beams

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**70.31**	0.47	0.150	0.164	0.150	0.160	0.231	0.151	0.251	0.130	0.144	0.123
	Static	**60.31**	0.35	0.258	0.281	0.252	0.263	0.406	0.259	0.263	0.223	0.264	0.212
	Static	**30.19**	0.34	0.909	0.903	0.980	0.994	1.045	0.930	1.448	0.751	0.689	0.990
	Static	**15.36**	0.35	1.318	1.335	1.489	1.500	3.594	1.360	3.086	0.920	0.694	1.930
Dynamic Means, Unfiltered	**54**	**70.291**	0.47	0.150	0.166	0.155	0.175	0.264	0.157	0.268	0.131	0.159	0.124
	54	**60.272**	0.48	0.261	0.279	0.248	0.270	0.529	0.266	0.345	0.211	0.278	0.197
	54	**30.075**	0.51	0.890	0.848	0.945	0.988	1.302	0.899	1.768	0.736	0.673	0.973
	54	**15.311**	0.39	1.276	1.260	1.401	1.409	3.000	1.330	2.944	0.896	0.689	1.819
Difference (Dynamic - Static)		***70.0***	0.000	0.000	0.002	0.005	0.015	0.033	0.006	0.017	0.001	0.015	0.001
		59.9	0.135	0.003	-0.002	-0.004	0.007	0.123	0.007	0.082	-0.012	0.014	-0.015
		29.9	0.168	-0.019	-0.055	-0.035	-0.006	0.257	-0.031	0.320	-0.015	-0.016	-0.017
		15.0	0.044	-0.042	-0.075	-0.088	-0.091	-0.594	-0.030	-0.142	-0.024	-0.005	-0.111
Dynamic Means, 35 Hz Filtered	**54**	**70.291**	0.47	0.150	0.163	0.157	0.176	0.262	0.158	0.269	0.130	0.156	0.127
	54	**60.272**	0.48	0.249	0.272	0.251	0.270	0.523	0.259	0.341	0.211	0.268	0.204
	54	**30.075**	0.51	0.880	0.855	0.951	0.979	1.296	0.904	1.774	0.727	0.668	0.967
	54	**15.311**	0.39	1.279	1.261	1.415	1.439	2.993	1.308	2.934	0.890	0.661	1.839
Difference (35 Hz Dynamic - Static)		***70.0***	0.000	0.000	-0.001	0.007	0.016	0.031	0.007	0.018	0.000	0.012	0.004
		59.9	0.135	-0.009	-0.009	-0.001	0.007	0.117	0.000	0.078	-0.012	0.004	-0.008
		29.9	0.168	-0.029	-0.048	-0.029	-0.015	0.251	-0.026	0.326	-0.024	-0.021	-0.023
		15.0	0.044	-0.039	-0.074	-0.074	-0.061	-0.601	-0.052	-0.152	-0.030	-0.033	-0.091

Table 51. *Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Right Curve 400 m Radius of Curvature, at 54 mph, Ford Fusion Lower Beams*

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**70.19**	0.49	0.172	0.187	0.170	0.189	0.321	0.175	0.252	0.150	0.192	0.140
	Static	**60.14**	0.32	0.293	0.310	0.290	0.310	0.457	0.296	0.319	0.257	0.302	0.236
	Static	**30.22**	0.41	0.891	0.858	0.950	0.970	1.144	0.904	1.498	0.740	0.689	0.962
	Static	**15.37**	0.34	1.307	1.292	1.430	1.470	3.578	1.344	3.083	0.900	0.647	1.860
Dynamic Means, Unfiltered	**54**	**70.146**	0.49	0.188	0.195	0.181	0.202	0.369	0.186	0.275	0.153	0.185	0.149
	54	**60.131**	0.55	0.324	0.380	0.350	0.414	0.874	0.363	0.557	0.248	0.294	0.235
	54	**30.165**	0.53	0.814	0.807	0.901	0.926	1.381	0.845	1.765	0.691	0.634	0.906
	54	**15.285**	0.39	1.267	1.213	1.353	1.391	3.137	1.285	2.957	0.869	0.576	1.752
Difference (Dynamic - Static)		***70.0***	-0.004	0.016	0.008	0.011	0.013	0.048	0.011	0.023	0.003	-0.007	0.009
		59.9	0.227	0.031	0.070	0.060	0.104	0.417	0.067	0.238	-0.009	-0.008	-0.001
		29.9	0.120	-0.077	-0.051	-0.049	-0.044	0.237	-0.059	0.267	-0.049	-0.055	-0.056
		15.0	0.048	-0.040	-0.079	-0.077	-0.079	-0.441	-0.059	-0.126	-0.031	-0.071	-0.108
Dynamic Means, 35 Hz Filtered	**54**	**70.146**	0.49	0.186	0.198	0.186	0.204	0.375	0.193	0.273	0.152	0.185	0.147
	54	**60.131**	0.55	0.322	0.378	0.349	0.410	0.862	0.363	0.552	0.250	0.291	0.233
	54	**30.165**	0.53	0.817	0.801	0.902	0.931	1.385	0.848	1.757	0.697	0.632	0.905
	54	**15.285**	0.39	1.259	1.227	1.357	1.386	3.153	1.283	2.969	0.862	0.584	1.734
Difference (35 Hz Dynamic - Static)		***70.0***	-0.004	0.014	0.011	0.016	0.015	0.054	0.018	0.021	0.002	-0.007	0.007
		59.9	0.227	0.029	0.068	0.059	0.100	0.405	0.067	0.233	-0.007	-0.011	-0.003
		29.9	0.120	-0.074	-0.057	-0.048	-0.039	0.241	-0.056	0.259	-0.043	-0.057	-0.057
		15.0	0.048	-0.048	-0.065	-0.073	-0.084	-0.425	-0.061	-0.114	-0.038	-0.063	-0.126

Table 52. Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 85 m Radius of Curvature, at 29 mph, Ford Fusion Lower Beams

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**58.946**	0.41	0.073	0.073	0.080	0.073	0.098	0.076	0.109	0.070	0.068	0.080
	Static	**29.588**	0.46	0.267	0.459	0.445	0.701	0.697	0.461	0.977	0.101	0.091	0.119
	Static	**15.005**	0.64	0.393	0.393	0.470	0.720	1.637	0.425	3.567	0.340	0.228	0.480
Dynamic Means, Unfiltered	**29**	**58.909**	0.53	0.106	0.104	0.107	0.131	0.147	0.117	0.177	0.078	0.072	0.092
	29	**29.537**	0.47	0.517	0.758	0.763	0.862	0.734	0.766	1.132	0.106	0.098	0.124
	29	**14.966**	0.65	0.419	0.579	0.629	1.342	1.769	0.596	4.110	0.355	0.239	0.494
Difference (Dynamic - Static)		***59.0***	0.116	0.033	0.031	0.027	0.058	0.049	0.041	0.068	0.008	0.004	0.012
		29.9	0.011	0.250	0.299	0.318	0.161	0.037	0.305	0.155	0.005	0.007	0.005
		15.0	0.013	0.026	0.186	0.159	0.622	0.132	0.171	0.543	0.015	0.011	0.014
Dynamic Means, 35 Hz Filtered	**29**	**58.909**	0.53	0.101	0.105	0.110	0.130	0.144	0.115	0.177	0.072	0.067	0.089
	29	**29.537**	0.47	0.516	0.758	0.767	0.865	0.734	0.765	1.127	0.110	0.099	0.126
	29	**14.966**	0.65	0.411	0.579	0.621	1.335	1.766	0.603	4.118	0.348	0.236	0.488
Difference (35 Hz Dynamic - Static)		***59.0***	0.116	0.028	0.032	0.030	0.057	0.046	0.039	0.068	0.002	-0.001	0.009
		29.9	0.011	0.249	0.299	0.322	0.164	0.037	0.304	0.150	0.009	0.008	0.007
		15.0	0.013	0.018	0.186	0.151	0.615	0.129	0.178	0.551	0.008	0.008	0.008

Table 53. Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 115 m Radius of Curvature, at 29 mph, Ford Fusion Lower Beams

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**59.33**	0.37	0.196	0.193	0.200	0.208	0.180	0.200	0.220	0.040	0.093	0.095
	Static	**29.68**	0.55	0.254	0.441	0.440	0.869	0.989	0.445	1.453	0.131	0.118	0.175
	Static	**15.10**	0.61	0.483	0.462	0.560	0.730	1.955	0.511	4.146	0.390	0.267	0.635
Dynamic Means, Unfiltered	**29**	**59.272**	0.43	0.213	0.197	0.213	0.210	0.206	0.211	0.243	0.059	0.156	0.168
	29	**29.654**	0.59	0.422	0.845	0.834	1.156	1.106	0.860	1.714	0.136	0.124	0.187
	29	**15.079**	0.66	0.501	0.568	0.611	1.067	2.191	0.600	5.114	0.378	0.278	0.690
Difference (Dynamic - Static)		***59.0***	0.058	0.017	0.004	0.013	0.002	0.026	0.011	0.023	0.019	0.063	0.073
		29.9	0.038	0.168	0.404	0.394	0.287	0.117	0.415	0.261	0.005	0.006	0.012
		15.0	0.054	0.018	0.106	0.051	0.337	0.236	0.089	0.968	-0.012	0.011	0.055
Dynamic Means, 35 Hz Filtered	**29**	**59.272**	0.43	0.206	0.201	0.214	0.209	0.202	0.209	0.242	0.063	0.155	0.168
	29	**29.654**	0.59	0.419	0.840	0.838	1.150	1.110	0.855	1.710	0.137	0.124	0.184
	29	**15.079**	0.66	0.506	0.578	0.623	1.062	2.183	0.597	5.117	0.388	0.288	0.689
Difference (35 Hz Dynamic - Static)		***59.0***	0.058	0.010	0.008	0.014	0.001	0.022	0.009	0.022	0.023	0.062	0.073
		29.9	0.038	0.165	0.399	0.398	0.281	0.121	0.410	0.257	0.006	0.006	0.009
		15.0	0.054	0.023	0.116	0.063	0.332	0.228	0.086	0.971	-0.002	0.021	0.054

Table 54. Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 210 m Radius of Curvature, at 44 mph, Ford Fusion Lower Beams

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**148.801**	0.41	0.018	0.021	0.020	0.030	0.029	0.023	0.020	0.020	0.020	0.020
	Static	**119.00**	0.32	0.053	0.052	0.058	0.060	0.056	0.059	0.057	0.044	0.042	0.048
	Static	**59.57**	0.49	0.250	0.305	0.308	0.362	0.448	0.308	0.464	0.050	0.064	0.074
	Static	**29.85**	0.57	0.372	0.421	0.480	0.682	1.482	0.447	2.058	0.340	0.195	0.419
	Static	**15.16**	0.62	0.612	0.585	0.760	0.791	2.791	0.645	3.746	0.480	0.351	1.111
Dynamic Means, Unfiltered	**44**	**148.803**	0.4	0.028	0.027	0.021	0.016	0.016	0.022	0.026	0.025	0.011	0.016
	44	**118.992**	0.46	0.053	0.061	0.056	0.060	0.052	0.051	0.065	0.050	0.039	0.054
	44	**59.554**	0.57	0.382	0.410	0.425	0.458	0.585	0.414	0.600	0.060	0.145	0.120
	44	**29.776**	0.62	0.448	0.671	0.687	1.183	1.842	0.690	2.549	0.337	0.197	0.408
	44	**14.987**	0.65	0.584	0.636	0.753	1.043	3.094	0.645	5.565	0.461	0.360	1.083
Difference (Dynamic - Static)		***220.0***	-0.005	0.010	0.006	0.001	-0.014	-0.013	-0.001	0.006	0.005	-0.009	-0.004
		119.9	0.139	0.000	0.009	-0.002	0.000	-0.004	-0.008	0.008	0.006	-0.003	0.006
		59.9	0.076	0.132	0.105	0.117	0.096	0.137	0.106	0.136	0.010	0.081	0.046
		29.9	0.049	0.076	0.250	0.207	0.501	0.360	0.243	0.491	-0.003	0.002	-0.011
		15.0	0.029	-0.028	0.051	-0.007	0.252	0.303	0.000	1.819	-0.019	0.009	-0.028
Dynamic Means, 35 Hz Filtered	**44**	**148.803**	0.4	0.025	0.024	0.024	0.024	0.023	0.027	0.026	0.023	0.012	0.020
	44	**118.992**	0.46	0.060	0.060	0.061	0.057	0.057	0.056	0.067	0.053	0.045	0.055
	44	**59.554**	0.57	0.380	0.409	0.421	0.455	0.583	0.416	0.601	0.058	0.144	0.122
	44	**29.776**	0.62	0.448	0.670	0.696	1.197	1.847	0.678	2.547	0.333	0.198	0.414
	44	**14.987**	0.65	0.604	0.631	0.755	1.044	3.086	0.641	5.556	0.472	0.352	1.091
Difference (35 Hz Dynamic - Static)		***220.0***	-0.005	0.007	0.003	0.004	-0.006	-0.006	0.004	0.006	0.003	-0.008	0.000
		119.9	0.139	0.007	0.008	0.003	-0.003	0.001	-0.003	0.010	0.009	0.003	0.007
		59.9	0.076	0.130	0.104	0.113	0.093	0.135	0.108	0.137	0.008	0.080	0.048
		29.9	0.049	0.076	0.249	0.216	0.515	0.365	0.231	0.489	-0.007	0.003	-0.005
		15.0	0.029	-0.008	0.046	-0.005	0.253	0.295	-0.004	1.810	-0.008	0.001	-0.020

Table 55. Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 250 m Radius of Curvature, at 44 mph, Ford Fusion Lower Beams

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**149.039**	0.16	0.031	0.031	0.036	0.041	0.037	0.039	0.033	0.030	0.027	0.030
	Static	**119.220**	0.52	0.071	0.074	0.080	0.091	0.079	0.083	0.093	0.058	0.061	0.069
	Static	**59.714**	0.47	0.262	0.330	0.357	0.439	0.459	0.346	0.620	0.090	0.071	0.110
	Static	**30.002**	0.62	0.422	0.483	0.530	0.779	1.546	0.517	2.232	0.350	0.225	0.450
	Static	**15.152**	0.62	0.643	0.602	0.820	0.850	2.826	0.669	3.523	0.510	0.363	1.120
Dynamic Means, Unfiltered	**44**	**148.902**	0.31	0.036	0.032	0.043	0.039	0.040	0.038	0.037	0.036	0.036	0.035
	44	**119.086**	0.49	0.096	0.098	0.103	0.103	0.114	0.099	0.117	0.062	0.078	0.085
	44	**59.689**	0.48	0.409	0.462	0.489	0.555	0.548	0.478	0.704	0.100	0.100	0.139
	44	**29.910**	0.7	0.536	0.852	0.884	1.529	1.962	0.870	2.755	0.367	0.267	0.487
	44	**15.071**	0.69	0.710	0.682	0.966	1.181	3.248	0.754	5.431	0.581	0.370	1.133
Difference (Dynamic - Static)		***220.0***	0.154	0.005	0.001	0.007	-0.002	0.003	-0.001	0.004	0.006	0.009	0.005
		119.9	-0.026	0.025	0.024	0.023	0.012	0.035	0.016	0.024	0.004	0.017	0.016
		59.9	0.010	0.147	0.132	0.132	0.116	0.089	0.132	0.084	0.010	0.029	0.029
		29.9	0.084	0.114	0.369	0.354	0.750	0.416	0.353	0.523	0.017	0.042	0.037
		15.0	0.074	0.067	0.080	0.146	0.331	0.422	0.085	1.908	0.071	0.007	0.013
Dynamic Means, 35 Hz Filtered	**44**	**148.902**	0.31	0.034	0.035	0.042	0.038	0.036	0.037	0.039	0.033	0.026	0.039
	44	**119.086**	0.49	0.092	0.092	0.103	0.103	0.106	0.095	0.120	0.071	0.072	0.084
	44	**59.689**	0.48	0.407	0.462	0.496	0.552	0.545	0.482	0.707	0.093	0.100	0.137
	44	**29.910**	0.7	0.548	0.849	0.883	1.540	1.964	0.869	2.751	0.374	0.263	0.495
	44	**15.071**	0.69	0.713	0.664	0.943	1.184	3.267	0.760	5.434	0.592	0.374	1.140
Difference (35 Hz Dynamic - Static)		***220.0***	0.154	0.003	0.004	0.006	-0.003	-0.001	-0.002	0.006	0.003	-0.001	0.009
		119.9	-0.026	0.021	0.018	0.023	0.012	0.027	0.012	0.027	0.013	0.011	0.015
		59.9	0.010	0.145	0.132	0.139	0.113	0.086	0.136	0.087	0.003	0.029	0.027
		29.9	0.084	0.126	0.366	0.353	0.761	0.418	0.352	0.519	0.024	0.038	0.045
		15.0	0.074	0.070	0.062	0.123	0.334	0.441	0.091	1.911	0.082	0.011	0.020

Table 56. *Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 335 m Radius of Curvature, at 54 mph, Ford Fusion Lower Beams*

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**218.90**	0.29	0.010	0.011	0.015	0.015	0.023	0.011	0.010	0.017	0.012	0.010
	Static	**119.30**	0.45	0.093	0.101	0.101	0.106	0.126	0.097	0.115	0.040	0.061	0.060
	Static	**59.68**	0.48	0.232	0.353	0.288	0.397	0.640	0.315	0.474	0.130	0.120	0.132
	Static	**29.86**	0.62	0.474	0.540	0.600	0.837	1.668	0.562	1.515	0.410	0.324	0.550
	Static	**15.24**	0.62	0.792	0.677	1.070	1.045	2.959	0.839	3.298	0.720	0.391	1.115
Dynamic Means, Unfiltered	**54**	**218.801**	0.51	0.021	0.017	0.009	0.019	0.016	0.018	0.024	0.022	0.012	0.024
	54	**119.220**	0.51	0.107	0.123	0.114	0.133	0.144	0.118	0.146	0.057	0.098	0.093
	54	**59.608**	0.53	0.297	0.441	0.353	0.494	0.718	0.397	0.620	0.130	0.140	0.138
	54	**29.840**	0.74	0.616	0.877	0.808	1.471	2.168	0.876	2.178	0.439	0.361	0.556
	54	**15.142**	0.73	0.872	0.764	1.156	1.338	3.381	0.937	5.504	0.754	0.394	1.135
Difference (Dynamic - Static)		***220.0***	0.216	0.011	0.006	-0.006	0.004	-0.007	0.007	0.014	0.005	0.000	0.014
		119.9	0.063	0.014	0.022	0.013	0.027	0.018	0.021	0.031	0.017	0.037	0.033
		59.9	0.049	0.065	0.088	0.065	0.097	0.078	0.082	0.146	0.000	0.020	0.006
		29.9	0.117	0.142	0.337	0.208	0.634	0.500	0.314	0.663	0.029	0.037	0.006
		15.0	0.112	0.080	0.087	0.086	0.293	0.422	0.098	2.206	0.034	0.003	0.020
Dynamic Means, 35 Hz Filtered	**54**	**218.801**	0.51	0.020	0.019	0.016	0.019	0.017	0.016	0.023	0.016	0.015	0.019
	54	**119.220**	0.51	0.111	0.122	0.118	0.129	0.142	0.121	0.143	0.061	0.090	0.089
	54	**59.608**	0.53	0.296	0.443	0.357	0.491	0.718	0.402	0.619	0.128	0.140	0.141
	54	**29.840**	0.74	0.606	0.875	0.817	1.462	2.164	0.877	2.167	0.441	0.355	0.561
	54	**15.142**	0.73	0.880	0.747	1.139	1.335	3.394	0.929	5.486	0.763	0.394	1.127
Difference (35 Hz Dynamic - Static)		***220.0***	0.216	0.010	0.008	0.001	0.004	-0.006	0.005	0.013	-0.001	0.003	0.009
		119.9	0.063	0.018	0.021	0.017	0.023	0.016	0.024	0.028	0.021	0.029	0.029
		59.9	0.049	0.064	0.090	0.069	0.094	0.078	0.087	0.145	-0.002	0.020	0.009
		29.9	0.117	0.132	0.335	0.217	0.625	0.496	0.315	0.652	0.031	0.031	0.011
		15.0	0.112	0.088	0.070	0.069	0.290	0.435	0.090	2.188	0.043	0.003	0.012

Table 57. *Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 400 m Radius of Curvature, at 54 mph, Ford Fusion Lower Beams*

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**218.64**	0.42	0.019	0.020	0.020	0.021	0.020	0.022	0.020	0.020	0.015	0.019
	Static	**118.93**	0.51	0.122	0.131	0.140	0.136	0.136	0.134	0.160	0.040	0.066	0.079
	Static	**58.95**	0.51	0.177	0.223	0.202	0.249	0.627	0.211	0.389	0.140	0.125	0.150
	Static	**29.15**	0.63	0.522	0.578	0.620	0.809	1.819	0.616	1.229	0.460	0.374	0.600
	Static	**14.55**	0.66	0.808	0.700	1.101	1.085	3.139	0.855	3.808	0.690	0.398	1.180
Dynamic Means, Unfiltered	**54**	**218.535**	0.57	0.030	0.031	0.022	0.028	0.028	0.029	0.029	0.018	0.023	0.026
	54	**118.866**	0.47	0.135	0.138	0.152	0.160	0.159	0.145	0.179	0.053	0.090	0.093
	54	**58.884**	0.55	0.204	0.264	0.254	0.325	0.736	0.254	0.564	0.139	0.141	0.146
	54	**29.129**	0.69	0.574	0.735	0.697	0.976	2.246	0.726	1.657	0.499	0.388	0.615
	54	**14.501**	0.66	0.919	0.782	1.238	1.299	3.472	0.948	5.054	0.782	0.430	1.150
Difference (Dynamic - Static)		***220.0***	0.146	0.011	0.011	0.002	0.007	0.008	0.007	0.009	-0.002	0.008	0.007
		119.9	-0.036	0.013	0.007	0.012	0.024	0.023	0.011	0.019	0.013	0.024	0.014
		59.9	0.038	0.027	0.041	0.052	0.076	0.109	0.043	0.175	-0.001	0.016	-0.004
		29.9	0.060	0.052	0.157	0.077	0.167	0.427	0.110	0.428	0.039	0.014	0.015
		15.0	-0.003	0.111	0.082	0.137	0.214	0.333	0.093	1.246	0.092	0.032	-0.030
Dynamic Means, 35 Hz Filtered	**54**	**218.535**	0.57	0.030	0.027	0.025	0.030	0.029	0.028	0.026	0.021	0.020	0.023
	54	**118.866**	0.47	0.139	0.147	0.153	0.159	0.158	0.148	0.177	0.052	0.093	0.097
	54	**58.884**	0.55	0.204	0.264	0.251	0.316	0.727	0.254	0.562	0.140	0.145	0.151
	54	**29.129**	0.69	0.575	0.729	0.692	0.973	2.243	0.707	1.638	0.501	0.384	0.613
	54	**14.501**	0.66	0.918	0.772	1.224	1.288	3.480	0.963	5.049	0.793	0.423	1.174
Difference (35 Hz Dynamic - Static)		***220.0***	0.146	0.011	0.007	0.005	0.009	0.009	0.006	0.006	0.001	0.005	0.004
		119.9	-0.036	0.017	0.016	0.013	0.023	0.022	0.014	0.017	0.012	0.027	0.018
		59.9	0.038	0.027	0.041	0.049	0.067	0.100	0.043	0.173	0.000	0.020	0.001
		29.9	0.060	0.053	0.151	0.072	0.164	0.424	0.091	0.409	0.041	0.010	0.013
		15.0	-0.003	0.110	0.072	0.123	0.203	0.341	0.108	1.241	0.103	0.025	-0.006

Table 58. Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Straight, at 69 mph, Ford Fusion Lower Beams

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**219.92**	0.69	0.066	0.070	0.078	0.008	0.091	0.077	0.100	0.040	0.041	0.040
	Static	**119.82**	0.64	0.125	0.135	0.141	0.084	0.194	0.143	0.232	0.080	0.076	0.090
	Static	**60.00**	0.55	0.259	0.259	0.280	0.221	0.361	0.270	0.457	0.230	0.198	0.260
	Static	**30.07**	0.66	0.669	0.645	0.720	0.674	1.784	0.686	1.340	0.600	0.516	0.749
	Static	**15.30**	0.64	1.232	1.076	1.348	1.302	3.423	1.267	4.048	0.900	0.438	1.303
Dynamic Means, Unfiltered	**69**	**219.860**	1.11	0.310	0.338	0.363	0.392	0.422	0.354	0.474	0.140	0.184	0.214
	69	**119.886**	0.66	0.117	0.134	0.143	0.161	0.205	0.145	0.237	0.073	0.091	0.084
	69	**59.868**	0.61	0.259	0.288	0.286	0.313	0.429	0.273	0.519	0.220	0.223	0.271
	69	**29.931**	0.71	0.642	0.627	0.713	0.765	2.060	0.672	1.528	0.589	0.499	0.746
	69	**15.205**	0.71	1.199	1.117	1.337	1.388	3.883	1.256	5.432	0.933	0.467	1.338
Difference (Dynamic - Static)		***220.0***	0.423	0.244	0.268	0.285	0.384	0.331	0.277	0.374	0.100	0.143	0.174
		119.9	0.022	-0.008	-0.001	0.002	0.077	0.011	0.002	0.005	-0.007	0.015	-0.006
		59.9	0.063	0.000	0.029	0.006	0.092	0.068	0.003	0.062	-0.010	0.025	0.011
		29.9	0.046	-0.027	-0.018	-0.007	0.091	0.276	-0.014	0.188	-0.011	-0.017	-0.003
		15.0	0.069	-0.033	0.041	-0.011	0.086	0.460	-0.011	1.384	0.033	0.029	0.035
Dynamic Means, 35 Hz Filtered	**69**	**219.860**	1.11	0.319	0.347	0.361	0.389	0.419	0.353	0.467	0.139	0.176	0.211
	69	**119.886**	0.66	0.120	0.135	0.144	0.160	0.193	0.145	0.238	0.076	0.077	0.084
	69	**59.868**	0.61	0.259	0.275	0.286	0.311	0.430	0.278	0.516	0.226	0.206	0.270
	69	**29.931**	0.71	0.648	0.632	0.705	0.769	2.065	0.666	1.525	0.594	0.508	0.747
	69	**15.205**	0.71	1.209	1.125	1.342	1.388	3.869	1.256	5.430	0.924	0.468	1.342
Difference (35 Hz Dynamic - Static)		***220.0***	0.423	0.253	0.277	0.283	0.381	0.328	0.276	0.367	0.099	0.135	0.171
		119.9	0.022	-0.005	0.000	0.003	0.076	-0.001	0.002	0.006	-0.004	0.001	-0.006
		59.9	0.063	0.000	0.016	0.006	0.090	0.069	0.008	0.059	-0.004	0.008	0.010
		29.9	0.046	-0.021	-0.013	-0.015	0.095	0.281	-0.020	0.185	-0.006	-0.008	-0.002
		15.0	0.069	-0.023	0.049	-0.006	0.086	0.446	-0.011	1.382	0.024	0.030	0.039

Table 59. *Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 85 m Radius of Curvature, at 29 mph, Lexus NX300 Lower Beams*

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**58.925**	1.70	0.039	0.040	0.040	0.039	0.046	0.037	0.050	0.040	0.038	0.050
	Static	**29.535**	1.77	0.243	0.232	0.260	0.249	0.277	0.240	0.360	0.240	0.214	0.289
	Static	**14.992**	1.95	0.794	0.762	0.910	0.917	1.021	0.820	2.726	0.770	0.522	1.340
Dynamic Means, Unfiltered	**29**	**58.864**	1.69	0.083	0.150	0.145	0.282	0.618	0.156	0.685	0.047	0.055	0.050
	29	**29.526**	1.75	0.238	0.260	0.285	0.342	1.094	0.265	1.108	0.229	0.206	0.290
	29	**14.986**	1.96	0.795	0.747	0.919	1.021	8.589	0.843	11.262	0.703	0.501	1.272
Difference (Dynamic - Static)		***59.0***	-0.009	0.044	0.110	0.105	0.243	0.572	0.119	0.635	0.007	0.017	0.000
		29.9	-0.016	-0.005	0.028	0.025	0.093	0.817	0.025	0.748	-0.011	-0.008	0.001
		15.0	0.011	0.001	-0.015	0.009	0.104	7.568	0.023	8.536	-0.067	-0.021	-0.068
Dynamic Means, 35 Hz Filtered	**29**	**58.864**	1.69	0.077	0.141	0.142	0.281	0.608	0.150	0.681	0.047	0.054	0.048
	29	**29.526**	1.75	0.240	0.260	0.279	0.346	1.085	0.266	1.107	0.235	0.207	0.286
	29	**14.986**	1.96	0.795	0.755	0.922	1.044	8.619	0.840	11.266	0.700	0.512	1.280
Difference (35 Hz Dynamic - Static)		***59.0***	-0.009	0.038	0.101	0.102	0.242	0.562	0.113	0.631	0.007	0.016	-0.002
		29.9	-0.016	-0.003	0.028	0.019	0.097	0.808	0.026	0.747	-0.005	-0.007	-0.003
		15.0	0.011	0.001	-0.007	0.012	0.127	7.598	0.020	8.540	-0.070	-0.010	-0.060

Table 60. Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 115 m Radius of Curvature, at 29 mph, Lexus NX300 Lower Beams

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**59.221**	1.65	0.052	0.060	0.060	0.063	0.084	0.059	0.080	0.050	0.048	0.060
	Static	**29.690**	1.86	0.331	0.322	0.370	0.380	0.417	0.345	0.930	0.330	0.266	0.480
	Static	**15.080**	1.95	0.962	0.884	1.140	1.127	1.136	1.010	4.839	0.947	0.594	1.737
Dynamic Means, Unfiltered	**29**	**59.163**	1.71	0.088	0.112	0.106	0.145	0.425	0.118	0.325	0.050	0.057	0.061
	29	**29.665**	1.85	0.370	0.363	0.418	0.531	1.130	0.394	2.264	0.333	0.275	0.489
	29	**15.026**	1.98	0.993	0.856	1.125	1.277	5.688	0.989	14.040	0.888	0.606	1.626
Difference (Dynamic - Static)		***59.0***	0.063	0.036	0.052	0.046	0.082	0.341	0.059	0.245	0.000	0.009	0.001
		29.9	-0.013	0.039	0.041	0.048	0.151	0.713	0.049	1.334	0.003	0.009	0.009
		15.0	0.034	0.031	-0.028	-0.015	0.150	4.552	-0.021	9.201	-0.059	0.012	-0.111
Dynamic Means, 35 Hz Filtered	**29**	**59.163**	1.71	0.086	0.109	0.105	0.147	0.421	0.116	0.325	0.054	0.061	0.061
	29	**29.665**	1.85	0.363	0.364	0.422	0.533	1.125	0.398	2.265	0.330	0.273	0.493
	29	**15.026**	1.98	0.973	0.870	1.144	1.275	5.669	0.994	14.063	0.877	0.594	1.635
Difference (35 Hz Dynamic - Static)		***59.0***	0.063	0.034	0.049	0.045	0.084	0.337	0.057	0.245	0.004	0.013	0.001
		29.9	-0.013	0.032	0.042	0.052	0.153	0.708	0.053	1.335	0.000	0.007	0.013
		15.0	0.034	0.011	-0.014	0.004	0.148	4.533	-0.016	9.224	-0.070	0.000	-0.102

Table 61. *Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 210 m Radius of Curvature, at 44 mph, Lexus NX300 Lower Beams*

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**150.000**	x	x	x	x	x	x	x	x	x	x	x
	Static	**119.079**	1.64	0.022	0.022	0.020	0.020	0.035	0.018	0.020	0.020	0.018	0.020
	Static	**59.605**	1.78	0.169	0.181	0.200	0.225	0.237	0.193	0.400	0.170	0.117	0.190
	Static	**29.775**	1.90	0.768	0.719	0.840	0.881	1.009	0.808	2.058	0.730	0.521	0.807
	Static	**15.085**	1.95	1.609	1.192	1.809	1.820	1.363	1.568	6.115	1.330	0.715	1.719
Dynamic Means, Unfiltered	**44**	**150.000**	x	x	x	x	x	x	x	x	x	x	x
	44	**119.019**	1.80	0.059	0.067	0.066	0.086	0.157	0.066	0.148	0.019	0.032	0.024
	44	**59.579**	1.87	0.331	0.387	0.435	0.560	0.863	0.413	1.276	0.175	0.141	0.208
	44	**29.701**	1.99	0.875	1.132	1.295	1.952	3.876	1.229	8.080	0.697	0.529	0.781
	44	**15.039**	2.02	1.643	1.358	1.958	2.296	7.023	1.721	23.897	1.312	0.744	1.791
Difference (Dynamic - Static)		***220.0***	x	x	x	x	x	x	x	x	x	x	x
		119.9	0.163	0.037	0.045	0.046	0.066	0.122	0.048	0.128	-0.001	0.014	0.004
		59.9	0.091	0.162	0.206	0.235	0.335	0.626	0.220	0.876	0.005	0.024	0.018
		29.9	0.093	0.107	0.413	0.455	1.071	2.867	0.421	6.022	-0.033	0.008	-0.026
		15.0	0.071	0.034	0.166	0.149	0.476	5.660	0.153	17.782	-0.018	0.029	0.072
Dynamic Means, 35 Hz Filtered	**44**	**150.000**	x	x	x	x	x	x	x	x	x	x	x
	44	**118.928**	1.80	0.054	0.069	0.067	0.086	0.158	0.065	0.146	0.016	0.026	0.025
	44	**59.579**	1.87	0.333	0.393	0.436	0.561	0.858	0.413	1.282	0.170	0.137	0.211
	44	**29.701**	1.99	0.884	1.136	1.295	1.950	3.883	1.228	8.082	0.695	0.537	0.780
	44	**15.039**	2.02	1.664	1.329	1.938	2.294	7.044	1.715	23.904	1.318	0.734	1.776
Difference (35 Hz Dynamic - Static)		***220.0***	x	x	x	x	x	x	x	x	x	x	x
		119.9	0.163	0.032	0.047	0.047	0.066	0.123	0.047	0.126	-0.004	0.008	0.005
		59.9	0.091	0.164	0.212	0.236	0.336	0.621	0.220	0.882	0.000	0.020	0.021
		29.9	0.093	0.116	0.417	0.455	1.069	2.874	0.420	6.024	-0.035	0.016	-0.027
		15.0	0.071	0.055	0.137	0.129	0.474	5.681	0.147	17.789	-0.012	0.019	0.057

Car passenger-side rearview mirror static analog illuminance data average at 15 m was 6.1193 lux, which is comparable to the digital average as reported in Table 61, 6.115 lux. Car driver-side rearview mirror static analog illuminance data average at 15m was 1.3546 lux, which is comparable to the digital average as reported in Table 61, 1.363 lux.

Table 62. *Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 250 m Radius of Curvature, at 44 mph, Lexus NX300 Lower Beams*

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**150.000**	x	x	x	x	x	x	x	x	x	x	x
	Static	**119.213**	1.77	0.021	0.021	0.030	0.023	0.033	0.025	0.030	0.020	0.021	0.028
	Static	**59.610**	1.75	0.233	0.251	0.280	0.291	0.347	0.259	0.483	0.200	0.178	0.230
	Static	**29.976**	1.93	0.811	0.841	0.897	0.961	1.305	0.839	2.412	0.720	0.627	0.810
	Static	**15.163**	1.94	1.770	1.507	2.000	2.010	1.424	1.748	6.012	1.440	0.767	2.020
Dynamic Means, Unfiltered	**44**	**149.946**	1.67	0.030	0.040	0.041	0.054	0.081	0.037	0.079	0.013	0.007	0.019
	44	**119.126**	1.76	0.030	0.040	0.041	0.036	0.062	0.031	0.072	0.019	0.014	0.019
	44	**59.570**	1.79	0.381	0.436	0.487	0.595	0.844	0.471	1.194	0.204	0.184	0.240
	44	**29.920**	1.98	0.896	1.190	1.283	1.942	4.040	1.207	7.783	0.710	0.607	0.775
	44	**15.072**	2.00	1.706	1.548	2.019	2.350	5.224	1.750	20.898	1.478	0.742	1.976
Difference (Dynamic - Static)		***220.0***	x	x	x	x	x	x	x	x	x	x	x
		119.9	-0.010	0.009	0.019	0.011	0.013	0.029	0.006	0.042	-0.001	-0.007	-0.009
		59.9	0.038	0.148	0.185	0.207	0.304	0.497	0.212	0.711	0.004	0.006	0.010
		29.9	0.046	0.085	0.349	0.386	0.981	2.735	0.368	5.371	-0.010	-0.020	-0.035
		15.0	0.056	-0.064	0.041	0.019	0.340	3.800	0.002	14.886	0.038	-0.025	-0.044
Dynamic Means, 35 Hz Filtered	**44**	**149.946**	1.67	0.028	0.043	0.041	0.051	0.078	0.037	0.078	0.013	0.013	0.019
	44	**119.126**	1.76	0.026	0.032	0.039	0.044	0.060	0.035	0.072	0.018	0.013	0.019
	44	**59.570**	1.79	0.362	0.434	0.486	0.596	0.836	0.465	1.193	0.206	0.177	0.236
	44	**29.920**	1.98	0.902	1.194	1.286	1.941	4.050	1.201	7.777	0.710	0.603	0.771
	44	**15.072**	2.00	1.707	1.553	2.018	2.358	5.227	1.754	20.812	1.475	0.736	1.968
Difference (35 Hz Dynamic - Static)		***220.0***	x	x	x	x	x	x	x	x	x	x	x
		119.9	-0.010	0.005	0.011	0.009	0.021	0.027	0.010	0.042	-0.002	-0.008	-0.009
		59.9	0.038	0.129	0.183	0.206	0.305	0.489	0.206	0.710	0.006	-0.001	0.006
		29.9	0.046	0.091	0.353	0.389	0.980	2.745	0.362	5.365	-0.010	-0.024	-0.039
		15.0	0.056	-0.063	0.046	0.018	0.348	3.803	0.006	14.800	0.035	-0.031	-0.052

Table 63. *Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 335 m Radius of Curvature, at 54 mph, Lexus NX300 Lower Beams*

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**218.917**	1.55	0.010	0.009	0.010	0.010	0.016	0.010	0.010	0.010	0.011	0.010
	Static	**119.340**	1.72	0.051	0.058	0.060	0.063	0.070	0.058	0.090	0.040	0.038	0.050
	Static	**59.685**	1.79	0.277	0.319	0.333	0.397	0.588	0.338	0.694	0.200	0.231	0.230
	Static	**29.876**	1.96	0.889	0.939	1.020	1.172	1.913	0.978	2.833	0.740	0.711	0.790
	Static	**15.123**	1.94	1.849	1.740	2.100	2.131	1.625	1.828	7.004	1.470	0.801	2.090
Dynamic Means, Unfiltered	**54**	**218.852**	1.63	0.008	0.010	0.021	0.013	0.023	0.014	0.019	0.000	-0.005	0.005
	54	**119.278**	1.74	0.087	0.119	0.117	0.139	0.167	0.108	0.218	0.048	0.027	0.068
	54	**59.571**	1.78	0.501	0.647	0.668	0.879	1.549	0.660	1.836	0.214	0.252	0.252
	54	**29.847**	1.99	1.118	1.423	1.540	2.489	6.458	1.480	9.509	0.739	0.730	0.790
	54	**15.116**	1.98	1.934	1.747	2.238	2.821	7.511	1.987	26.912	1.488	0.868	2.070
Difference (Dynamic - Static)		***220.0***	0.078	-0.002	0.001	0.011	0.003	0.007	0.004	0.009	-0.010	-0.016	-0.005
		119.9	0.025	0.036	0.061	0.057	0.076	0.097	0.050	0.128	0.008	-0.011	0.018
		59.9	-0.011	0.224	0.328	0.335	0.482	0.961	0.322	1.142	0.014	0.021	0.022
		29.9	0.027	0.229	0.484	0.520	1.317	4.545	0.502	6.676	-0.001	0.019	0.000
		15.0	0.044	0.085	0.007	0.138	0.690	5.886	0.159	19.908	0.018	0.067	-0.020
Dynamic Means, 35 Hz Filtered	**54**	**218.852**	1.63	0.009	0.009	0.015	0.016	0.015	0.011	0.019	0.005	-0.001	0.008
	54	**119.278**	1.74	0.090	0.110	0.121	0.140	0.165	0.111	0.219	0.049	0.030	0.065
	54	**59.571**	1.78	0.502	0.648	0.666	0.887	1.557	0.663	1.832	0.212	0.238	0.254
	54	**29.847**	1.99	1.104	1.422	1.539	2.485	6.473	1.481	9.513	0.739	0.736	0.792
	54	**15.116**	1.98	1.917	1.763	2.223	2.790	7.490	2.013	26.910	1.493	0.840	2.082
Difference (35 Hz Dynamic - Static)		***220.0***	0.078	-0.001	0.000	0.005	0.006	-0.001	0.001	0.009	-0.005	-0.012	-0.002
		119.9	0.025	0.039	0.052	0.061	0.077	0.095	0.053	0.129	0.009	-0.008	0.015
		59.9	-0.011	0.225	0.329	0.333	0.490	0.969	0.325	1.138	0.012	0.007	0.024
		29.9	0.027	0.215	0.483	0.519	1.313	4.560	0.503	6.680	-0.001	0.025	0.002
		15.0	0.044	0.068	0.023	0.123	0.659	5.865	0.185	19.906	0.023	0.039	-0.008

Car passenger-side rearview mirror static analog illuminance data average at 15 m was 7.0085 lux, which is comparable to the digital average as reported in Table 63, 7.004 lux.

Table 64. *Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Left Curve 400 m Radius of Curvature, at 54 mph, Lexus NX300 Lower Beams*

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**218.552**	1.75	0.010	0.011	0.010	0.011	0.018	0.010	0.010	0.010	0.014	0.010
	Static	**119.003**	1.83	0.087	0.090	0.100	0.108	0.118	0.098	0.140	0.060	0.061	0.069
	Static	**59.102**	1.85	0.280	0.310	0.328	0.370	0.515	0.318	0.570	0.200	0.211	0.240
	Static	**29.313**	2.02	0.938	0.953	1.010	1.190	1.789	1.012	2.620	0.738	0.761	0.832
	Static	**14.649**	2.02	1.922	1.770	2.220	2.300	2.238	1.985	10.781	1.510	0.820	2.210
Dynamic Means, Unfiltered	**54**	**218.507**	1.77	0.015	0.024	0.013	0.024	0.027	0.038	0.023	0.011	0.020	0.012
	54	**118.899**	1.73	0.107	0.121	0.128	0.141	0.142	0.128	0.212	0.050	0.055	0.079
	54	**59.067**	1.85	0.489	0.633	0.647	0.852	1.575	0.652	1.673	0.222	0.215	0.272
	54	**29.278**	1.97	1.074	1.309	1.440	2.104	5.326	1.369	7.426	0.734	0.726	0.801
	54	**14.559**	1.99	1.975	1.868	2.325	2.617	5.674	2.117	23.342	1.585	0.886	2.188
Difference (Dynamic - Static)		***220.0***	0.021	0.005	0.013	0.003	0.013	0.009	0.028	0.013	0.001	0.006	0.002
		119.9	-0.098	0.020	0.031	0.028	0.033	0.024	0.030	0.072	-0.010	-0.006	0.010
		59.9	0.001	0.209	0.323	0.319	0.482	1.060	0.334	1.103	0.022	0.004	0.032
		29.9	-0.050	0.136	0.356	0.430	0.914	3.537	0.357	4.806	-0.004	-0.035	-0.031
		15.0	-0.031	0.053	0.098	0.105	0.317	3.436	0.132	12.561	0.075	0.066	-0.022
Dynamic Means, 35 Hz Filtered	**54**	**218.507**	1.77	0.013	0.022	0.015	0.023	0.030	0.026	0.024	0.008	0.000	0.009
	54	**118.899**	1.73	0.108	0.123	0.133	0.144	0.150	0.134	0.214	0.057	0.048	0.081
	54	**59.067**	1.85	0.497	0.632	0.644	0.854	1.569	0.644	1.667	0.220	0.229	0.271
	54	**29.278**	1.97	1.079	1.311	1.438	2.119	5.350	1.366	7.430	0.737	0.716	0.801
	54	**14.559**	1.99	1.991	1.859	2.309	2.634	5.664	2.102	23.309	1.594	0.859	2.200
Difference (35 Hz Dynamic - Static)		***220.0***	0.021	0.003	0.011	0.005	0.012	0.012	0.016	0.014	-0.002	-0.014	-0.001
		119.9	-0.098	0.021	0.033	0.033	0.036	0.032	0.036	0.074	-0.003	-0.013	0.012
		59.9	0.001	0.217	0.322	0.316	0.484	1.054	0.326	1.097	0.020	0.018	0.031
		29.9	-0.050	0.141	0.358	0.428	0.929	3.561	0.354	4.810	-0.001	-0.045	-0.031
		15.0	-0.031	0.069	0.089	0.089	0.334	3.426	0.117	12.528	0.084	0.039	-0.010

Table 65. *Illuminance and Pitch Values Recorded with Vehicle Stationary Versus Dynamic - Straight, at 69 mph, Lexus NX300 Lower Beams*

	Speed (mph)	Distance (m)	Pitch (deg)	Cycle Eye Pt (RH1) (lux)	Cycle Left Mirror (RH2) (lux)	Cycle Right Mirror (RH3) (lux)	Car Eye Pt (RH4) (lux)	Car Driver-Side Mirror (RH5) (lux)	Car Inside Mirror (RH6) (lux)	Car Passenger-Side Mirror (RH7) (lux)	Truck Eye Pt (RH8) (lux)	Truck Driver-Side Mirror (RH9) (lux)	Truck Passenger-Side Mirror (RH10) (lux)
Static Means	**Static**	**219.994**	1.95	0.079	0.081	0.091	0.097	0.093	0.087	0.130	0.050	0.050	0.070
	Static	**119.885**	1.95	0.140	0.148	0.166	0.180	0.174	0.158	0.270	0.080	0.087	0.120
	Static	**60.041**	1.89	0.273	0.299	0.320	0.370	0.536	0.312	0.598	0.190	0.226	0.240
	Static	**30.063**	1.96	0.951	1.082	1.071	1.250	2.785	1.093	2.670	0.770	0.741	0.810
	Static	**15.319**	1.97	1.812	2.004	2.140	2.266	2.875	1.998	8.679	1.590	1.291	2.427
Dynamic Means, Unfiltered	**69**	**219.897**	1.94	0.058	0.059	0.059	0.058	0.056	0.046	0.077	0.028	0.039	0.046
	69	**119.846**	2.00	0.175	0.179	0.186	0.210	0.194	0.181	0.330	0.088	0.103	0.131
	69	**59.886**	1.93	0.286	0.320	0.336	0.393	0.561	0.335	0.650	0.181	0.244	0.252
	69	**29.936**	1.97	0.950	1.065	1.017	1.212	2.667	1.052	2.493	0.741	0.748	0.765
	69	**15.222**	2.00	1.759	1.960	2.151	2.274	2.990	2.003	8.455	1.630	1.242	2.339
Difference (Dynamic - Static)		***220.0***	-0.009	-0.021	-0.022	-0.032	-0.039	-0.037	-0.041	-0.053	-0.022	-0.011	-0.024
		119.9	0.051	0.035	0.031	0.020	0.030	0.020	0.023	0.060	0.008	0.016	0.011
		59.9	0.043	0.013	0.021	0.016	0.023	0.025	0.023	0.052	-0.009	0.018	0.012
		29.9	0.009	-0.001	-0.017	-0.054	-0.038	-0.118	-0.041	-0.177	-0.029	0.007	-0.045
		15.0	0.029	-0.053	-0.044	0.011	0.008	0.115	0.005	-0.224	0.040	-0.049	-0.088
Dynamic Means, 35 Hz Filtered	**69**	**219.897**	1.94	0.056	0.056	0.059	0.062	0.062	0.058	0.076	0.032	0.035	0.048
	69	**119.846**	2.00	0.164	0.173	0.192	0.214	0.207	0.187	0.327	0.087	0.099	0.130
	69	**59.886**	1.93	0.293	0.323	0.341	0.386	0.557	0.333	0.654	0.186	0.244	0.251
	69	**29.936**	1.97	0.950	1.054	1.022	1.216	2.679	1.042	2.493	0.745	0.735	0.768
	69	**15.222**	2.00	1.781	1.958	2.154	2.281	2.979	1.982	8.460	1.628	1.232	2.354
Difference (35 Hz Dynamic - Static)		***220.0***	-0.009	-0.023	-0.025	-0.032	-0.035	-0.031	-0.029	-0.054	-0.018	-0.015	-0.022
		119.9	0.051	0.024	0.025	0.026	0.034	0.033	0.029	0.057	0.007	0.012	0.010
		59.9	0.043	0.020	0.024	0.021	0.016	0.021	0.021	0.056	-0.004	0.018	0.011
		29.9	0.009	-0.001	-0.028	-0.049	-0.034	-0.106	-0.051	-0.177	-0.025	-0.006	-0.042
		15.0	0.029	-0.031	-0.046	0.014	0.015	0.104	-0.016	-0.219	0.038	-0.059	-0.073

Receptor heads 5 (Car Driver-Side Rearview Mirror) and 7 (Car Passenger-Side Rearview Mirror) tended to show higher measured illuminance values and dynamic-static difference values than the other receptor heads. For the Ford Fusion, dynamic-static difference values were highest for left curve and straight scenarios and ranged from 1.2 to 2.2 lux. For the Lexus NX300, dynamic-static difference values were highest for left curve scenarios and ranged from 3.4 to 19.9 lux. The following figures illustrate static and dynamic illuminance values for the test fixture car passenger-side rearview mirror in the straight test scenario at the 15 m measurement distance.

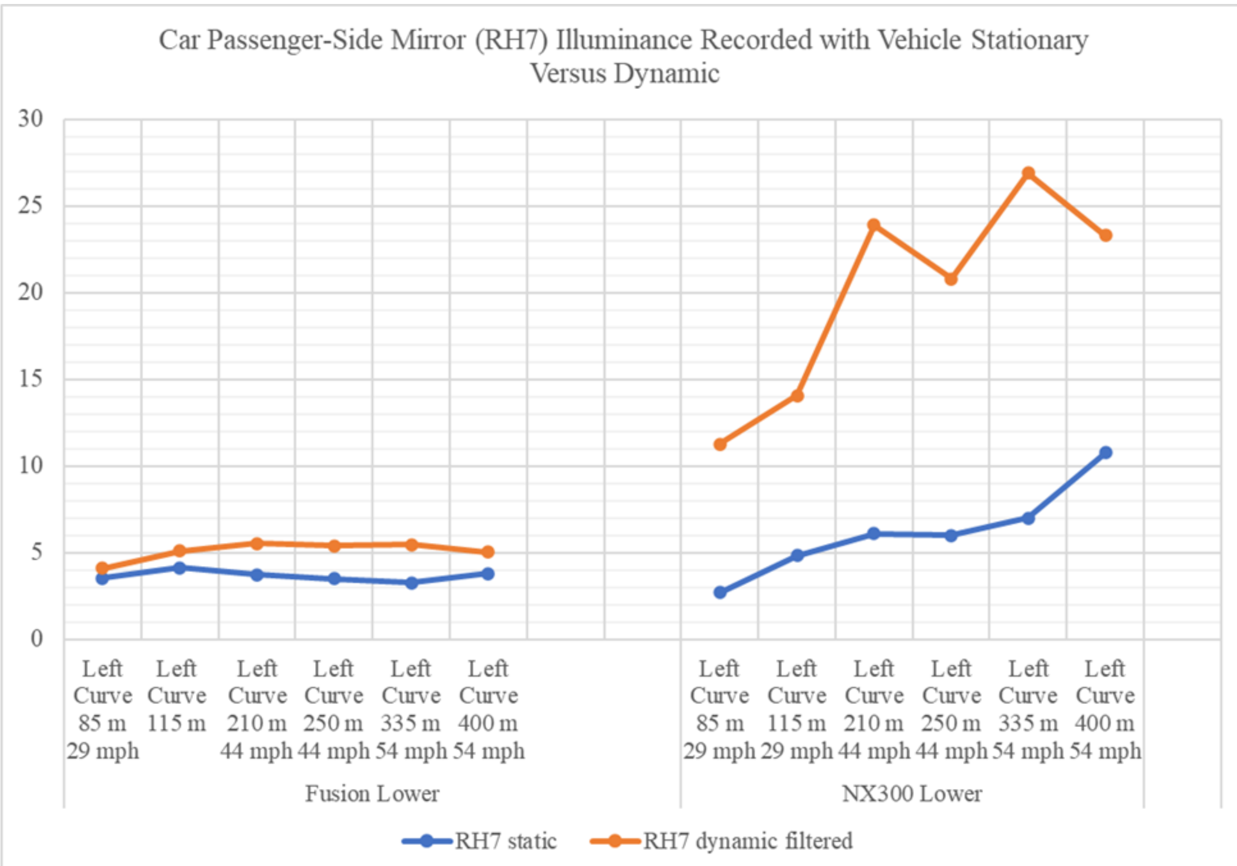

Figure 31. *Car Passenger-Side Mirror (RH7) Illuminance Recorded with Vehicle Stationary Versus Dynamic Left Curve Test Scenario at 15 m, Ford Fusion and Lexus NX300*

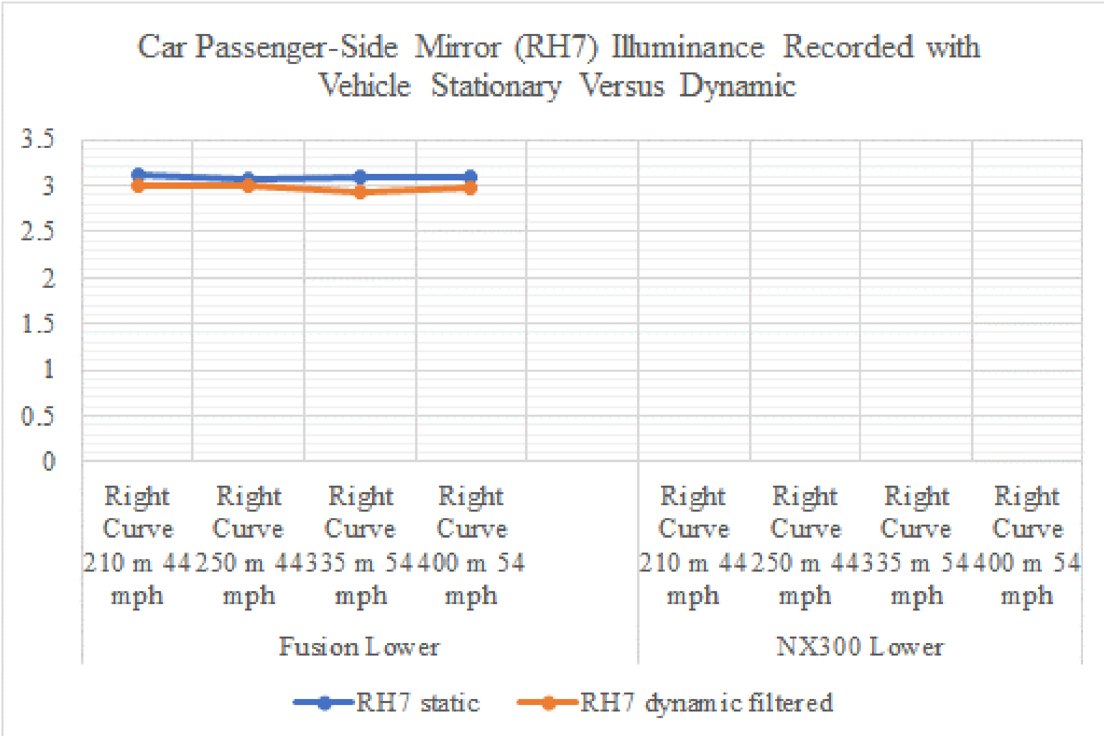

Figure 32. *Car Passenger-Side Mirror (RH7) Illuminance Recorded with Vehicle Stationary Versus Dynamic Right Curve Test Scenario at 15 m, Ford Fusion and Lexus NX300*

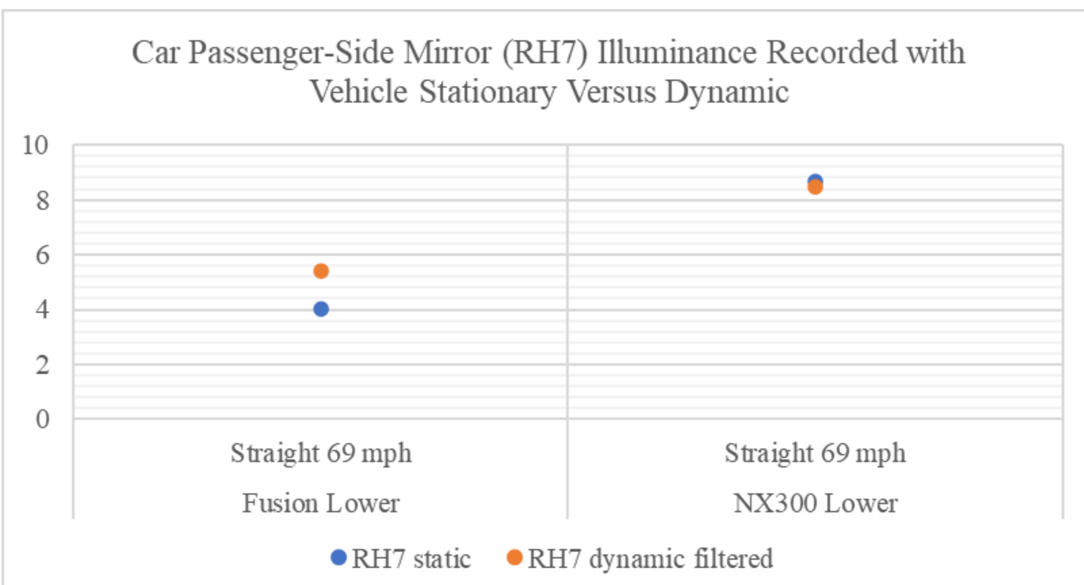

Figure 33. *Car Passenger-Side Mirror (RH7) Illuminance Recorded with Vehicle Stationary Versus Dynamic Straight Test Scenario at 15 m, Ford Fusion and Lexus NX300*

The magnitude of stationary versus dynamic illuminance measurements for the test fixture car passenger-side rearview mirror receptor head (RH7) varied by test vehicle and test scenario path curvature. The above figures show stationary and dynamic illuminance measurements for the Ford Fusion right curves to be very close, with all differences being 0.15 lux or less. The differences between stationary and dynamic measurements for the Ford Fusion in left curves was 2.2 lux or less, while for the Lexus NX300 the differences were as high as 19.9 lux. For straight scenarios, the stationary versus dynamic illuminance value difference was 0.2 lux for the Lexus NX300 and 1.4 lux for the Ford Fusion.

The reason for these higher illuminance values for receptor heads 5 and 7 was not able to be identified. A number of potential contributing factors were examined but no evidence of them having an effect was found. Analog illuminance values were confirmed to be comparable to digital illuminance values. Illuminance sensor calibration and test vehicle path accuracy were also ruled out as contributing factors. No measurement system or test procedure related factor was identified as a cause of or contributing factor to these stationary versus dynamic illuminance value differences. Test vehicle related contributing factors are possible but not known. Setting aside the values from receptor heads 5 and 7, difference values for other measurement points were consistently approximately 0.5 lux or less, with most being below 0.2 lux. Based on these low difference values, it is believed that dynamically influenced variation was not a major contributor to variability in the test based on examination of measured illuminance values.

Examination of results for the difference between dynamic filtered illuminance data and stationary illuminance measurements at the specified measurement distances indicates that dynamically-influenced variation was not a major contributor to variability in the test. Pitch was found to have a major influence on illuminance measurements; however, the sources of pitch variance were primarily static in nature (resulting from waviness in the track pavement) and not dynamic (acceleration, or dynamic oscillations).

6.2.3 Assessment of the Consistency of Dynamic Test Scenario Vehicle Pitch Angle and Illuminance Values

While stationary and 5 mph test trials were not performed with the Volvo XC90 as they were with the other two test vehicles, data from repeatability assessment test trials with the XC90 vehicle can be used to demonstrate the consistency of test vehicle pitch angle and illuminance data. An assessment of test procedure repeatability [8] was conducted in which the Volvo XC90 test vehicle was subjected to the full NHTSA test procedure once each night for 10 nights, generating 10 datasets. All test trials were run at a vehicle speed corresponding to the middle of the specified speed range for each test scenario. Therefore, the pitch and illuminance results shown below are not pitch values occurring at specific distances (as for stationary measurements), but instead are the maximum pitch values occurring within each of the measurement distance sub-ranges.

Tables 66 through 90 present NHTSA test procedure test repeatability test results for the Volvo XC90 in lower beam mode. The tables contain the maximum illuminance and pitch values, as well as corresponding descriptive statistics for vehicle pitch. Mean Relative Pitch is also presented, where relative pitch is calculated as the difference between Pitch Maximum (for the measurement distance sub-range), as well as average pitch (over the entire measurement distance). A separate table is provided for each measurement distance sub-range for each test scenario. As stated previously, the vehicle pitch channel was not accurately zero-calibrated. As such, values for maximum and average pitch for the Volvo XC90 test vehicle are subject to slight inaccuracy.

Table 66. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Straight at 65 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 220 - 120 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.0839	0.0905	0.0774	1.3100	1.2052	0.1048
	2	0.0847	0.0805	0.0564	1.3100	1.2028	0.1072
	3	0.0796	0.0857	0.0662	1.3200	1.2170	0.1030
	4	0.0713	0.0772	0.0522	1.3600	1.2287	0.1313
	5	0.0745	0.0865	0.0634	1.2800	1.1739	0.1061
	6	0.0777	0.0865	0.0614	1.2900	1.1640	0.1260
	7	0.0717	0.0745	0.0554	1.3200	1.1974	0.1226
	8	0.0794	0.0718	0.0559	1.3000	1.1729	0.1271
	9	0.0817	0.0884	0.0679	1.3100	1.1890	0.1210
	10	0.0815	0.0686	0.0581	1.2500	1.1510	0.0990
Mean		0.0786	0.0810	0.0614	1.3050	1.1902	0.1148
StdDev		0.0048	0.0076	0.0076	0.0288	0.0245	0.0119
Min		0.0713	0.0686	0.0522	1.2500	1.1510	0.0990
Max		0.0847	0.0905	0.0774	1.3600	1.2287	0.1313

Table 67. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Straight at 65 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 119.9 - 60 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** **(**Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)**)** **(degrees)**
	1	0.2164	0.1886	0.2027	1.3100	1.2052	0.1048
	2	0.2117	0.2197	0.2007	1.3100	1.2028	0.1072
	3	0.2540	0.2111	0.2146	1.3200	1.2170	0.1030
	4	0.2003	0.1802	0.2043	1.3200	1.2287	0.0913
	5	0.2224	0.2220	0.2417	1.3300	1.1739	0.1561
	6	0.2207	0.2021	0.2187	1.2800	1.1640	0.1160
	7	0.2126	0.2032	0.2099	1.3100	1.1974	0.1126
	8	0.2070	0.1967	0.2078	1.2700	1.1729	0.0971
	9	0.2263	0.2285	0.2140	1.3000	1.1890	0.1110
	10	0.2062	0.1941	0.2174	1.2700	1.1510	0.1190
Mean		0.2178	0.2046	0.2132	1.3020	1.1902	0.1118
StdDev		0.0150	0.0156	0.0118	0.0215	0.0245	0.0177
Min		0.2003	0.1802	0.2007	1.2700	1.1510	0.0913
Max		0.2540	0.2285	0.2417	1.3300	1.2287	0.1561

Table 68. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Straight at 65 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 59.9 - 30 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.6612	0.6101	0.8944	1.3000	1.2052	0.0948
	2	0.6966	0.6223	0.9296	1.2900	1.2028	0.0872
	3	0.7458	0.6724	0.9829	1.2800	1.2170	0.0630
	4	0.6696	0.6189	0.9084	1.3000	1.2287	0.0713
	5	0.7578	0.6904	1.0446	1.2400	1.1739	0.0661
	6	0.7183	0.6732	0.9823	1.2500	1.1640	0.0860
	7	0.6881	0.6271	0.9345	1.2300	1.1974	0.0326
	8	0.6906	0.6289	0.9351	1.2700	1.1729	0.0971
	9	0.7159	0.6450	0.9659	1.2500	1.1890	0.0610
	10	0.6864	0.6292	0.9558	1.2200	1.1510	0.0690
Mean		0.7030	0.6417	0.9534	1.2630	1.1902	0.0728
StdDev		0.0312	0.0274	0.0434	0.0291	0.0245	0.0193
Min		0.6612	0.6101	0.8944	1.2200	1.1510	0.0326
Max		0.7578	0.6904	1.0446	1.3000	1.2287	0.0971

Table 69. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Straight at 65 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 29.9 - 15 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	2.0289	1.8674	1.4975	1.2400	1.2052	0.0348
	2	2.0849	1.9467	1.5481	1.3000	1.2028	0.0972
	3	2.1389	1.9467	1.6041	1.3000	1.2170	0.0830
	4	2.0344	1.8627	1.4906	1.3200	1.2287	0.0913
	5	2.2345	2.0505	1.6129	1.2600	1.1739	0.0861
	6	2.1589	2.0081	1.5958	1.2600	1.1640	0.0960
	7	2.0775	1.9306	1.5257	1.2400	1.1974	0.0426
	8	2.0986	1.9632	1.5525	1.2600	1.1729	0.0871
	9	2.1214	1.9585	1.5668	1.2700	1.1890	0.0810
	10	2.1124	2.0240	1.5753	1.2300	1.1510	0.0790
Mean		2.1090	1.9558	1.5569	1.2680	1.1902	0.0778
StdDev		0.0605	0.0612	0.0426	0.0297	0.0245	0.0215
Min		2.0289	1.8627	1.4906	1.2300	1.1510	0.0348
Max		2.2345	2.0505	1.6129	1.3200	1.2287	0.0972

Table 70. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Same Direction Straight at 65 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 100 - 60 m*

Descriptive Statistic	**Repetition**	**Truck Driver-Side Mirror (RH9) (lux)**	**Car Pass.-Side Mirror (RH7) (lux)**	**Cycle Right Mirror (RH3) (lux)**	**Cycle Left Mirror (RH2) (lux)**	**Car Inside Mirror (RH6) (lux)**	**Truck Pass.-Side Mirror (RH10) (lux)**	**Car Driver-Side Mirror (RH5) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.1742	0.2265	0.2036	0.1928	0.2076	0.1905	0.2142	1.3100	1.2134	0.0966
	2	0.1879	0.2443	0.2006	0.2237	0.2034	0.1933	0.2376	1.3100	1.2054	0.1046
	3	0.2047	0.2614	0.2249	0.2163	0.2268	0.2105	0.2372	1.3200	1.2168	0.1032
	4	0.1676	0.2212	0.1904	0.2311	0.1883	0.1884	0.2088	1.3200	1.2228	0.0972
	5	0.2033	0.2592	0.2264	0.1955	0.2236	0.2206	0.2338	1.3300	1.1800	0.1500
	6	0.1849	0.2475	0.2161	0.2124	0.2128	0.1998	0.2181	1.2800	1.1679	0.1121
	7	0.1898	0.2313	0.2022	0.1937	0.1994	0.1926	0.2104	1.3100	1.1830	0.1270
	8	0.1803	0.2318	0.1959	0.1982	0.2075	0.1882	0.2103	1.2700	1.1752	0.0948
	9	0.2134	0.2453	0.2041	0.2130	0.2371	0.2015	0.2484	1.3000	1.1894	0.1106
	10	0.1765	0.2277	0.1988	0.1959	0.2118	0.1932	0.2055	1.2700	1.1546	0.1154
Mean		0.1883	0.2396	0.2063	0.2073	0.2119	0.1979	0.2224	1.3020	1.1909	0.1111
StdDev		0.0148	0.0140	0.0121	0.0138	0.0142	0.0105	0.0153	0.0215	0.0228	0.0169
Min		0.1676	0.2212	0.1904	0.1928	0.1883	0.1882	0.2055	1.2700	1.1546	0.0948
Max		0.2134	0.2614	0.2264	0.2311	0.2371	0.2206	0.2484	1.3300	1.2228	0.1500

Table 71. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Same Direction Straight at 65 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 59.9 - 30 m*

Descriptive Statistic	**Repetition**	**Truck Driver-Side Mirror (RH9) (lux)**	**Car Pass.-Side Mirror (RH7) (lux)**	**Cycle Right Mirror (RH3) (lux)**	**Cycle Left Mirror (RH2) (lux)**	**Car Inside Mirror (RH6) (lux)**	**Truck Pass.-Side Mirror (RH10) (lux)**	**Car Driver-Side Mirror (RH5) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.7277	0.8773	0.6469	0.6375	0.6288	0.9714	0.6579	1.3000	1.2134	0.0866
	2	0.7495	0.9380	0.6674	0.6331	0.6614	0.9969	0.7065	1.2900	1.2054	0.0846
	3	0.8046	0.9690	0.7042	0.6693	0.7073	1.0606	0.7475	1.2800	1.2168	0.0632
	4	0.7055	0.8856	0.6467	0.6093	0.6132	0.9510	0.6627	1.3000	1.2228	0.0772
	5	0.8611	0.9981	0.7435	0.6959	0.7106	1.1131	0.7416	1.2400	1.1800	0.0600
	6	0.7971	0.9554	0.6999	0.6638	0.7012	1.0751	0.7193	1.2500	1.1679	0.0821
	7	0.7617	0.8820	0.6641	0.6234	0.6495	1.0332	0.6712	1.2300	1.1830	0.0470
	8	0.7503	0.8993	0.6677	0.6265	0.6455	1.0189	0.6894	1.2700	1.1752	0.0948
	9	0.7900	0.9327	0.6897	0.6624	0.6787	1.0536	0.7143	1.2500	1.1894	0.0606
	10	0.7671	0.9161	0.6689	0.6548	0.6510	1.0564	0.6996	1.2200	1.1546	0.0654
Mean		0.7715	0.9253	0.6799	0.6476	0.6647	1.0330	0.7010	1.2630	1.1909	0.0721
StdDev		0.0440	0.0406	0.0298	0.0261	0.0336	0.0494	0.0311	0.0291	0.0228	0.0151
Min		0.7055	0.8773	0.6467	0.6093	0.6132	0.9510	0.6579	1.2200	1.1546	0.0470
Max		0.8611	0.9981	0.7435	0.6959	0.7106	1.1131	0.7475	1.3000	1.2228	0.0948

Table 72. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Same Direction Straight at 65 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 29.9 - 15 m*

Descriptive Statistic	**Repetition**	**Truck Driver-Side Mirror (RH9) (lux)**	**Car Pass.-Side Mirror (RH7) (lux)**	**Cycle Right Mirror (RH3) (lux)**	**Cycle Left Mirror (RH2) (lux)**	**Car Inside Mirror (RH6) (lux)**	**Truck Pass.-Side Mirror (RH10) (lux)**	**Car Driver-Side Mirror (RH5) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	1.3818	2.8020	2.0299	1.7567	1.9039	2.3340	1.8805	1.2400	1.2134	0.0266
	2	1.4225	2.9685	2.0892	1.7936	1.9548	2.4511	1.9900	1.3000	1.2054	0.0946
	3	1.5010	3.0301	2.1462	1.8666	1.9644	2.5601	2.0225	1.3000	1.2168	0.0832
	4	1.3759	2.8490	2.0167	1.7714	1.8863	2.3576	1.9202	1.3200	1.2228	0.0972
	5	1.4768	3.1229	2.1820	1.9133	2.0336	2.6120	2.0751	1.2600	1.1800	0.0800
	6	1.4680	3.0239	2.1735	1.8648	2.0133	2.5324	2.0367	1.2600	1.1679	0.0921
	7	1.4157	2.8659	2.0910	1.8174	1.9059	2.3902	1.9460	1.2400	1.1830	0.0570
	8	1.4444	2.8723	2.0833	1.8672	1.9488	2.4440	1.9543	1.2600	1.1752	0.0848
	9	1.4899	2.9796	2.1075	1.8390	1.9661	2.4827	1.9616	1.2700	1.1894	0.0806
	10	1.4305	2.9359	2.1285	1.8727	1.9753	2.4293	1.9383	1.2300	1.1546	0.0754
Mean		1.4407	2.9450	2.1048	1.8363	1.9552	2.4593	1.9725	1.2680	1.1909	0.0771
StdDev		0.0433	0.0990	0.0550	0.0502	0.0471	0.0891	0.0587	0.0297	0.0228	0.0211
Min		1.3759	2.8020	2.0167	1.7567	1.8863	2.3340	1.8805	1.2300	1.1546	0.0266
Max		1.5010	3.1229	2.1820	1.9133	2.0336	2.6120	2.0751	1.3200	1.2228	0.0972

Table 73. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Left Curve 85 m Radius of Curvature at 27 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 59.9 - 30 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.4289	0.3729	0.3203	1.1600	1.0341	0.1259
	2	0.4544	0.3725	0.3390	1.1500	1.0353	0.1147
	3	0.4757	0.4031	0.3552	1.1400	1.0422	0.0978
	4	0.4185	0.3491	0.3183	1.1200	1.0467	0.0733
	5	0.5173	0.4497	0.4438	1.1300	1.0110	0.1190
	6	0.4614	0.3985	0.3536	1.1000	1.0098	0.0902
	7	0.4349	0.3703	0.3369	1.1300	1.0091	0.1209
	8	0.4361	0.3921	0.3460	1.1000	0.9984	0.1016
	9	0.4469	0.3946	0.3459	1.1000	0.9940	0.1060
	10	0.4299	0.3642	0.3318	1.1200	1.0256	0.0944
Mean		0.4504	0.3867	0.3491	1.1250	1.0206	0.1044
StdDev		0.0291	0.0280	0.0355	0.0212	0.0186	0.0163
Min		0.4185	0.3491	0.3183	1.1000	0.9940	0.0733
Max		0.5173	0.4497	0.4438	1.1600	1.0467	0.1259

Table 74. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Left Curve 85 m Radius of Curvature at 27 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 29.9 - 15 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	1.3736	1.2871	1.1060	1.2100	1.0341	0.1759
	2	1.4577	1.3566	1.1759	1.2200	1.0353	0.1847
	3	1.5710	1.4012	1.2259	1.2300	1.0422	0.1878
	4	1.3907	1.2840	1.1071	1.2300	1.0467	0.1833
	5	1.5804	1.4223	1.2364	1.1800	1.0110	0.1690
	6	1.5410	1.3794	1.2115	1.1700	1.0098	0.1602
	7	1.4526	1.3607	1.1652	1.1800	1.0091	0.1709
	8	1.4862	1.3788	1.1897	1.1800	0.9984	0.1816
	9	1.5071	1.3817	1.1805	1.1700	0.9940	0.1760
	10	1.4438	1.3668	1.1523	1.2100	1.0256	0.1844
Mean		1.4804	1.3619	1.1750	1.1980	1.0206	0.1774
StdDev		0.0705	0.0446	0.0446	0.0244	0.0186	0.0087
Min		1.3736	1.2840	1.1060	1.1700	0.9940	0.1602
Max		1.5804	1.4223	1.2364	1.2300	1.0467	0.1878

Table 75. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Left Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 150 - 120 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.0564	0.0571	0.0365	1.0300	1.0484	0.0184
	2	0.0471	0.0477	0.0341	1.0100	1.0513	0.0413
	3	0.0589	0.0633	0.0370	1.0300	1.0622	0.0322
	4	0.0545	0.0509	0.0314	1.0100	1.0702	0.0602
	5	0.0479	0.0571	0.0333	0.9900	1.0209	0.0309
	6	0.0565	0.0585	0.0386	0.9600	1.0136	0.0536
	7	0.0418	0.0667	0.0303	1.0000	1.0257	0.0257
	8	0.0452	0.0467	0.0320	0.9900	1.0328	0.0428
	9	0.0581	0.0635	0.0473	1.0100	1.0294	0.0194
	10	0.0556	0.0533	0.0321	1.0000	1.0238	0.0238
Mean		0.0522	0.0565	0.0353	1.0030	1.0378	0.0348
StdDev		0.0061	0.0068	0.0050	0.0206	0.0190	0.0143
Min		0.0418	0.0467	0.0303	0.9600	1.0136	0.0184
Max		0.0589	0.0667	0.0473	1.0300	1.0702	0.0602

Table 76. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Left Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 119.9 - 60 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.1574	0.1315	0.1133	1.0300	1.0484	0.0184
	2	0.1431	0.1324	0.1140	1.0100	1.0513	0.0413
	3	0.1587	0.1505	0.1323	1.0300	1.0622	0.0322
	4	0.1275	0.1450	0.1200	1.0100	1.0702	0.0602
	5	0.1586	0.1475	0.1301	0.9900	1.0209	0.0309
	6	0.1542	0.1478	0.1281	0.9600	1.0136	0.0536
	7	0.1570	0.1324	0.1172	1.0000	1.0257	0.0257
	8	0.1441	0.1358	0.1183	0.9900	1.0328	0.0428
	9	0.1520	0.1448	0.1196	1.0100	1.0294	0.0194
	10	0.1436	0.1368	0.1210	1.0000	1.0238	0.0238
Mean		0.1496	0.1404	0.1214	1.0030	1.0378	0.0348
StdDev		0.0100	0.0074	0.0066	0.0206	0.0190	0.0143
Min		0.1275	0.1315	0.1133	0.9600	1.0136	0.0184
Max		0.1587	0.1505	0.1323	1.0300	1.0702	0.0602

Table 77. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Left Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 59.9 - 30 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.5320	0.4950	0.5874	1.2400	1.0484	0.1916
	2	0.5646	0.5379	0.6122	1.2400	1.0513	0.1887
	3	0.6034	0.5684	0.6480	1.2600	1.0622	0.1978
	4	0.5339	0.5215	0.5750	1.2800	1.0702	0.2098
	5	0.6671	0.6582	0.7888	1.2100	1.0209	0.1891
	6	0.6013	0.5499	0.6558	1.2000	1.0136	0.1864
	7	0.5662	0.5371	0.6203	1.2100	1.0257	0.1843
	8	0.5635	0.5437	0.6228	1.2200	1.0328	0.1872
	9	0.5780	0.5581	0.6348	1.2100	1.0294	0.1806
	10	0.5639	0.5158	0.5993	1.2000	1.0238	0.1762
Mean		0.5774	0.5486	0.6345	1.2270	1.0378	0.1892
StdDev		0.0393	0.0440	0.0599	0.0271	0.0190	0.0093
Min		0.5320	0.4950	0.5750	1.2000	1.0136	0.1762
Max		0.6671	0.6582	0.7888	1.2800	1.0702	0.2098

Table 78. Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Left Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 29.9 - 15 m

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	1.8284	1.6695	1.3826	1.2300	1.0484	0.1816
	2	1.9250	1.7467	1.4164	1.2300	1.0513	0.1787
	3	2.0040	1.7824	1.4749	1.2500	1.0622	0.1878
	4	1.8392	1.6663	1.3478	1.2800	1.0702	0.2098
	5	2.0471	1.8057	1.4883	1.2100	1.0209	0.1891
	6	2.0109	1.7888	1.4725	1.2000	1.0136	0.1864
	7	1.9220	1.7542	1.4164	1.2100	1.0257	0.1843
	8	1.9476	1.7605	1.4310	1.2200	1.0328	0.1872
	9	1.9556	1.7803	1.4441	1.2100	1.0294	0.1806
	10	1.8975	1.7280	1.3917	1.2200	1.0238	0.1962
Mean		1.9377	1.7483	1.4265	1.2260	1.0378	0.1882
StdDev		0.0713	0.0479	0.0449	0.0237	0.0190	0.0091
Min		1.8284	1.6663	1.3478	1.2000	1.0136	0.1787
Max		2.0471	1.8057	1.4883	1.2800	1.0702	0.2098

Table 79. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Same Direction Left Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 100 - 60 m*

Descriptive Statistic	**Repetition**	**Truck Driver-Side Mirror (RH9) (lux)**	**Car Pass.-Side Mirror (RH7) (lux)**	**Cycle Right Mirror (RH3) (lux)**	**Cycle Left Mirror (RH2) (lux)**	**Car Inside Mirror (RH6) (lux)**	**Truck Pass.-Side Mirror (RH10) (lux)**	**Car Driver-Side Mirror (RH5) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.1535	0.1423	0.1290	0.1531	0.1538	0.1239	0.1671	1.3500	1.1058	0.2442
	2	0.1333	0.1489	0.1310	0.1467	0.1496	0.1349	0.1655	1.3500	1.1083	0.2417
	3	0.1425	0.1622	0.1318	0.1541	0.1423	0.1495	0.1616	1.3500	1.1214	0.2286
	4	0.1332	0.1468	0.1320	0.1428	0.1417	0.1169	0.1547	1.3600	1.1369	0.2231
	5	0.1443	0.1667	0.1408	0.1554	0.1596	0.1358	0.1634	1.3200	1.0796	0.2404
	6	0.1513	0.1605	0.1424	0.1529	0.1484	0.1376	0.1800	1.3300	1.0746	0.2554
	7	0.1437	0.1512	0.1304	0.1450	0.1405	0.1274	0.1632	1.3400	1.0822	0.2578
	8	0.1374	0.1469	0.1307	0.1370	0.1355	0.1315	0.1473	1.3300	1.0929	0.2371
	9	0.1513	0.1585	0.1386	0.1475	0.1573	0.1329	0.1755	1.3400	1.0881	0.2519
	10	0.1300	0.1562	0.1310	0.1471	0.1369	0.1274	0.1572	1.3400	1.0843	0.2557
Mean		0.1420	0.1540	0.1338	0.1482	0.1466	0.1318	0.1636	1.3410	1.0974	0.2436
StdDev		0.0084	0.0079	0.0049	0.0058	0.0085	0.0088	0.0095	0.0120	0.0202	0.0118
Min		0.1300	0.1423	0.1290	0.1370	0.1355	0.1169	0.1473	1.3200	1.0746	0.2231
Max		0.1535	0.1667	0.1424	0.1554	0.1596	0.1495	0.1800	1.3600	1.1369	0.2578

Table 80. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Same Direction Left Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 59.9 - 30 m*

Descriptive Statistic	**Repetition**	**Truck Driver-Side Mirror (RH9) (lux)**	**Car Pass.-Side Mirror (RH7) (lux)**	**Cycle Right Mirror (RH3) (lux)**	**Cycle Left Mirror (RH2) (lux)**	**Car Inside Mirror (RH6) (lux)**	**Truck Pass.-Side Mirror (RH10) (lux)**	**Car Driver-Side Mirror (RH5) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.4660	0.6635	0.5281	0.5022	0.5065	0.6139	0.5971	1.2400	1.1058	0.1342
	2	0.4669	0.6998	0.5623	0.5332	0.5517	0.6332	0.6263	1.2400	1.1083	0.1317
	3	0.5039	0.7540	0.5968	0.5841	0.5842	0.6686	0.6667	1.2600	1.1214	0.1386
	4	0.4509	0.6737	0.5385	0.4897	0.5250	0.6130	0.5892	1.2800	1.1369	0.1431
	5	0.5879	0.8131	0.6663	0.6351	0.6535	0.7696	0.7005	1.2100	1.0796	0.1304
	6	0.4663	0.7569	0.5860	0.5794	0.5701	0.6691	0.6375	1.2000	1.0746	0.1254
	7	0.4748	0.6922	0.5571	0.5225	0.5580	0.6447	0.6095	1.2100	1.0822	0.1278
	8	0.5054	0.6818	0.5473	0.5369	0.5301	0.6411	0.6190	1.2200	1.0929	0.1271
	9	0.4836	0.7027	0.5687	0.5493	0.5682	0.6599	0.5994	1.2100	1.0881	0.1219
	10	0.4523	0.6854	0.5327	0.5261	0.5366	0.6359	0.5958	1.2000	1.0843	0.1157
Mean		0.4858	0.7123	0.5684	0.5458	0.5584	0.6549	0.6241	1.2270	1.0974	0.1296
StdDev		0.0404	0.0472	0.0410	0.0432	0.0409	0.0449	0.0356	0.0271	0.0202	0.0080
Min		0.4509	0.6635	0.5281	0.4897	0.5065	0.6130	0.5892	1.2000	1.0746	0.1157
Max		0.5879	0.8131	0.6663	0.6351	0.6535	0.7696	0.7005	1.2800	1.1369	0.1431

Table 81. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Same Direction Left Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 29.9 - 15 m*

Descriptive Statistic	**Repetition**	**Truck Driver-Side Mirror (RH9) (lux)**	**Car Pass.-Side Mirror (RH7) (lux)**	**Cycle Right Mirror (RH3) (lux)**	**Cycle Left Mirror (RH2) (lux)**	**Car Inside Mirror (RH6) (lux)**	**Truck Pass.-Side Mirror (RH10) (lux)**	**Car Driver-Side Mirror (RH5) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	1.2061	2.6178	1.7898	1.5564	1.6755	1.9502	1.8555	1.2300	1.1058	0.1242
	2	1.2466	2.7851	1.8783	1.6064	1.7620	2.0717	1.9436	1.2300	1.1083	0.1217
	3	1.3208	2.9569	1.9335	1.6646	1.7933	2.1832	2.0235	1.2500	1.1214	0.1286
	4	1.1901	2.6469	1.7767	1.5449	1.6700	1.9746	1.8502	1.2800	1.1369	0.1431
	5	1.3113	3.0147	1.9613	1.7225	1.8204	2.2062	2.0497	1.2100	1.0796	0.1304
	6	1.2861	2.9197	1.9229	1.6944	1.8211	2.1571	2.0111	1.2000	1.0746	0.1254
	7	1.2629	2.7734	1.8659	1.6045	1.7321	2.0592	1.9127	1.2100	1.0822	0.1278
	8	1.2381	2.7550	1.8871	1.6255	1.7558	2.0591	1.8930	1.2200	1.0929	0.1271
	9	1.2510	2.8194	1.8799	1.6450	1.7819	2.0879	1.9358	1.2100	1.0881	0.1219
	10	1.2116	2.6870	1.8162	1.5878	1.7496	2.0186	1.8722	1.2200	1.0843	0.1357
Mean		1.2525	2.7976	1.8712	1.6252	1.7562	2.0768	1.9347	1.2260	1.0974	0.1286
StdDev		0.0439	0.1324	0.0611	0.0573	0.0527	0.0851	0.0719	0.0237	0.0202	0.0066
Min		1.1901	2.6178	1.7767	1.5449	1.6700	1.9502	1.8502	1.2000	1.0746	0.1217
Max		1.3208	3.0147	1.9613	1.7225	1.8211	2.2062	2.0497	1.2800	1.1369	0.1431

Table 82. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Right Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 50 - 30 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	4.2510	1.0675	1.3199	1.1700	1.0573	0.1127
	2	4.3778	1.1769	1.2635	1.2200	1.0956	0.1244
	3	4.3198	1.1548	1.2526	1.2100	1.0665	0.1435
	4	4.6592	1.3263	1.2832	1.1800	1.0636	0.1164
	5	5.4189	1.7226	1.3128	1.1500	1.0190	0.1310
	6	5.2271	1.5926	1.3329	1.1900	1.0318	0.1582
	7	6.3615	2.2153	1.4435	1.1500	1.0253	0.1247
	8	3.1957	0.8230	1.2628	1.1600	1.0324	0.1276
	9	4.1388	1.0883	1.2982	1.1500	1.0475	0.1025
	10	3.2442	0.8314	1.3128	1.1500	1.0464	0.1036
Mean		4.5194	1.2999	1.3082	1.1730	1.0485	0.1245
StdDev		0.9648	0.4327	0.0547	0.0263	0.0231	0.0172
Min		3.1957	0.8230	1.2526	1.1500	1.0190	0.1025
Max		6.3615	2.2153	1.4435	1.2200	1.0956	0.1582

Table 83. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Right Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 29.9 - 15 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	2.2759	2.3415	1.5723	1.1400	1.0573	0.0827
	2	2.2133	2.3166	1.5431	1.1900	1.0956	0.0944
	3	2.1969	2.3135	1.5314	1.1300	1.0665	0.0635
	4	2.2492	2.3582	1.5647	1.1300	1.0636	0.0664
	5	2.2610	2.3248	1.5844	1.1000	1.0190	0.0810
	6	2.2948	2.4009	1.6015	1.0800	1.0318	0.0482
	7	2.4332	2.5329	1.6771	1.1100	1.0253	0.0847
	8	2.2695	2.3888	1.5808	1.1100	1.0324	0.0776
	9	2.2493	2.3926	1.5657	1.1300	1.0475	0.0825
	10	2.3022	2.4061	1.5906	1.1300	1.0464	0.0836
Mean		2.2745	2.3776	1.5812	1.1250	1.0485	0.0765
StdDev		0.0646	0.0651	0.0398	0.0292	0.0231	0.0134
Min		2.1969	2.3135	1.5314	1.0800	1.0190	0.0482
Max		2.4332	2.5329	1.6771	1.1900	1.0956	0.0944

Table 84. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Left Curve 335 m Radius of Curvature at 52 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 220 - 120 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.0600	0.0611	0.0378	1.3200	1.0932	0.2268
	2	0.0565	0.0550	0.0348	1.2900	1.0906	0.1994
	3	0.0576	0.0603	0.0434	1.2400	1.0633	0.1767
	4	0.0467	0.0541	0.0365	1.2700	1.0867	0.1833
	5	0.0566	0.0498	0.0377	1.2300	1.0588	0.1712
	6	0.0487	0.0559	0.0406	1.2000	1.0432	0.1568
	7	0.0499	0.0564	0.0395	1.2600	1.0549	0.2051
	8	0.0462	0.0504	0.0322	1.2300	1.0466	0.1834
	9	0.0601	0.0572	0.0406	1.2300	1.0526	0.1774
	10	0.0566	0.0611	0.0415	1.2600	1.0663	0.1937
Mean		0.0539	0.0561	0.0384	1.2530	1.0656	0.1874
StdDev		0.0054	0.0040	0.0034	0.0347	0.0183	0.0197
Min		0.0462	0.0498	0.0322	1.2000	1.0432	0.1568
Max		0.0601	0.0611	0.0434	1.3200	1.0932	0.2268

Table 85. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Left Curve 335 m Radius of Curvature at 52 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 119.9 - 60 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.1456	0.1439	0.1493	1.3500	1.0932	0.2568
	2	0.1615	0.1468	0.1512	1.3500	1.0906	0.2594
	3	0.1550	0.1522	0.1667	1.3600	1.0633	0.2967
	4	0.1484	0.1491	0.1485	1.3500	1.0867	0.2633
	5	0.1674	0.1618	0.1798	1.3500	1.0588	0.2912
	6	0.1621	0.1526	0.1667	1.3100	1.0432	0.2668
	7	0.1596	0.1633	0.1581	1.3100	1.0549	0.2551
	8	0.1550	0.1473	0.1576	1.3200	1.0466	0.2734
	9	0.1518	0.1405	0.1598	1.3200	1.0526	0.2674
	10	0.1473	0.1367	0.1512	1.3300	1.0663	0.2637
Mean		0.1554	0.1494	0.1589	1.3350	1.0656	0.2694
StdDev		0.0072	0.0085	0.0099	0.0190	0.0183	0.0141
Min		0.1456	0.1367	0.1485	1.3100	1.0432	0.2551
Max		0.1674	0.1633	0.1798	1.3600	1.0932	0.2967

Table 86. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Left Curve 335 m Radius of Curvature at 52 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 59.9 - 30 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	0.5930	0.5367	0.7088	1.2600	1.0932	0.1668
	2	0.6135	0.5933	0.7466	1.2700	1.0906	0.1794
	3	0.6427	0.5922	0.7782	1.2400	1.0633	0.1767
	4	0.5717	0.5551	0.7075	1.2500	1.0867	0.1633
	5	0.6879	0.6936	0.8962	1.2200	1.0588	0.1612
	6	0.6383	0.6229	0.7830	1.1900	1.0432	0.1468
	7	0.6211	0.6006	0.7576	1.2200	1.0549	0.1651
	8	0.5878	0.5697	0.7453	1.2100	1.0466	0.1634
	9	0.6253	0.5857	0.7533	1.2200	1.0526	0.1674
	10	0.5886	0.5682	0.7388	1.2300	1.0663	0.1637
Mean		0.6170	0.5918	0.7615	1.2310	1.0656	0.1654
StdDev		0.0342	0.0433	0.0534	0.0242	0.0183	0.0089
Min		0.5717	0.5367	0.7075	1.1900	1.0432	0.1468
Max		0.6879	0.6936	0.8962	1.2700	1.0932	0.1794

Table 87. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Left Curve 335 m Radius of Curvature at 52 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 29.9 - 15 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	1.9073	1.7389	1.4202	1.2500	1.0932	0.1568
	2	2.0295	1.8030	1.4931	1.2700	1.0906	0.1794
	3	2.0789	1.8382	1.5333	1.2400	1.0633	0.1767
	4	1.9111	1.7076	1.4210	1.2300	1.0867	0.1433
	5	2.1116	1.8807	1.5413	1.2100	1.0588	0.1512
	6	2.0792	1.8759	1.5337	1.1900	1.0432	0.1468
	7	2.0313	1.8123	1.4838	1.2200	1.0549	0.1651
	8	2.0495	1.8892	1.5091	1.2100	1.0466	0.1634
	9	2.0399	1.8307	1.4946	1.2100	1.0526	0.1574
	10	1.9813	1.7846	1.4639	1.2200	1.0663	0.1537
Mean		2.0220	1.8161	1.4894	1.2250	1.0656	0.1594
StdDev		0.0690	0.0603	0.0437	0.0232	0.0183	0.0119
Min		1.9073	1.7076	1.4202	1.1900	1.0432	0.1433
Max		2.1116	1.8892	1.5413	1.2700	1.0932	0.1794

Table 88. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Right Curve 335 m Radius of Curvature at 52 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 70 - 60 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	2.8524	1.2526	0.2492	1.1700	1.0272	0.1428
	2	2.7304	1.1897	0.2440	1.1800	1.0505	0.1295
	3	2.5607	1.1064	0.2449	1.1600	1.0160	0.1440
	4	2.8525	1.3195	0.2530	1.1600	1.0299	0.1301
	5	3.5101	1.9525	0.2539	1.1400	1.0136	0.1264
	6	3.0750	1.4762	0.2519	1.1200	1.0029	0.1171
	7	4.2736	2.5720	0.2700	1.1000	0.9750	0.1250
	8	2.0115	0.7423	0.2434	1.1200	0.9939	0.1261
	9	3.2380	1.6783	0.2636	1.1600	1.0269	0.1331
	10	3.0930	1.5287	0.2571	1.1500	1.0152	0.1348
Mean		3.0197	1.4818	0.2531	1.1460	1.0151	0.1309
StdDev		0.5996	0.5058	0.0086	0.0255	0.0210	0.0082
Min		2.0115	0.7423	0.2434	1.1000	0.9750	0.1171
Max		4.2736	2.5720	0.2700	1.1800	1.0505	0.1440

Table 89. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Right Curve 335 m Radius of Curvature at 52 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 59.9 - 30 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	1.7940	0.7025	1.1544	1.1600	1.0272	0.1328
	2	1.6848	0.6665	1.1150	1.1900	1.0505	0.1395
	3	1.4157	0.6851	1.1085	1.1400	1.0160	0.1240
	4	1.7730	0.6569	1.1281	1.1600	1.0299	0.1301
	5	2.3752	0.7205	1.1612	1.1500	1.0136	0.1364
	6	1.9198	0.6935	1.1669	1.1300	1.0029	0.1271
	7	3.2105	1.1425	1.2596	1.1100	0.9750	0.1350
	8	0.9706	0.6904	1.1124	1.1200	0.9939	0.1261
	9	2.0887	0.7004	1.1599	1.1600	1.0269	0.1331
	10	1.9974	0.6941	1.1605	1.1600	1.0152	0.1448
Mean		1.9230	0.7353	1.1527	1.1480	1.0151	0.1329
StdDev		0.5921	0.1442	0.0440	0.0235	0.0210	0.0064
Min		0.9706	0.6569	1.1085	1.1100	0.9750	0.1240
Max		3.2105	1.1425	1.2596	1.1900	1.0505	0.1448

Table 90. *Maximum Illuminance and Pitch Values from NHTSA Test Procedure Repeatability Data, Oncoming Right Curve 335 m Radius of Curvature at 52 mph, Volvo XC90 Lower Beams, Measurement Distance Sub-Range 29.9 - 15 m*

Descriptive Statistic	**Repetition**	**Car Eye Pt (RH4) (lux)**	**Cycle Eye Pt (RH1) (lux)**	**Truck Eye Pt (RH8) (lux)**	**Pitch Max over Measurement Distance Sub-range (degrees)**	**Pitch Average across Entire Measurement Distance Range (degrees)**	**Relative Pitch** (Difference between Pitch Maximum (sub-range) and Pitch Average (entire Measurement Distance Range)) **(degrees)**
	1	2.1561	2.1633	1.5035	1.1100	1.0272	0.0828
	2	2.0612	2.0777	1.4743	1.1600	1.0505	0.1095
	3	2.0537	2.0503	1.4581	1.1100	1.0160	0.0940
	4	2.1102	2.1038	1.4917	1.1300	1.0299	0.1001
	5	2.1305	2.1038	1.5102	1.1100	1.0136	0.0964
	6	2.1478	2.1322	1.5099	1.1000	1.0029	0.0971
	7	2.2703	2.2007	1.5807	1.0800	0.9750	0.1050
	8	2.1255	2.1550	1.5199	1.1000	0.9939	0.1061
	9	2.1554	2.1266	1.5197	1.1200	1.0269	0.0931
	10	2.1568	2.1661	1.5304	1.1100	1.0152	0.0948
Mean		2.1368	2.1279	1.5098	1.1130	1.0151	0.0979
StdDev		0.0602	0.0453	0.0333	0.0211	0.0210	0.0077
Min		2.0537	2.0503	1.4581	1.0800	0.9750	0.0828
Max		2.2703	2.2007	1.5807	1.1600	1.0505	0.1095

Mean Relative Pitch was 0.27 degrees or less for all Volvo test scenarios. Standard deviations of both average vehicle pitch and relative pitch were 0.025 degrees or less for all measurement distance sub-ranges of all test scenarios.

6.3 Verification of Test Procedure Compatibility With Different Light Source Types

The objective of this assessment was to verify whether the proposed NHTSA ADB test procedure produced accurate results with vehicle headlighting systems of different light source types. Vehicles having headlighting systems with different light source types were tested to see if there were any compatibility issues between the light source types and the proposed NHTSA ADB test procedure. Lamp source types tested included halogen (Ford Fusion) and two LED-based (Lexus NX300, Volvo XC90) headlighting systems.

The most important scenario to verify, due to its more extreme conditions, was the lower radius of curvature scenario at its higher speed. Thus, only the 85-meter radius left curve scenario with a measurement distance range of 15.0 to 59.9 meters was used for this analysis. As this assessment could be performed with test vehicles' headlighting systems in lower beam mode, stimulus lamps were not utilized with the NHTSA test fixture.

Illuminance data conformance to glare limit values was determined for each designated measurement distance sub-range by evaluating the maximum illuminance value with respect to the corresponding glare limit; if the maximum illuminance value was less than or equal to the associated glare limit then it met the requirement. If the maximum illuminance value was greater than the associated glare limit, then it did not meet the requirement for that measurement distance sub-range.

The following table shows the illuminance data results of the NHTSA test procedure for the three lower beam vehicles tested in the 85-meter left curve for the oncoming orientation. The maximum illuminance value presented in the tables is the highest measured value from any relevant receptor head.

Table 91. *NHTSA Test Procedure Results - Oncoming Left Curve 85 m Radius of Curvature, Lower Beam Mode*

Vehicle, Headlamp Type	Measurement Distance Sub-Range (m)	Glare Limit (lux)	Max. Illuminance (lux)	Glare Limit Met or Exceeded
Ford Fusion, Halogen	15-29.9	3.1	1.606	Met
	30-59.9	1.8	0.837	Met
Lexus NX300, LED	15-29.9	3.1	1.038	Met
	30-59.9	1.8	0.528	Met
Volvo XC90, LED	15-29.9	3.1	1.374	Met
	30-59.9	1.8	0.429	Met

The following figure illustrates data for a test scenario trial (oncoming left curve with 85-meter radius of curvature with the Ford Fusion lower beams at 29 mph) in which glare limits were met for each measure distance sub-range.

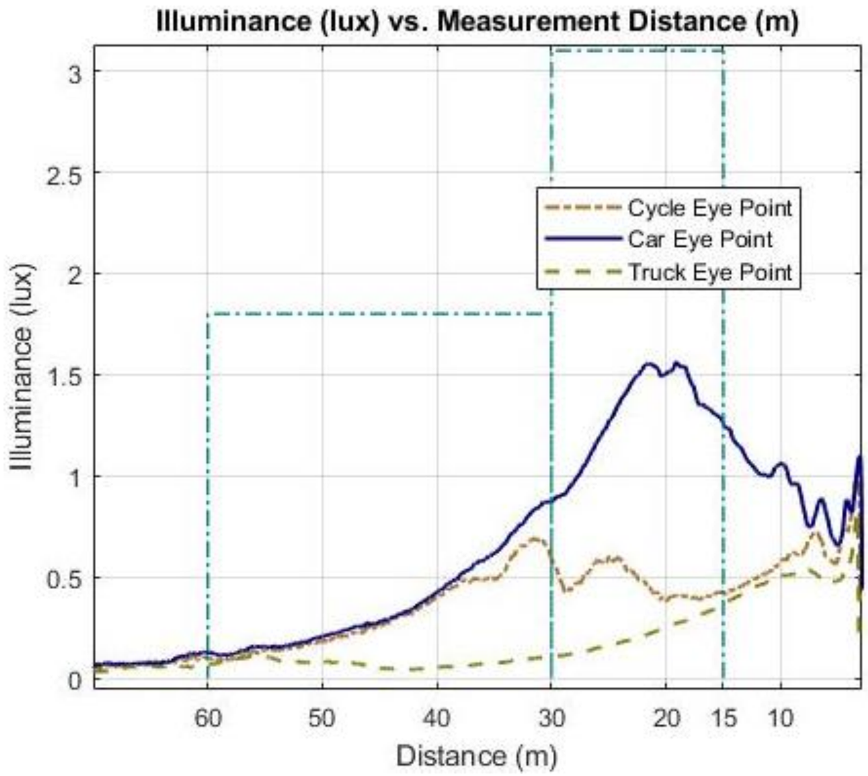

Figure 34. *Example of Test Trial in which All Glare Limits Were Met: Oncoming Left Curve 85 m Radius of Curvature, Lower Beam (Ford Fusion), at 29 mph (Fusion2_0006)*

The following table shows the illuminance data results of the NHTSA test procedure for the three lower beam vehicles tested in the 85-meter left curve for the same-direction orientation.

Table 92. *NHTSA Test Procedure Results - Same Direction Left Curve 85 m Radius of Curvature, Lower Beam Mode*

Vehicle, Headlamp Type	Measurement Distance Sub-Range (m)	Glare Limit (lux)	Max. Illuminance (lux)	Glare Limit Met or Exceeded
Ford Fusion, Halogen	15-29.9	18.9	4.067	Met
	30-59.9	18.9	1.066	Met
Lexus NX300, LED	15-29.9	18.9	11.080	Met
	30-59.9	18.9	2.337	Met
Volvo XC90, LED	15-29.9	18.9	2.175	Met
	30-59.9	18.9	0.490	Met

All three test vehicles with headlighting systems operating in lower beam met the glare limits at each measurement distance sub-range for the left curve scenario with 85-meter radius of curvature and a measurement distance range of 15.0 to 59.9 meters. Given that this test scenario with tight curve radius was considered to be a worst-case test scenario, the test vehicle's headlighting systems' ability to meet glare limits for this scenario are taken to indicate that they would also be able to meet glare limits in less challenging test scenarios. As such, it appears that the NHTSA test procedure worked as intended for each of the tested light source types.

6.4 Evaluation of Late-Model Vehicles' Lower Beam Performance With Respect To NHTSA-Proposed ADB Glare Limit Criteria

One objective of testing vehicles in lower beam mode was to evaluate current FMVSS-compliant vehicles' lower beam headlighting system performance against the glare limits as baseline results for the NHTSA ADB compliance test procedure. Test results from one test procedure repetition are shown for the Ford Fusion and Lexus NX300, while 10 test procedure repetitions taking from a test procedure repeatability assessment [8] are presented for the Volvo XC90. The following table shows the matrix of test trials. As shown in the table, both lower and upper speed conditions and all curve conditions were completed for comparison for the Ford Fusion, all of which were within the ranges indicated by the NHTSA compliance test procedure. A subset of these conditions, the higher speed conditions, were completed for the Lexus NX300.

Table 93. *Test Matrix, Lower Beam Vehicles Versus Glare Limits*

Trial	Curve Direction	Radius of Curvature (m)	Test Vehicle Speed (mph)	Maximum Measurement Distance (m)
1	Straight	NA	61	220
2	Straight	NA	69	220
3	Left	85	26	59.9
4	Left	85	29	59.9
5	Left	115	26	59.9
6	Left	115	29	59.9
7	Left	210	41	150
8	Left	210	44	150
9	Left	250	41	150
10	Left	250	44	150
11	Left	335	51	220
12	Left	335	54	220
13	Left	400	51	220
14	Left	400	54	220
15	Right	210	41	50
16	Right	210	44	50
17	Right	250	41	50
18	Right	250	44	50
19	Right	335	51	70
20	Right	335	54	70
21	Right	400	51	70
22	Right	400	54	70

6.4.1 *Ford Fusion Lower Beam - Test Scenario Outcomes*

Table 94 summarizes the NHTSA test procedure oncoming test scenario outcomes (i.e., test results) for the Ford Fusion. Passing results were obtained for all oncoming orientation test scenarios except the oncoming straight 69-mph test scenario. During data processing, this test trial was found to be invalid because the test vehicle was still accelerating to reach the target speed at the start of the measurement distance range, which resulted in a glare exceedance. Had this issue been identified during testing, the trial would have been re-run to obtain a valid trial and likely would have passed. As such, the Ford Fusion's headlighting system in lower beam mode has the ability to meet glare limits and achieve passing outcomes in all oncoming orientation NHTSA ADB test scenarios.

Table 94. *NHTSA Test Procedure Test Scenario Outcomes, Oncoming Scenarios, Ford Fusion Lower Beams*

Test Procedure	Orientation	Curve Direction	Radius of Curvature (m)	Speed (mph)	Test Scenario Outcome
NHTSA	Oncoming	Straight	0	61	Pass
NHTSA	Oncoming	Straight	0	69	Invalid*
NHTSA	Oncoming	Left	85	26	Pass
NHTSA	Oncoming	Left	85	29	Pass
NHTSA	Oncoming	Left	115	26	Pass
NHTSA	Oncoming	Left	115	29	Pass
NHTSA	Oncoming	Left	210	41	Pass
NHTSA	Oncoming	Left	210	44	Pass
NHTSA	Oncoming	Left	250	41	Pass
NHTSA	Oncoming	Left	250	44	Pass
NHTSA	Oncoming	Left	335	51	Pass
NHTSA	Oncoming	Left	335	54	Pass
NHTSA	Oncoming	Left	400	51	Pass
NHTSA	Oncoming	Left	400	54	Pass
NHTSA	Oncoming	Right	210	41	Pass
NHTSA	Oncoming	Right	210	44	Pass
NHTSA	Oncoming	Right	250	41	Pass
NHTSA	Oncoming	Right	250	44	Pass
NHTSA	Oncoming	Right	335	51	Pass
NHTSA	Oncoming	Right	335	54	Pass
NHTSA	Oncoming	Right	400	51	Pass
NHTSA	Oncoming	Right	400	54	Pass

*This was an invalid test trial since the vehicle was still accelerating to reach the target speed at the start of the measurement distance range, which resulted in a glare exceedance.

The following figures illustrate the details of the 'Invalid' test scenario outcome result. Figure 35 illustrates illuminance as a function of measurement distance and shows a glare exceedance at the start of the measurement range.

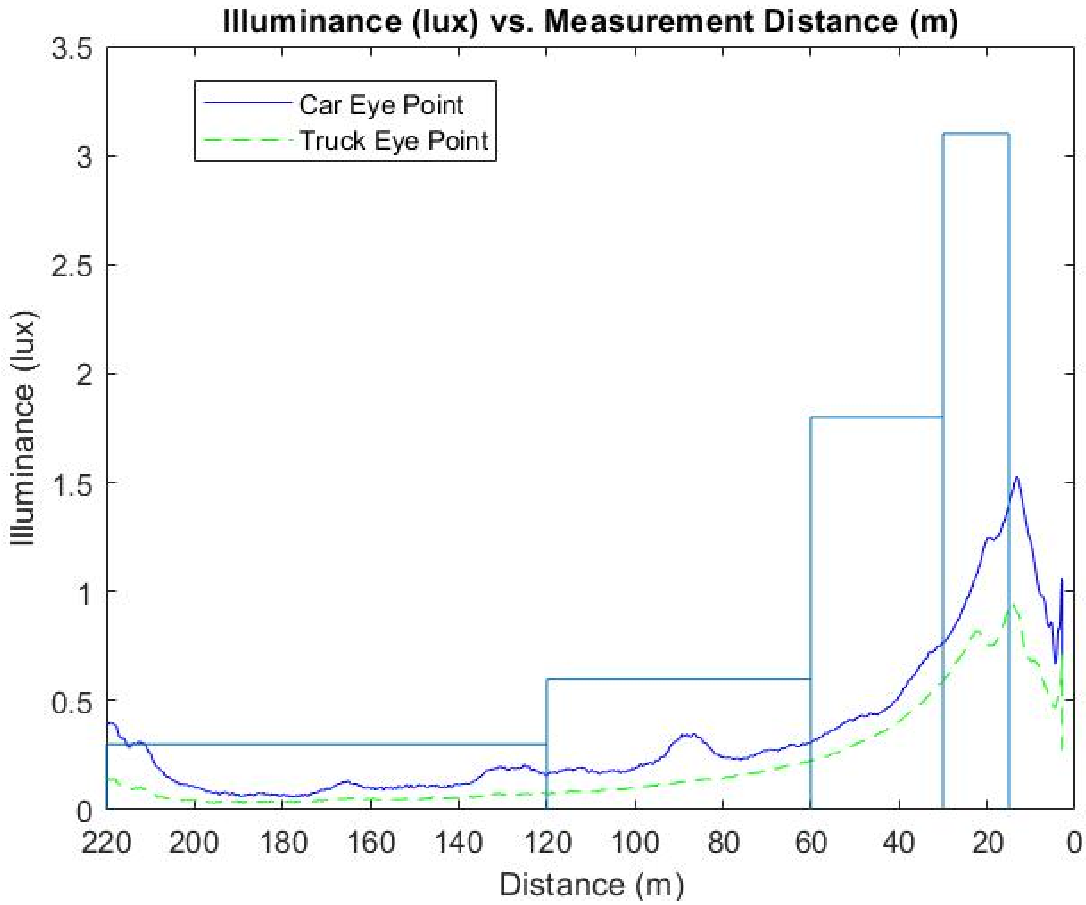

Figure 35. *NHTSA Test Procedure, Oncoming Scenarios, Ford Fusion Lower Beams (Fusion2_0030) - Illuminance for Full Measurement Distance Range*

Figure 36, which plots speed as a function of distance, shows that the test vehicle was still attempting to accelerate to 69 mph when it reached the start of the measurement distance range (220 m). Figure 37 illustrates vehicle pitch angle as a function of measurement distance and shows greater than 1 degree of positive pitch angle at the start of the measurement range.

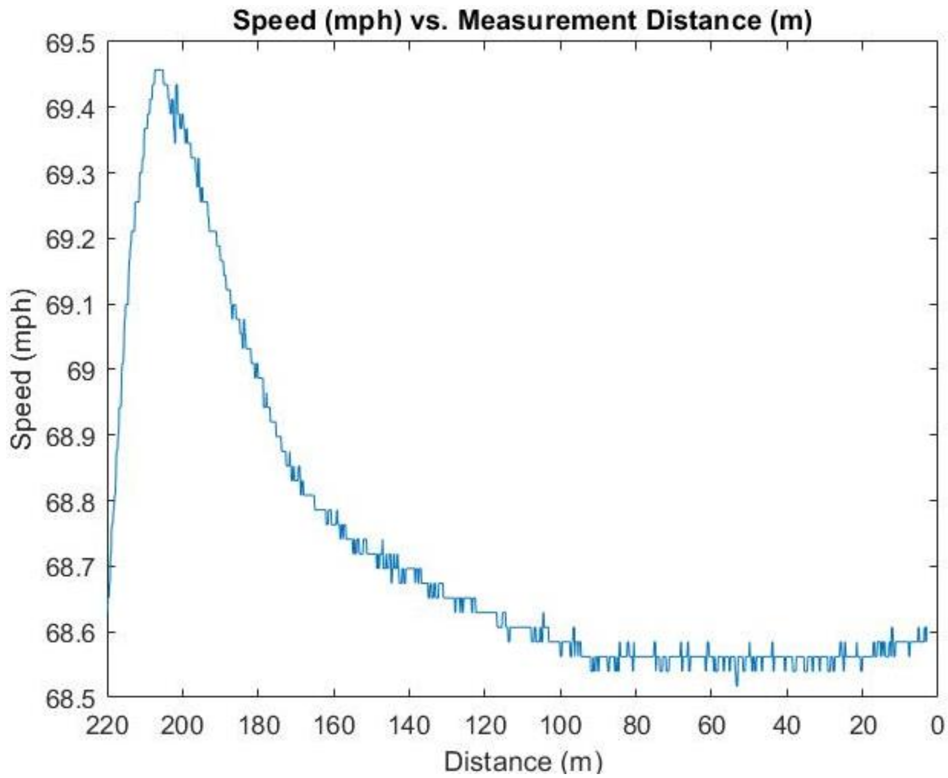

Figure 36. *NHTSA Test Procedure, Oncoming Scenarios, Ford Fusion Lower Beams (Fusion2_0030) – Speed Over Full Measurement Distance Range*

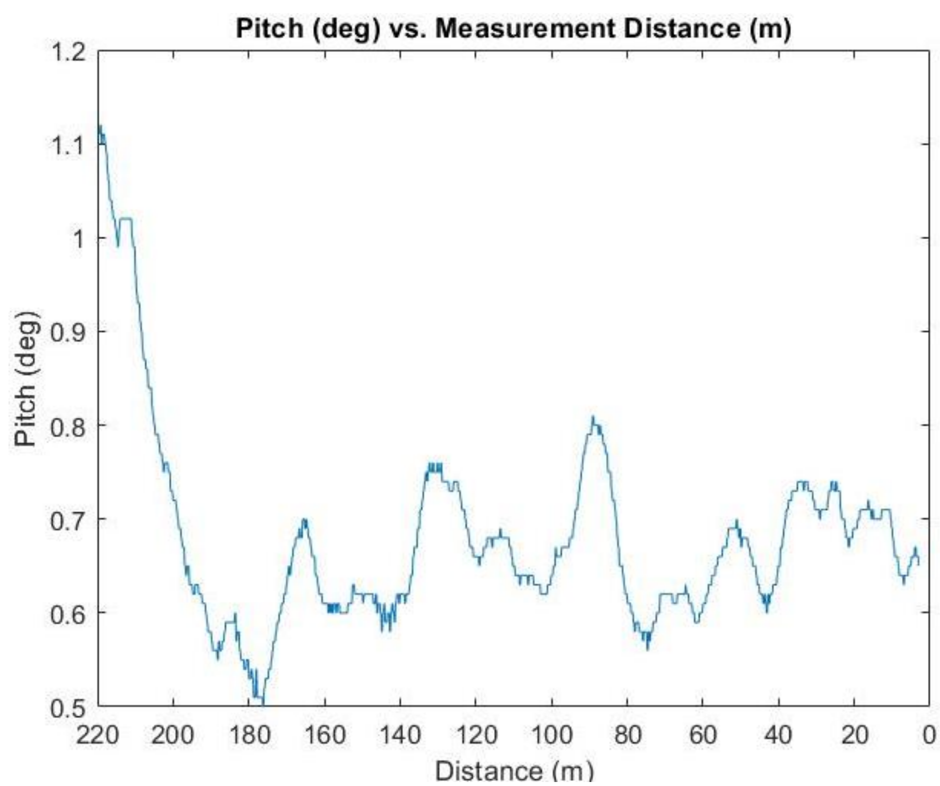

Figure 37. *NHTSA Test Procedure, Oncoming Scenarios, Ford Fusion Lower Beams (Fusion2_0030) – Pitch Over Full Measurement Distance Range*

The following table provides test scenario outcomes of the NHTSA test procedure for the same direction scenarios using the Ford Fusion in lower beam mode. As shown in Table 95, the Ford Fusion's headlighting system in lower beam mode met glare limits and achieved passing outcomes in all same direction test scenarios.

Table 95. *NHTSA Test Procedure Test Scenario Outcomes, Same Direction Scenarios, Ford Fusion Lower Beams*

Test Procedure	Orientation	Curve Direction	Radius of Curvature (m)	Speed (mph)	Test Scenario Outcome
NHTSA	Same Direction	Straight	0	61	Pass
NHTSA	Same Direction	Straight	0	69	Pass
NHTSA	Same Direction	Left	85	26	Pass
NHTSA	Same Direction	Left	85	29	Pass
NHTSA	Same Direction	Left	115	26	Pass
NHTSA	Same Direction	Left	115	29	Pass
NHTSA	Same Direction	Left	210	41	Pass
NHTSA	Same Direction	Left	210	44	Pass
NHTSA	Same Direction	Left	250	41	Pass
NHTSA	Same Direction	Left	250	44	Pass
NHTSA	Same Direction	Left	335	51	Pass
NHTSA	Same Direction	Left	335	54	Pass
NHTSA	Same Direction	Left	400	51	Pass
NHTSA	Same Direction	Left	400	54	Pass
NHTSA	Same Direction	Right	210	41	Pass
NHTSA	Same Direction	Right	210	44	Pass
NHTSA	Same Direction	Right	250	41	Pass
NHTSA	Same Direction	Right	250	44	Pass
NHTSA	Same Direction	Right	335	51	Pass
NHTSA	Same Direction	Right	335	54	Pass
NHTSA	Same Direction	Right	400	51	Pass
NHTSA	Same Direction	Right	400	54	Pass

These Ford Fusion lower beam test results show that it is possible for a current lower beam system to meet the proposed glare limits in the NHTSA ADB test scenarios.

6.4.2 *Lexus NX300 Lower Beam - Test Scenario Outcomes*

The following table provides test scenario outcomes of the NHTSA ADB test procedure for the Lexus NX300 with headlighting system in lower beam mode in oncoming orientation test scenarios. Passing results were obtained for three of eleven oncoming test scenarios.

Table 96. *NHTSA Test Procedure Test Scenario Outcomes, Oncoming Scenarios, Lexus NX300 Lower Beams*

Test Procedure	Orientation	Curve Direction	Radius of Curvature (m)	Speed (mph)	Test Scenario Outcome
NHTSA	Oncoming	Straight	0	69	Pass
NHTSA	Oncoming	Left	85	29	Pass
NHTSA	Oncoming	Left	115	29	Pass
NHTSA	Oncoming	Left	210	44	Fail
NHTSA	Oncoming	Left	250	44	Fail
NHTSA	Oncoming	Left	335	54	Fail
NHTSA	Oncoming	Left	400	54	Fail
NHTSA	Oncoming	Right	210	44	Fail
NHTSA	Oncoming	Right	250	44	Fail
NHTSA	Oncoming	Right	335	54	Fail
NHTSA	Oncoming	Right	400	54	Fail

The following table provides test outcomes of the NHTSA test procedure for the same direction scenarios using the Lexus NX300 with lower beams. Passing results were obtained for seven of eleven same direction test scenarios

Table 97. *NHTSA Test Procedure Test Scenario Outcomes, Same Direction Scenarios, Lexus NX300 Lower Beams*

Test Procedure	Orientation	Curve Direction	Radius of Curvature (m)	Speed (mph)	Test Scenario Outcome
NHTSA	Same Direction	Straight	0	69	Pass
NHTSA	Same Direction	Left	85	29	Pass
NHTSA	Same Direction	Left	115	29	Pass
NHTSA	Same Direction	Left	210	44	Fail
NHTSA	Same Direction	Left	250	44	Fail
NHTSA	Same Direction	Left	335	54	Fail
NHTSA	Same Direction	Left	400	54	Fail
NHTSA	Same Direction	Right	210	44	Pass
NHTSA	Same Direction	Right	250	44	Pass
NHTSA	Same Direction	Right	335	54	Pass
NHTSA	Same Direction	Right	400	54	Pass

The Lexus NX300's headlighting system in lower beam mode exceeded glare limits in some test scenarios. For the oncoming test scenario orientation, the Lexus NX300 lower beams did not attain passing results for the left or right curves having a radius of 210 meters or greater. For the same direction test scenarios, the Lexus NX300 lower beams did not attain passing results for the left curves with a radius of 210 meters or greater. As noted previously, the Lexus test vehicle was a

European market vehicle model with lower beam pattern modified to be FMVSS No. 108 compliant[9].

6.4.3 Volvo XC90 Lower Beam - Test Scenario Outcomes

Tables 98 through 105 present NHTSA test scenario outcome repeatability results for the Volvo XC90 by measurement distance range for each test repetition along with a test outcome per test scenario. For each measurement distance, a cell with “Met” indicates that all receptor head values had maximum illuminance values that met the applicable glare limit. A cell with an “Exceeded” would indicate that least one receptor head had a maximum illuminance value that exceeded (i.e., did not meet) the glare limit.

[9] Per Toyota.

Table 98. *Glare Limit Conformance Results by Test Repetition - Oncoming, Straight at 65 mph, Volvo XC90 Lower Beams*

	Repetition									
Measurement Distance Sub-Range	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
220 - 120 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
119.9 - 60 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
59.9 - 30 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
29.9 - 15 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
Test Scenario (Full measurement distance)	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Table 99. *Glare Limit Conformance Results by Test Repetition - Same Direction, Straight at 65 mph, Volvo XC90 Lower Beams*

	Repetition									
Measurement Distance Sub-Range	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
100 - 60 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
59.9 - 30 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
29.9 - 15 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
Test Scenario (Full measurement distance)	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Table 100. *Glare Limit Conformance Results by Test Repetition - Oncoming, Left Curve 85 m Radius of Curvature at 27 mph, Volvo XC90 Lower Beams*

	Repetition									
Measurement Distance Sub-Range	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
59.9 - 30 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
29.9 - 15 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
Test Scenario (Full measurement distance)	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Table 101. *Glare Limit Conformance Results by Test Repetition - Oncoming, Left Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams*

	Repetition									
Measurement Distance Sub-Range	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
150 - 120 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
119.9 - 60 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
59.9 - 30 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
29.9 - 15 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
Test Scenario (Full measurement distance)	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Table 102. *Glare Limit Conformance Results by Test Repetition - Same Direction, Left Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams*

	Repetition									
Measurement Distance Sub-Range	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
100 - 60 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
59.9 - 30 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
29.9 - 15 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
Test Scenario (Full measurement distance)	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Table 103. *Glare Limit Conformance Results by Test Repetition - Oncoming, Right Curve 210 m Radius of Curvature at 42 mph, Volvo XC90 Lower Beams*

	Repetition									
Measurement Distance Sub-Range	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
50 - 30 m	Exceeded*	Exceeded*	Exceeded*	Exceeded*	Exceeded*	Exceeded*	Exceeded**	Exceeded*	Exceeded*	Exceeded*
29.9 - 15 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
Test Scenario (Full measurement distance)	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail

*Only Receptor Head 4 had a glare exceedance

** Both Receptor Head 4 and Receptor Head 1 had glare exceedances

The following figure illustrates the XC90's performance in one instance of the oncoming right 210-m curve scenario in which illuminance at the car eye point exceeded the glare limit in the first measurement distance sub-range.

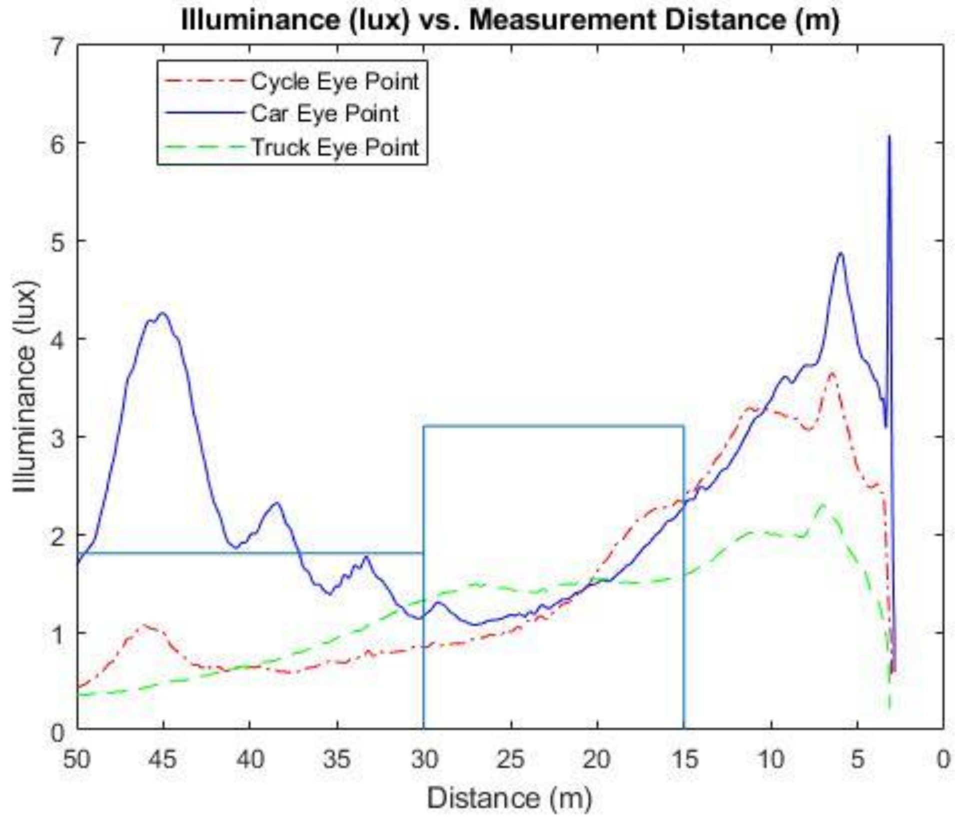

Figure 38. *Example of Test Trial in which the Glare Limit Was Exceeded: Oncoming Right Curve 210 m Radius of Curvature, Lower Beam (Volvo XC90), at 42 mph, Repetition #4 (TestRep_0080)*

Table 104. *Glare Limit Conformance Results by Test Repetition - Oncoming, Left Curve 335 m Radius of Curvature at 52 mph, Volvo XC90 Lower Beams*

	Repetition									
Measurement Distance Sub-Range	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
220 - 120 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
119.9 - 60 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
59.9 - 30 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
29.9 - 15 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
Test Scenario (Full measurement distance)	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Table 105. *Glare Limit Conformance Results by Test Repetition - Oncoming, Right Curve 335 m Radius of Curvature at 52 mph, Volvo XC90 Lower Beams*

	Repetition									
Measurement Distance Sub-Range	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
70 - 60 m	Exceeded**	Exceeded**	Exceeded**	Exceeded**	Exceeded**	Exceeded**	Exceeded**	Exceeded**	Exceeded**	Exceeded**
59.9 - 30 m	Met	Met	Met	Met	Exceeded*	Exceeded*	Exceeded*	Met	Exceeded*	Exceeded*
29.9 - 15 m	Met	Met	Met	Met	Met	Met	Met	Met	Met	Met
Test Scenario (Full measurement distance)	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail

*Only Receptor Head 4 had a glare exceedance
** Both Receptor Head 4 and Receptor Head 1 had glare exceedances

The Volvo XC90 lower beams performed well under the limits for the straight and left curve scenarios (85 m, 210 m, 335 m), but exceeded the limits for the right direction curves. All receptor heads for all repetitions met the glare limits for all measurement distance sub-ranges for each of the straight and left curve scenarios. For the NHTSA oncoming, right curve test scenarios, the following glare limit exceedances were observed:

- Right 210-m curve had at least one receptor head in all repetitions exceeded the glare limit for the measurement distance sub-range of 50 - 30 m.
- Right 335-m curve had at least one receptor head in all repetitions with a maximum illuminance value that exceeded the glare limit for the measurement distance sub-range of 70 - 60 m.
- Five repetitions of the oncoming, right 335-m curve test scenario had at least one receptor head with illuminance values that exceeded the glare limit for the measurement distance sub-range of 59.9 - 30 m.

6.5 Results For Testing of an ADB-Equipped Vehicle Per the NHTSA Test Procedure

The objective of this test was to determine if there were any problems or gaps identified when running an ADB-equipped vehicle through the proposed NHTSA ADB test procedure. This would allow for refinement of test procedure documentation and identification of any changes needed to the regulatory text. The intent was to execute, monitor, and document every specified test parameter, and consider how the parameters affect the test results. Each of the NHTSA test fixture stimulus lamp sets were used to determine if there were any issues in test outcome, or problems with the test procedure caused by using this method of lamp stimulus presentation. For each of the lamp conditions, every scenario was run, totaling 72 left curve trials, 48 right curve trials, and 12 straight-path trials.

A single ADB-equipped vehicle, a Lexus NX300, was involved in this portion of the testing. The Lexus NX300 was a European mass production model modified to meet United States VOR (visually optically aligned right) standards and to have lower and upper beam patterns compliant with FMVSS No. 108[10]. While the vehicle was equipped with ADB, the ADB system was not designed to pass any NHTSA or SAE ADB test procedure.

The following table shows the test scenario conditions carried out. In the table, both lower and upper speed conditions were completed for comparison, each of which were within the speed ranges indicated by the NHTSA test procedure. Each row of the table was completed six times, once for each NHTSA stimulus lamp condition (oncoming car, truck, and motorcycle headlamps; same direction car, truck, and motorcycle taillamps). In addition, this whole set of trials was performed twice, creating two repetitions of the data.

[10] Based on communication from Toyota. NHTSA did not test this vehicle's lower beam photometry to confirm FMVSS No. 108 compliance.

Table 106. *Test Matrix, ADB-Equipped Vehicle (Lexus NX300), NHTSA Test Procedure*

All 3 Lamp Conditions	Both Orientations / Both Lamp Types	Curve Direction	Radius of Curvature (m)	Vehicle Speed (mph)
Camry, F-150 Truck, and Harley Davidson Motorcycle Lamps	Oncoming (Headlamps), and Same Direction (Taillamps)	Right	210	41
			210	44
			250	41
			250	44
			335	51
			335	54
			400	51
			400	54
		Left	85	26
			85	29
			115	26
			115	29
			210	41
			210	44
			250	41
			250	44
			335	51
			335	54
			400	51
			400	54
		Straight	NA	61
			NA	69

The following set of tables provide summaries of ADB test performance, with a breakdown of test results for each stimulus lamp condition.

Overall, the results presented in this section show mix of results varying by radius of curvature and measurement distance, providing a good breakdown of where the vehicle's headlamps may need improvement in performance in order to pass the test procedure.

6.5.1 ADB-Equipped Vehicle Results for Car Camry Stimulus Lamps

Table 107 provides test results by measurement distance for the first repetition of each test scenario with the oncoming car (Camry) headlamps on the NHTSA test fixture.

Table 107. *NHTSA Test Procedure Glare Limit Conformance, Oncoming, Camry Stimulus Headlamps, ADB (Lexus NX300), First Repetition*

Curve Direction	**Radius of Curvature (m)**	**Speed (mph)**	**220-120 m**	**119.9-60 m**	**59.9-30 m**	**29.9-15 m**
Left	85	26	n/a	n/a	Met	Met
Left	85	29	n/a	n/a	Met	Met
Left	115	26	n/a	n/a	Met	Met
Left	115	29	n/a	n/a	Met	Met
Left	210	41	Met	Exceeded	Exceeded	Met
Left	210	44	Met	Exceeded	Exceeded	Met
Left	250	41	Met	Exceeded	Exceeded	Met
Left	250	44	Met	Exceeded	Exceeded	Met
Left	335	51	Met	Exceeded	Exceeded	Met
Left	335	54	Met (spike)	Exceeded	Exceeded	Met
Left	400	51	Met	Exceeded	Exceeded	Met
Left	400	54	Met	Exceeded	Exceeded	Met
Right	210	41	n/a	n/a	Met	Met
Right	210	44	n/a	n/a	Met	Met
Right	250	41	n/a	n/a	Met	Met
Right	250	44	n/a	n/a	Met	Met
Right	335	51	n/a	Exceeded	Met	Met
Right	335	54	n/a	Exceeded	Met	Met
Right	400	51	n/a	Exceeded	Met	Met
Right	400	54	n/a	Exceeded	Met	Met
Straight	0	61	Met (spike)	Met	Met	Met
Straight	0	69	Met	Met	Met	Met

As shown in the table above, there was a ‘spike,’ or momentary glare exceedance,” noted for the left 335-meter radius of curvature trial in the 220 - 120 m measurement distance sub-range, with the test vehicle traveling at 54 mph. This test trial was not a failure due to the momentary glare exceedance, but did exceed glare limits in two other measurement distance sub-ranges, which resulted in a test failure. The following figures provide plots of that trial, showing where the ‘spike’ occurred.

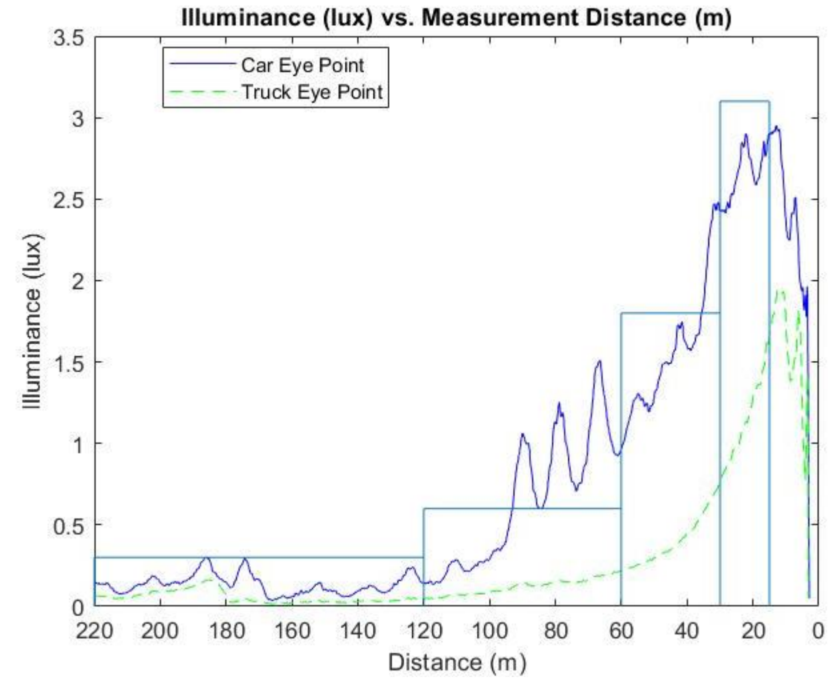

Figure 39. *Example of Test Trial With a Momentary Glare Exceedance in the 220 - 120 m Measurement Distance Sub-Range: Oncoming Left Curve 335 m Radius of Curvature, Camry Stimulus Headlamps, ADB (Lexus NX300), at 54 mph, First Repetition (Lexus1_0086)*

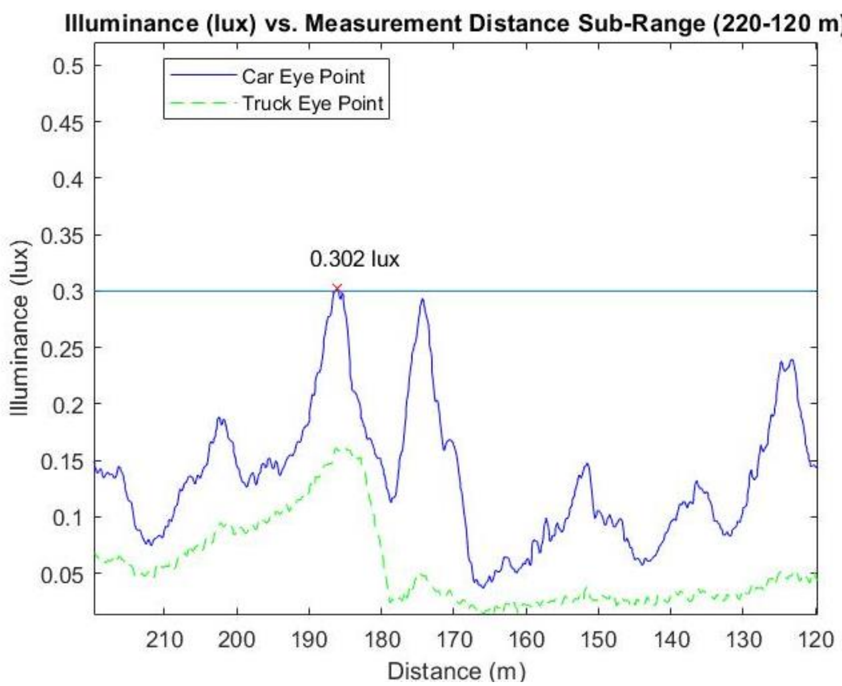

Figure 40. *Example of Momentary Glare Exceedance in the 220 - 120 m Measurement Distance Sub-Range: Oncoming Left Curve 335 m Radius of Curvature, Camry Stimulus Headlamps, ADB (Lexus NX300), at 54 mph, First Repetition (Lexus1_0086)*

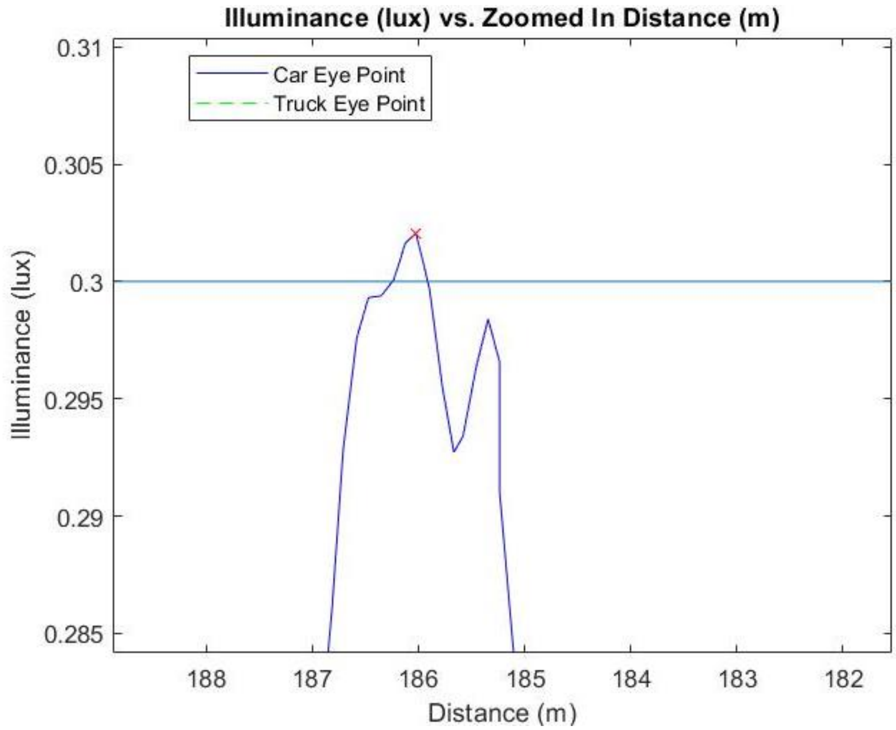

Figure 41. *Example of Momentary Glare Exceedance in the 220 - 120 m Measurement Distance Sub-Range, Zoomed In: Oncoming Left Curve 335 m Radius of Curvature, Camry Stimulus Headlamps, ADB (Lexus NX300), at 54 mph, First Repetition (Lexus1_0086)*

The following table provides test results by measurement distance for the second repetition using the oncoming car (Camry) headlamps on the NHTSA test fixture.

Table 108. *NHTSA Test Procedure Glare Limit Conformance, Oncoming, Camry Stimulus Headlamps, ADB (Lexus NX300), Second Repetition*

Curve Direction	Radius of Curvature (m)	Speed (mph)	220-120 m	119.9-60 m	59.9-30 m	29.9-15 m
Left	85	26	n/a	n/a	Met	Met
Left	85	29	n/a	n/a	Met	Met
Left	115	26	n/a	n/a	Met	Met
Left	115	29	n/a	n/a	Met	Met
Left	210	41	Met	Exceeded	Exceeded	Met
Left	210	44	Met	Exceeded	Exceeded	Met
Left	250	41	Met	Exceeded	Met	Met
Left	250	44	Met	Exceeded	Exceeded	Met
Left	335	51	Met	Exceeded	Exceeded	Met
Left	335	54	Met	Exceeded	Exceeded	Met
Left	400	51	Met	Exceeded	Met	Met
Left	400	54	Met	Exceeded	Exceeded	Met
Right	210	41	n/a	n/a	Met (spike)	Met
Right	210	44	n/a	n/a	Met (spike)	Met
Right	250	41	n/a	n/a	Exceeded	Met
Right	250	44	n/a	n/a	Exceeded	Met
Right	335	51	n/a	Exceeded	Met	Met
Right	335	54	n/a	Exceeded	Met	Met
Right	400	51	n/a	Exceeded	Met	Met
Right	400	54	n/a	Exceeded	Met	Met
Straight	0	61	Met	Met	Met	Met
Straight	0	69	Met	Met	Met	Met

The following figures are plots of Camry stimulus headlamp trial data illustrating ‘Met’ and ‘Exceeded’ test results of the different measurement distance sub-ranges.

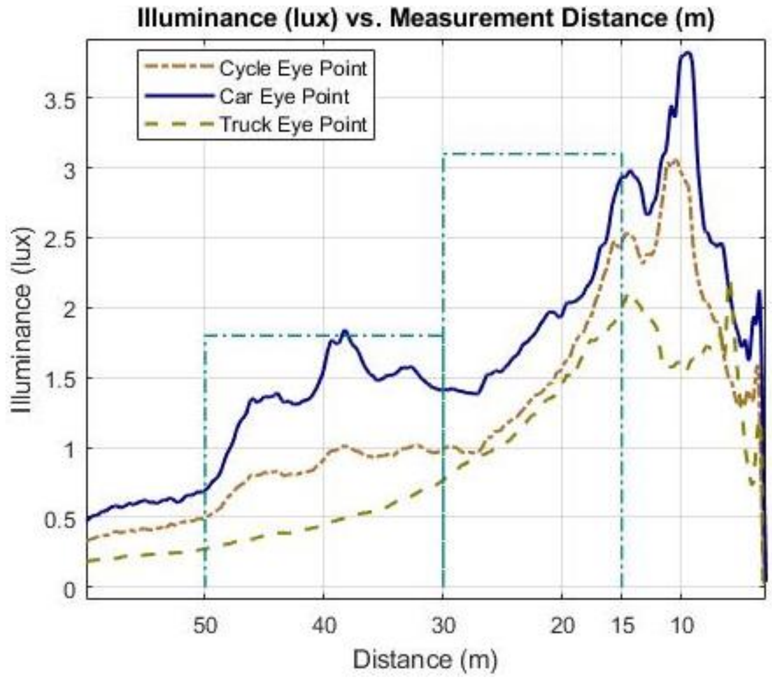

Figure 42. *Example of Test Trial in Which Glare Limits Were Met Despite a Momentary Glare Exceedance: Oncoming Right Curve 210 m Radius of Curvature, Camry Stimulus Headlamps, ADB (Lexus NX300), at 41 mph, Second Repetition (LexusNHTSAADB_0108)*

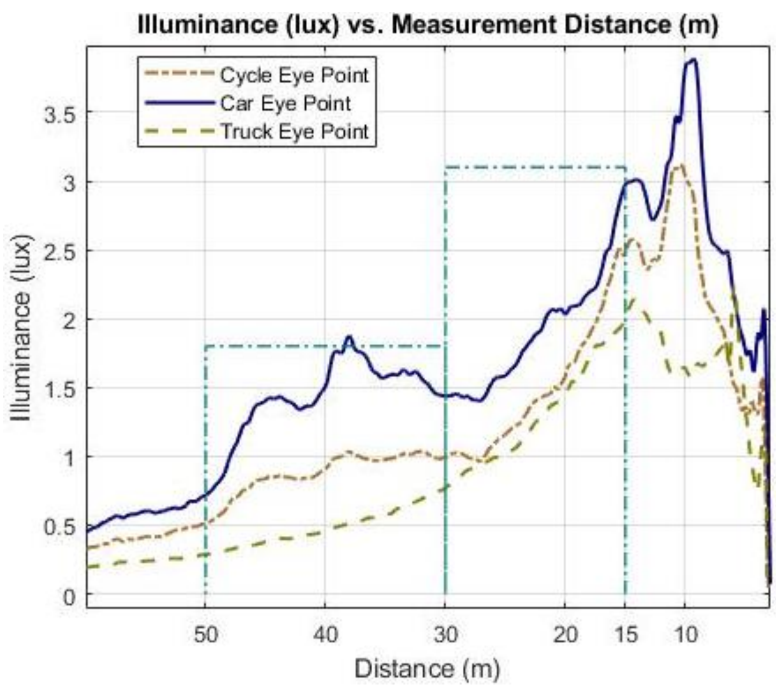

Figure 43. *Example of Test Trial in Which Glare Limits Were Met Despite a Momentary Glare Exceedance: Oncoming Right Curve 210 m Radius of Curvature, Camry Stimulus Headlamps, ADB (Lexus NX300), at 44 mph, Second Repetition (LexusNHTSAADB_0109)*

Two oncoming test scenarios with the Camry stimulus headlamps had test results that were different between the first and second test repetitions. For the oncoming, right 250-m curve test scenario, measured illuminance exceeded the 50 - 30 m glare limit at both test vehicle speeds in the second repetition data (see Table 108), but not in the first repetition (see Table 107). The following figures illustrate illuminance versus distance for the two second-repetition trials that had glare exceedances.

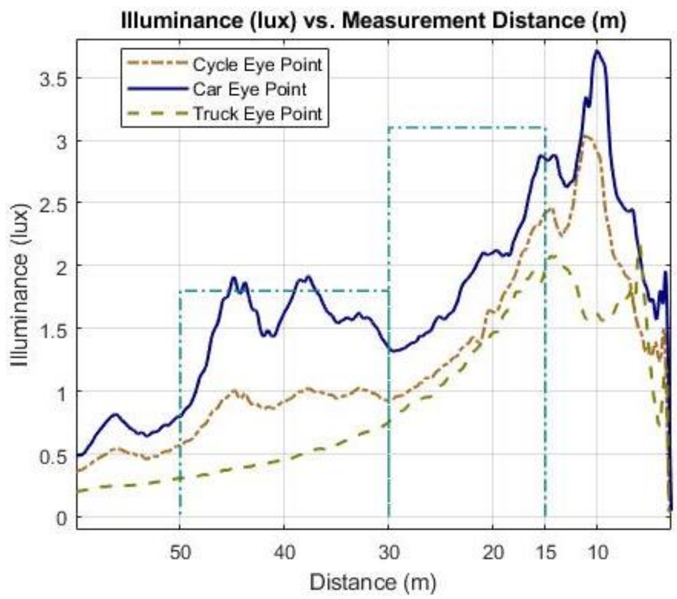

Figure 44. *Example of Test Trial in Which Not all Glare Limits Were Met: Oncoming Right Curve 250 m Radius of Curvature, Camry Stimulus Headlamps, ADB (Lexus NX300), at 41 mph, Second Repetition (LexusNHTSAADB_0110)*

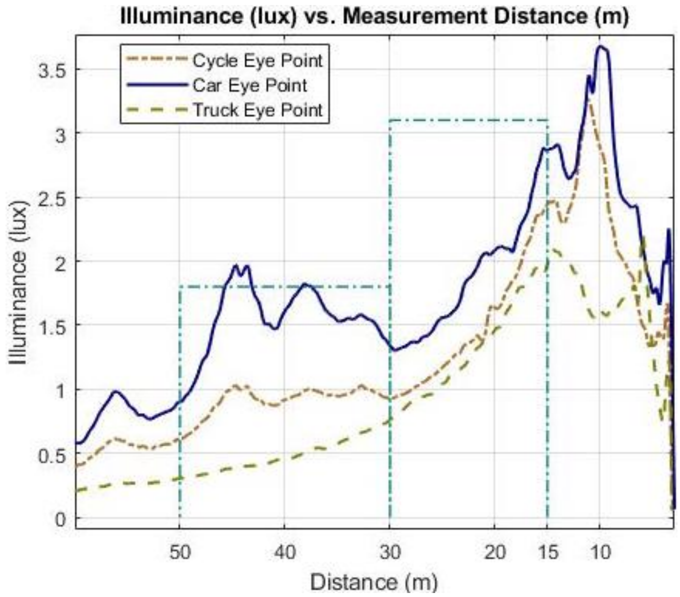

Figure 45. *Example of Test Trial in Which Not all Glare Limits Were Met: Oncoming Right Curve 250 m Radius of Curvature, Camry Stimulus Headlamps, ADB (Lexus NX300), at 44 mph, Second Repetition (LexusNHTSAADB_0111*

The oncoming left 400-m curve test scenario at 51 mph also showed a glare limit exceedance in one repetition (first repetition) but not the other. The following figures illustrate illuminance versus distance for both repetitions of that scenario.

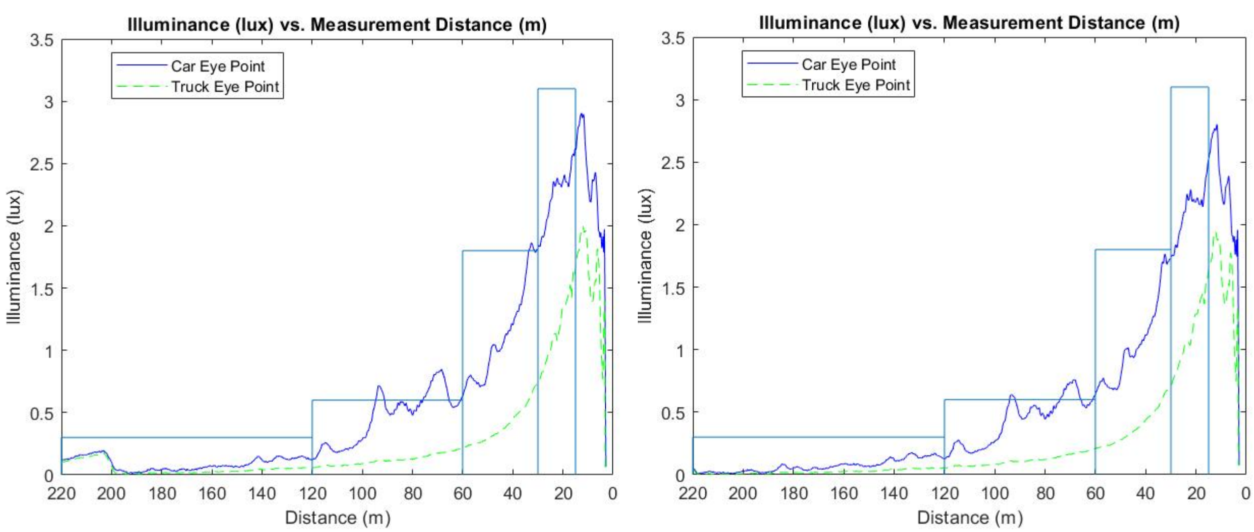

Figure 46. *Oncoming Left Curve 400 m Radius of Curvature, Camry Stimulus Headlamps, ADB (Lexus NX300), at 51 mph, Both Repetitions (Lexus1_0087, LexusNHTSAADB_0011)*

The following figure provides zoomed views of the sub-range in which the glare limit exceedance occurred.

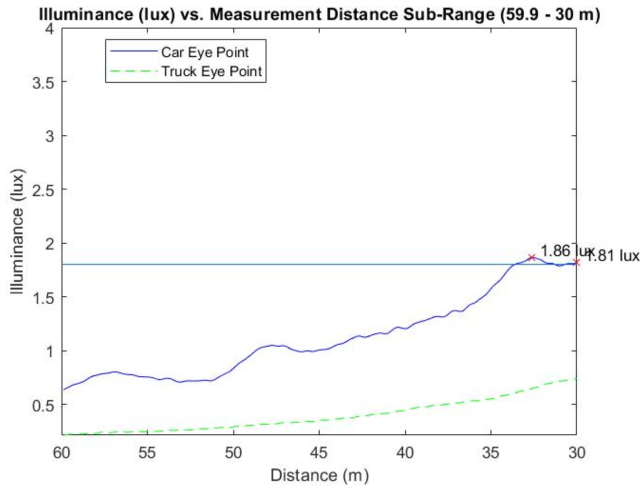

Figure 47. *Oncoming Left Curve 400 m Radius of Curvature, Camry Stimulus Headlamps, ADB (Lexus NX300), at 51 mph, Both Repetitions (Lexus1_0087, LexusNHTSAADB_0011), 59.9 – 30 m Sub-Range*

The following table provides test outcomes for the first repetition using the same direction Camry taillamps on the NHTSA test fixture.

Table 109. *NHTSA Test Procedure Glare Limit Conformance, Same Direction, Camry Stimulus Taillamps, ADB (Lexus NX300), First Repetition*

Curve Direction	Radius of Curvature (m)	Speed (mph)	220-120 m	119.9-60 m	59.9-30 m	29.9-15 m
Left	85	26	n/a	n/a	Met	Exceeded
Left	85	29	n/a	n/a	Met	Exceeded
Left	115	26	n/a	n/a	Met	Met
Left	115	29	n/a	n/a	Met	Met
Left	210	41	n/a	Exceeded	Met	Exceeded
Left	210	44	n/a	Exceeded	Met	Exceeded
Left	250	41	n/a	Exceeded	Met	Met
Left	250	44	n/a	Exceeded	Met	Exceeded
Left	335	51	n/a	Met	Met	Exceeded
Left	335	54	n/a	Met	Met	Exceeded
Left	400	51	n/a	Met	Met	Exceeded
Left	400	54	n/a	Met	Met	Exceeded
Right	210	41	n/a	n/a	Met	Met
Right	210	44	n/a	n/a	Met	Met
Right	250	41	n/a	n/a	Met	Met
Right	250	44	n/a	n/a	Met	Met
Right	335	51	n/a	Met	Met	Met
Right	335	54	n/a	Met	Met	Met
Right	400	51	n/a	Met	Met	Met
Right	400	54	n/a	Met	Met	Met
Straight	0	61	n/a	Met	Met	Met
Straight	0	69	n/a	Met	Met	Met

The following table provides test outcomes for the second repetition using the same direction Camry taillamps on the NHTSA test fixture.

Table 110. *NHTSA Test Procedure Glare Limit Conformance, Same Direction, Camry Stimulus Taillamps, ADB (Lexus NX300), Second Repetition*

Curve Direction	Radius of Curvature (m)	Speed (mph)	220-120 m	119.9-60 m	59.9-30 m	29.9-15 m
Left	85	26	n/a	n/a	Met	Exceeded
Left	85	29	n/a	n/a	Met	Exceeded
Left	115	26	n/a	n/a	Met	Met
Left	115	29	n/a	n/a	Met	Met
Left	210	41	n/a	Exceeded	Met	Met
Left	210	44	n/a	Exceeded	Met	Exceeded
Left	250	41	n/a	Exceeded	Met	Met
Left	250	44	n/a	Exceeded	Met	Exceeded
Left	335	51	n/a	Met	Met	Exceeded
Left	335	54	n/a	Met	Met	Exceeded
Left	400	51	n/a	Met	Met	Met
Left	400	54	n/a	Met	Met	Exceeded
Right	210	41	n/a	n/a	Met	Met
Right	210	44	n/a	n/a	Met	Met
Right	250	41	n/a	n/a	Met	Met
Right	250	44	n/a	n/a	Met	Met
Right	335	51	n/a	Met	Met	Met
Right	335	54	n/a	Met	Met	Met
Right	400	51	n/a	Met	Met	Met
Right	400	54	n/a	Met	Met	Met
Straight	0	61	n/a	Met	Met	Met
Straight	0	69	n/a	Met	Met	Met

Both the left 210-m scenario run at 41 mph and the left 400-m curve scenario run at 51 mph had differences in test results between the first and second repetitions. Disagreement in test results was associated with the 29.9 - 15 m measurement distance sub-range in both cases. The next figure illustrates illuminance versus distance as well as glare limit conformance for the second trial repetition for which the test outcome was a passing result.

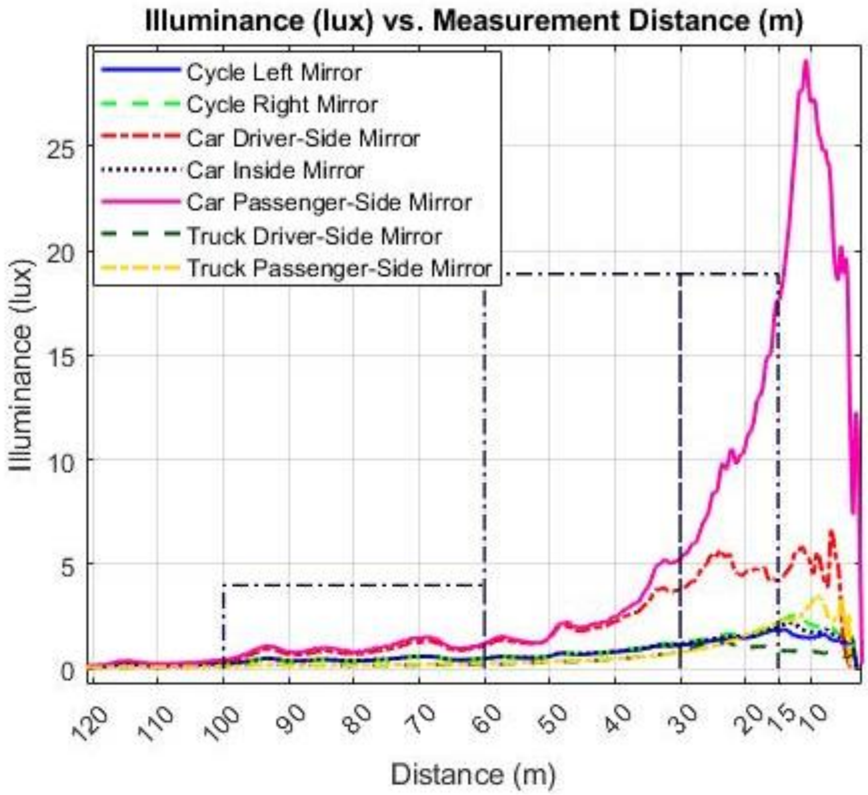

Figure 48. *Example of Test Scenario Trial in which All Glare Limits Were Met: Same Direction Left Curve 400 m Radius of Curvature, Camry Stimulus Taillamps, ADB (Lexus NX300), at 51 mph, Second Repetition (LexusNHTSAADB_0027)*

For the same direction left 250-m curve, glare limit exceedances were observed for both the 119.9 - 60 m and 29.9 - 15 m measurement distance sub-ranges in both repetitions of this test scenario. The following figure illustrates the second repetition.

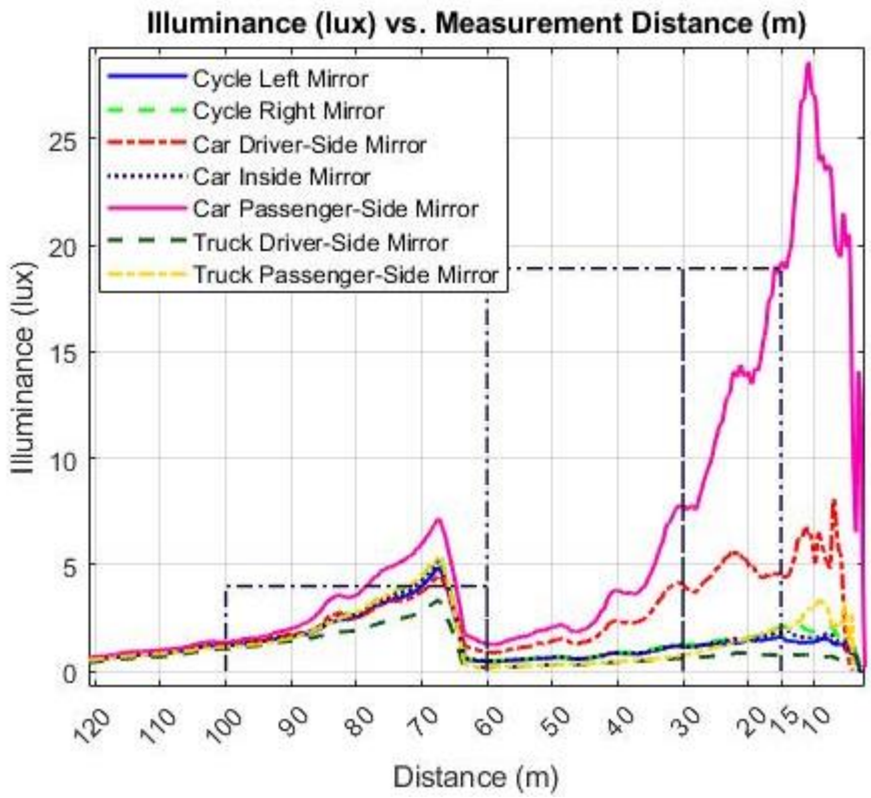

Figure 49. *Example of Test Trial in Which Not all Glare Limits Were Met: Same Direction Left Curve 250 m Radius of Curvature, Camry Stimulus Taillamps, ADB (Lexus NX300), at 44 mph, Second Repetition (LexusNHTSAADB_0024)*

6.5.2 ADB-Equipped Vehicle Results for F-150 Truck Stimulus Lamps

The following table provides test scenario outcomes for the first repetition using the oncoming F-150 truck headlamps on the NHTSA test fixture.

Table 111. *NHTSA Test Procedure Glare Limit Conformance, Oncoming, F-150 Truck Stimulus Headlamps, ADB (Lexus NX300), First Repetition*

Curve Direction	Radius of Curvature (m)	Speed (mph)	220-120 m	119.9-60 m	59.9-30 m	29.9-15 m
Left	85	26	n/a	n/a	Met	Met
Left	85	29	n/a	n/a	Met	Met
Left	115	26	n/a	n/a	Met	Met
Left	115	29	n/a	n/a	Met	Met
Left	210	41	Met	Exceeded	Exceeded	Met
Left	210	44	Met	Exceeded	Exceeded	Met
Left	250	41	Met	Met (spike)	Met (spike)	Met
Left	250	44	Met	Exceeded	Exceeded	Met
Left	335	51	Met	Exceeded	Exceeded	Met
Left	335	54	Exceeded	Exceeded	Exceeded	Met
Left	400	51	Met	Exceeded	Exceeded	Met
Left	400	54	Met	Exceeded	Exceeded	Met
Right	210	41	n/a	n/a	Exceeded	Met
Right	210	44	n/a	n/a	Exceeded	Met
Right	250	41	n/a	n/a	Exceeded	Met
Right	250	44	n/a	n/a	Exceeded	Met
Right	335	51	n/a	Exceeded	Met	Met
Right	335	54	n/a	Exceeded	Met	Met
Right	400	51	n/a	Exceeded	Met	Met
Right	400	54	n/a	Exceeded	Met	Met
Straight	0	61	Met	Met	Met	Met
Straight	0	69	Met	Met	Met	Met

The following table provides test scenario outcomes for the second repetition using the oncoming F-150 truck headlamps on the NHTSA test fixture.

Table 112. *NHTSA Test Procedure Glare Limit Conformance, Oncoming, F-150 Truck Stimulus Headlamps, ADB (Lexus NX300), Second Repetition*

Curve Direction	Radius of Curvature (m)	Speed (mph)	220-120 m	119.9-60 m	59.9-30 m	29.9-15 m
Left	85	26	n/a	n/a	Met	Met
Left	85	29	n/a	n/a	Met	Met
Left	115	26	n/a	n/a	Met	Met
Left	115	29	n/a	n/a	Met	Met
Left	210	41	Met	Met	Exceeded	Met
Left	210	44	Met	Exceeded	Exceeded	Met
Left	250	41	Met	Exceeded	Met	Met
Left	250	44	Met	Exceeded	Met	Met
Left	335	51	Met	Exceeded	Exceeded	Met
Left	335	54	Met	Exceeded	Exceeded	Met
Left	400	51	Met	Exceeded	Exceeded	Met
Left	400	54	Met	Exceeded	Exceeded	Met
Right	210	41	n/a	n/a	Exceeded	Met
Right	210	44	n/a	n/a	Exceeded	Met
Right	250	41	n/a	n/a	Exceeded	Met
Right	250	44	n/a	n/a	Met	Met
Right	335	51	n/a	Exceeded	Met	Met
Right	335	54	n/a	Exceeded	Met	Met
Right	400	51	n/a	Exceeded	Met	Met
Right	400	54	n/a	Exceeded	Met	Met
Straight	0	61	Met	Met	Met	Met
Straight	0	69	Met	Met	Met	Met

In general, the first and second repetitions matched for NHTSA oncoming scenarios with the F-150 stimulus vehicle and ADB-equipped Lexus NX300. Disagreement between the first and second repetitions were present in the following scenarios:

- Left curve with radius of 210 m, speed of 41 mph, and measurement distance sub-range 119.9 - 60 m
- Left curve with radius of 250 m, speed of 41 mph, and measurement distance sub-ranges 119.9 - 60 m and 59.9 - 30 m
- Left curve with radius of 250 m, speed of 44 mph, and measurement distance sub-range 59.9 - 30 m
- Left curve with radius of 335 m, speed of 54 mph, and measurement distance sub-range 220 - 120 m
- Right curve with radius of 250 m, speed of 44 mph, and measurement distance sub-range 59.9 - 30 m

Only the disagreement for the 250-m left curve at 44 mph was associated with a different test scenario test outcome. The following figure illustrates data for the left curve with radius of 250 m and speed of 44 mph, for which the first repetition showed a glare limit exceedance in the 59.9 - 30 m measurement distance sub-range, but the second repetition did not.

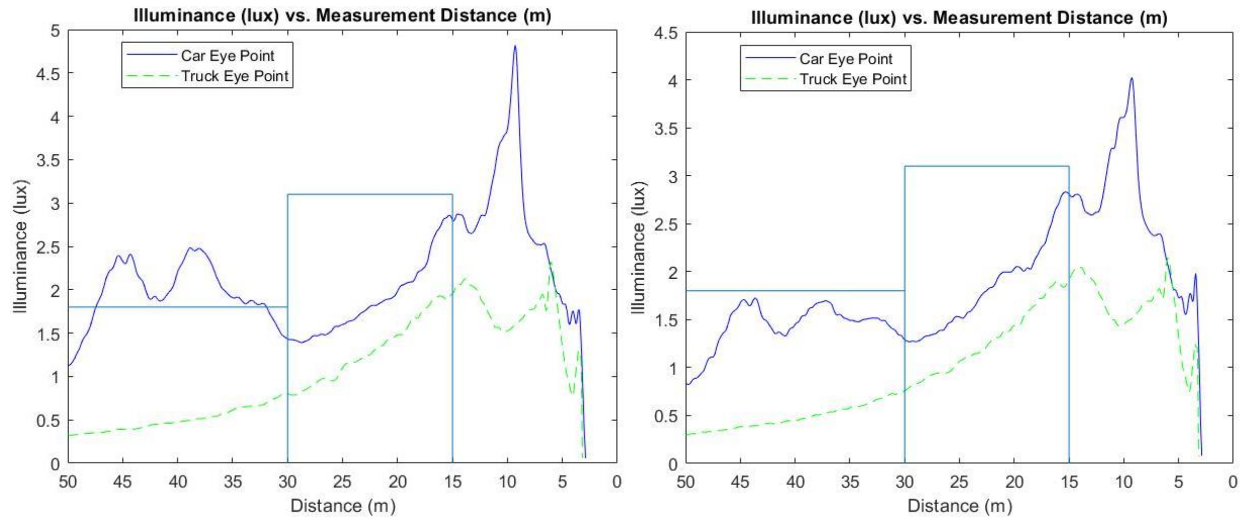

Figure 50. *Oncoming Right 250-m Curve, F-150 Truck Stimulus Headlamps, ADB (Lexus NX300), at 44 mph (Lexus1_0012, LexusNHTSAADB_0142)*

The following table provides test scenario outcomes for the first test repetition of same direction test scenarios with F-150 truck taillamps on the NHTSA test fixture.

Table 113. *NHTSA Test Procedure Glare Limit Conformance, Same Direction, F-150 Truck Stimulus Headlamps, ADB (Lexus NX300), First Repetition*

Curve Direction	Radius of Curvature (m)	Speed (mph)	220-120 m	119.9-60 m	59.9-30 m	29.9-15 m
Left	85	26	n/a	n/a	Met	Exceeded
Left	85	29	n/a	n/a	Met	Exceeded
Left	115	26	n/a	n/a	Met	Met
Left	115	29	n/a	n/a	Met	Met
Left	210	41	n/a	Exceeded	Met	Exceeded
Left	210	44	n/a	Exceeded	Met	Exceeded
Left	250	41	n/a	Exceeded	Met	Exceeded
Left	250	44	n/a	Exceeded	Met	Exceeded
Left	335	51	n/a	Met	Met	Exceeded
Left	335	54	n/a	Met	Met	Exceeded
Left	400	51	n/a	Met	Met	Exceeded
Left	400	54	n/a	Met	Met	Exceeded
Right	210	41	n/a	n/a	Met	Met
Right	210	44	n/a	n/a	Met	Met
Right	250	41	n/a	n/a	Met	Met
Right	250	44	n/a	n/a	Met	Met
Right	335	51	n/a	Met	Met	Met
Right	335	54	n/a	Met	Met	Met
Right	400	51	n/a	Met	Met	Met
Right	400	54	n/a	Met	Met	Met
Straight	0	61	n/a	Met	Met	Met
Straight	0	69	n/a	Met	Met	Met

The following table provides test scenario outcomes for the second repetition using the same direction F-150 truck taillamps on the NHTSA test fixture.

Table 114. *NHTSA Test Procedure Glare Limit Conformance, Same Direction, F-150 Truck Stimulus Headlamps, ADB (Lexus NX300), Second Repetition*

Curve Direction	Radius of Curvature (m)	Speed (mph)	220-120 m	119.9-60 m	59.9-30 m	29.9-15 m
Left	85	26	n/a	n/a	Met	Exceeded
Left	85	29	n/a	n/a	Met	Exceeded
Left	115	26	n/a	n/a	Met	Met
Left	115	29	n/a	n/a	Met	Met
Left	210	41	n/a	Exceeded	Met	Exceeded
Left	210	44	n/a	Exceeded	Met	Exceeded
Left	250	41	n/a	Exceeded	Met	Met
Left	250	44	n/a	Exceeded	Met	Met
Left	335	51	n/a	Met	Met	Exceeded
Left	335	54	n/a	Met	Met	Exceeded
Left	400	51	n/a	Met	Met	Met
Left	400	54	n/a	Met	Met	Exceeded
Right	210	41	n/a	n/a	Met	Met
Right	210	44	n/a	n/a	Met	Met
Right	250	41	n/a	n/a	Met	Met
Right	250	44	n/a	n/a	Met	Met
Right	335	51	n/a	Met	Met	Met
Right	335	54	n/a	Met	Met	Met
Right	400	51	n/a	Met	Met	Met
Right	400	54	n/a	Met	Met	Met
Straight	0	61	n/a	Met	Met	Met
Straight	0	69	n/a	Met	Met	Met

In general, the first and second repetitions matched for NHTSA same direction scenarios with the F-150 stimulus vehicle and ADB-equipped Lexus NX300. Disagreement between the first and second repetitions were present in the following scenarios:

- Left 250-m curve at 41 mph, and measurement distance sub-range 29.9 - 15 m
- Left 250-m curve at 44 mph, and measurement distance sub-range 29.9 - 15 m
- Left 400-m curve at 51 mph, and measurement distance sub-range 29.9 - 15 m

The following figure illustrates the disagreement between repetitions of the left 400-m curve scenario run at 51 mph.

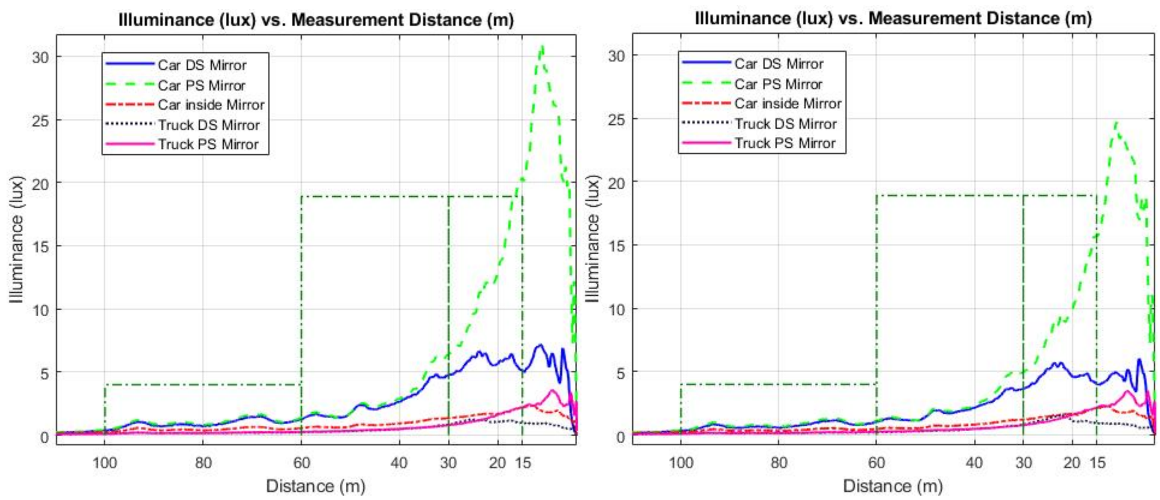

Figure 51. *Plots of Same Direction Left 400 m, F-150 Truck Stimulus Taillamps, ADB (Lexus NX300), at 51 mph, First and Second Repetitions (Lexus2_0027, LexusNHTSAADB_0055)*

6.5.3 ADB-Equipped Vehicle Results for Motorcycle Stimulus Lamps

The following table provides test scenario outcomes for the first repetition using the oncoming Harley Davidson motorcycle headlamp on the NHTSA test fixture.

Table 115. *NHTSA Test Procedure Glare Limit Conformance, Oncoming, Harley Davidson Motorcycle Stimulus Headlamp, ADB (Lexus NX300), First Repetition*

Curve Direction	Radius of Curvature (m)	Speed (mph)	220-120 m	119.9-60 m	59.9-30 m	29.9-15 m
Left	85	26	n/a	n/a	Exceeded	Exceeded
Left	85	29	n/a	n/a	Exceeded	Exceeded
Left	115	26	n/a	n/a	Met	Met
Left	115	29	n/a	n/a	Exceeded	Met
Left	210	41	Met	Exceeded	Exceeded	Met
Left	210	44	Met	Exceeded	Exceeded	Met
Left	250	41	Exceeded	Exceeded	Exceeded	Met
Left	250	44	Exceeded	Exceeded	Met	Met
Left	335	51	Exceeded	Exceeded	Met	Met
Left	335	54	Exceeded	Exceeded	Exceeded	Met
Left	400	51	Exceeded	Exceeded	Met	Met
Left	400	54	Exceeded	Exceeded	Met	Exceeded
Right	210	41	n/a	n/a	Met	Met
Right	210	44	n/a	n/a	Met	Exceeded
Right	250	41	n/a	n/a	Met	Met
Right	250	44	n/a	n/a	Met	Met
Right	335	51	n/a	Exceeded	Met	Exceeded
Right	335	54	n/a	Exceeded	Met	Exceeded
Right	400	51	n/a	Exceeded	Met	Met
Right	400	54	n/a	Exceeded	Met	Exceeded
Straight	0	61	Exceeded	Met	Met	Met
Straight	0	69	Exceeded	Met	Met	Met

The following table provides test scenario outcomes for the second repetition using the oncoming motorcycle headlamp on the NHTSA test fixture.

Table 116. *NHTSA Test Procedure Glare Limit Conformance, Oncoming, Harley Davidson Motorcycle Stimulus Headlamp, ADB (Lexus NX300), Second Repetition*

Curve Direction	Radius of Curvature (m)	Speed (mph)	220-120 m	119.9-60 m	59.9-30 m	29.9-15 m
Left	85	26	n/a	n/a	Exceeded	Met
Left	85	29	n/a	n/a	Exceeded	Exceeded
Left	115	26	n/a	n/a	Met	Met
Left	115	29	n/a	n/a	Exceeded	Met
Left	210	41	Met	Exceeded	Met	Met
Left	210	44	Met	Exceeded	Exceeded	Met
Left	250	41	Exceeded	Exceeded	Exceeded	Met
Left	250	44	Exceeded	Exceeded	Met	Met
Left	335	51	Exceeded	Exceeded	Met	Exceeded
Left	335	54	Exceeded	Exceeded	Met	Exceeded
Left	400	51	Exceeded	Exceeded	Met	Met
Left	400	54	Exceeded	Exceeded	Met	Met
Right	210	41	n/a	n/a	Met	Met
Right	210	44	n/a	n/a	Met	Exceeded
Right	250	41	n/a	n/a	Met	Met
Right	250	44	n/a	n/a	Met	Met
Right	335	51	n/a	Exceeded	Met	Exceeded
Right	335	54	n/a	Exceeded	Met	Exceeded
Right	400	51	n/a	Exceeded	Met	Met
Right	400	54	n/a	Exceeded	Met	Met
Straight	0	61	Met	Met	Met	Met
Straight	0	69	Exceeded	Met	Met	Met

In general, the first and second repetitions matched for NHTSA oncoming scenarios with Harley Davidson motorcycle stimulus headlamp and ADB-equipped Lexus NX300. Disagreement between the first and second repetitions were present in the following scenarios:

- Left 85-m curve at 26 mph, measurement distance sub-range 29.9 - 15 m
- Left 210-m curve at 41 mph, measurement distance rub-range 59.9 - 30 m
- Left 335-m curve at 51 mph, measurement distance rub-range 29.9 - 15 m
- Left 335-m curve at 54 mph, measurement distance sub-ranges 59.9 - 30 m and 29.9 - 15 m
- Left 400-m curve at 54 mph, measurement distance sub-range 29.9 - 15 m
- Right 400-m curve at 54 mph, measurement distance sub-range 29.9 - 15 m
- Straight at 61 mph and measurement distance sub-range 220 - 120 m

Despite these differences, only one test scenario's test outcome was different between the two test repetitions: the oncoming straight scenario at 61 mph. The following figure illustrates the oncoming straight 61 mph second repetition for which there was a glare exceedance in the 220 - 120 m measurement distance sub-range.

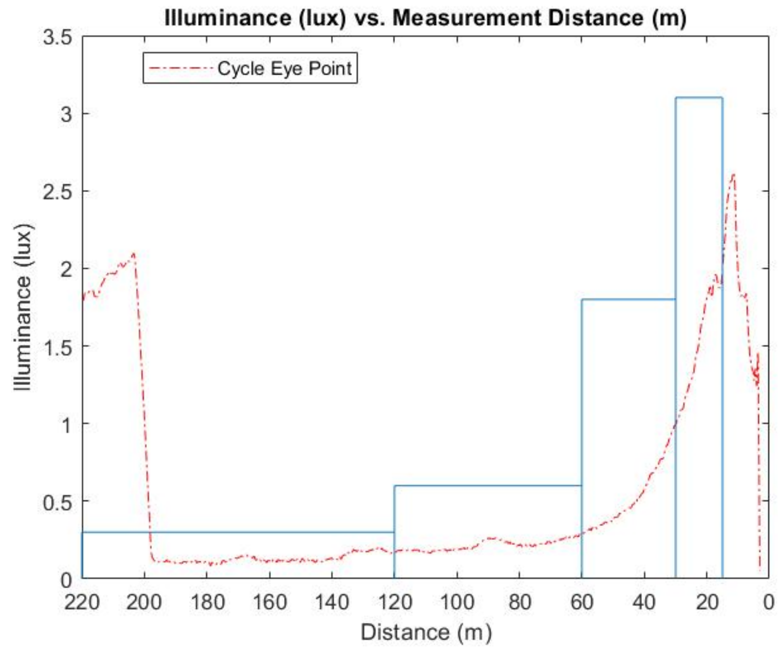

Figure 52. *Oncoming Straight, Motorcycle Stimulus Headlamp, ADB (Lexus NX300), at 61 mph, First Repetition*

The following table provides test scenario outcomes for the first repetition using the same direction motorcycle taillamp on the NHTSA test fixture.

Table 117. *NHTSA Test Procedure Glare Limit Conformance, Same Direction, Harley Davidson Motorcycle Stimulus Taillamp, ADB (Lexus NX300), First Repetition*

Curve Direction	Radius of Curvature (m)	Speed (mph)	220-120 m	119.9-60 m	59.9-30 m	29.9-15 m
Left	85	26	n/a	n/a	Met	Met
Left	85	29	n/a	n/a	Met	Met
Left	115	26	n/a	n/a	Met	Exceeded
Left	115	29	n/a	n/a	Met	Met
Left	210	41	n/a	Exceeded	Exceeded	Exceeded
Left	210	44	n/a	Exceeded	Exceeded	Exceeded
Left	250	41	n/a	Exceeded	Exceeded	Exceeded
Left	250	44	n/a	Exceeded	Exceeded	Exceeded
Left	335	51	n/a	Exceeded	Exceeded	Exceeded
Left	335	54	n/a	Exceeded	Exceeded	Exceeded
Left	400	51	n/a	Exceeded	Exceeded	Exceeded
Left	400	54	n/a	Exceeded	Exceeded	Met
Right	210	41	n/a	n/a	Exceeded	Met
Right	210	44	n/a	n/a	Exceeded	Met
Right	250	41	n/a	n/a	Exceeded	Met
Right	250	44	n/a	n/a	Exceeded	Met
Right	335	51	n/a	Exceeded	Exceeded	Met
Right	335	54	n/a	Exceeded	Exceeded	Met
Right	400	51	n/a	Exceeded	Exceeded	Met
Right	400	54	n/a	Exceeded	Exceeded	Met
Straight	0	61	n/a	Met	Met	Met
Straight	0	69	n/a	Met	Met	Met

The following table provides test scenario outcomes for the second repetition using the same direction motorcycle taillamp on the NHTSA test fixture.

Table 118. *NHTSA Test Procedure Glare Limit Conformance, Same Direction, Harley Davidson Motorcycle Stimulus Taillamp, ADB (Lexus NX300), Second Repetition*

Curve Direction	Radius of Curvature (m)	Speed (mph)	220-120 m	119.9-60 m	59.9-30 m	29.9-15 m
Left	85	26	n/a	n/a	Met	Met
Left	85	29	n/a	n/a	Met	Met
Left	115	26	n/a	n/a	Met	Met
Left	115	29	n/a	n/a	Met	Exceeded
Left	210	41	n/a	Exceeded	Exceeded	Exceeded
Left	210	44	n/a	Exceeded	Exceeded	Exceeded
Left	250	41	n/a	Exceeded	Exceeded	Exceeded
Left	250	44	n/a	Exceeded	Exceeded	Exceeded
Left	335	51	n/a	Exceeded	Exceeded	Exceeded
Left	335	54	n/a	Exceeded	Exceeded	Exceeded
Left	400	51	n/a	Exceeded	Exceeded	Exceeded
Left	400	54	n/a	Exceeded	Exceeded	Exceeded
Right	210	41	n/a	n/a	Exceeded	Exceeded
Right	210	44	n/a	n/a	Exceeded	Exceeded
Right	250	41	n/a	n/a	Exceeded	Exceeded
Right	250	44	n/a	n/a	Exceeded	Exceeded
Right	335	51	n/a	Exceeded	Exceeded	Exceeded
Right	335	54	n/a	Exceeded	Exceeded	Exceeded
Right	400	51	n/a	Exceeded	Exceeded	Exceeded
Right	400	54	n/a	Exceeded	Exceeded	Exceeded
Straight	0	61	n/a	Met	Met	Met
Straight	0	69	n/a	Met	Met	Met

In general, the first and second repetitions matched for NHTSA same direction scenarios with Harley Davidson motorcycle stimulus taillamp and ADB-equipped Lexus NX300. Differences between the first and second test set repetitions all involved the 29.9 - 15 m measurement distance sub-range. Disagreement between the first and second repetitions were present in the following scenarios:

- Left 115-m curve at 26 mph
- Left 115-m curve at 29 mph
- Left 400-m curve at 54 mph
- Right 210-m curve at 41 mph
- Right 210-m curve at 44 mph
- Right 250-m curve at 41 mph
- Right 250-m curve at 44 mph
- Right 335-m curve at 51 mph,
- Right 335-m curve at 54 mph

- Right 400-m curve at 51 mph
- Right 400-m curve at 54 mph

Only 2 of these 11first-second repetition differences results in a difference in test outcome. Both the 26 mph and 29 mph left 115-m curve test scenarios had different test outcomes for the first and second test repetitions.

Overall, testing of an ADB-equipped vehicle per the NHTSA ADB test scenarios showed that while some differences in illuminance across test repetitions were seen in some cases, in most cases those differences did not result in a difference in test outcome (i.e., pass or fail).

6.6 Results For Testing of an ADB-Equipped Vehicle Per the SAE J3069 ADB Test Procedure

Testing of the SAE J3069 test procedure was performed to support discussion of any differences between the NHTSA and SAE test procedures. Data and information were needed to be able to effectively discuss the trade-offs between gains in realism of test scenarios, afforded by the NHTSA test procedure, versus repeatability and efficiency of testing.

As part of this effort, it was desired to assess the level of effort involved in carrying out the SAE test procedure. In general, there was approximately 2 minutes between test trials of the same lamp type and approximately 5 minutes between trials in which the stimulus lamp(s) had to be changed, resulting in approximately 45 minutes of test time (how long the procedure takes to run) to complete the full set of 18 scenarios one time.

A single ADB-equipped vehicle (Lexus NX300) was run in ADB mode such that the data could be analyzed and test scenario outcome determined. The Lexus NX300 was a European mass production model modified to meet United States VOR (visually optically aligned right) standards and to have lower and upper beam patterns compliant with FMVSS No. 108[11]. While the vehicle was equipped with ADB, the ADB system was not designed to pass the SAE J3069 ADB test procedure.

As part of this assessment, each test scenario was run at two different speeds, where 28 mph represented a minimum speed at which the ADB system was active and 61 mph represented operation at a higher speed similar to that run in NHTSA ADB test procedure straight test scenarios.

The vehicle was also run in lower beam mode for each steady-lamp test scenario for comparison to the ADB results. Each of the four SAE lamp conditions was run in their respective scenarios as shown in the following test matrix. The matrix was completed twice during testing, creating two repetitions of data for comparison.

[11] Based on communication from Toyota. NHTSA did not test this vehicle's lower beam photometry to confirm FMVSS No. 108 compliance.

Table 119. *SAE J3069 Test Matrix, All SAE Lamps, ADB-Equipped Vehicle (Lexus NX300)*

Direction	SAE Lamp Type	SAE Fixture Location	SAE Lamp Status	Trial Number
Opposing	SAE Car/Truck Headlamps	1 (2 lanes left of ADB test lane)	Steady	1
		2 (1 lane right of ADB test lane)	Steady	2
		3 (2 lanes right of ADB test lane)	Steady	3
	SAE Motorcycle Headlamp	1 (2 lanes left of ADB test lane)	Steady	4
			Sudden Reveal	5
		2 (1 lane right of ADB test lane)	Steady	6
			Sudden Reveal	7
		3 (2 lanes right of ADB test lane)	Steady	8
			Sudden Reveal	9
Preceding	SAE Car/Truck Taillamps	1 (2 lanes left of ADB test lane)	Steady	10
		2 (1 lane right of ADB test lane)	Steady	11
		3 (2 lanes right of ADB test lane)	Steady	12
	SAE Motorcycle Taillamp	1 (2 lanes left of ADB test lane)	Steady	13
			Sudden Reveal	14
		2 (1 lane right of ADB test lane)	Steady	15
			Sudden Reveal	16
		3 (2 lanes right of ADB test lane)	Steady	17
			Sudden Reveal	18

*Note: ADB test lane width is 3.66 m.

Tables in the following sections provide summaries of both lower beam and ADB headlighting system performance as assessed via the SAE J3069 test procedure. The tables provide results for glare limit conformance by measurement distance for each scenario. Whenever the result is coupled with a parenthetical reference, that reference provides details as to the test assessment condition in which the ADB result is compared to the lower beam value, answering whether the ADB value was less than the SAE J3069 test procedure criterion of 1.25 times the lower beam value, despite being above the glare limit. For instance, a ‘Met (< LB)’ in the table indicates the ADB value was over the actual glare limit but below 1.25 times the lower beam value.

6.6.1 ADB-Equipped Vehicle Results for SAE Test Procedure with Car/Truck Stimulus Lamps

The following table provides test results for the first repetition of the SAE J3069 test procedure using the opposing car/truck headlamps.

Table 120. SAE J3069 Glare Limit Conformance - Opposing, Car/Truck Headlamps, ADB (Lexus NX300), First Repetition

SAE Fixture Location	Lamp Presentation	Lamp Mode	Test Vehicle Speed (mph)	155 m	120 m	60 m	30 m
1	Steady	Lower	61	Met	Met	Met	Met
1	Steady	ADB	28	Met	Met	Met	Met
1	Steady	ADB	61	Met	Met	Met	Met
2	Steady	Lower	61	Met	Met	Met	Met
2	Steady	ADB	28	Met	Met	Met	Met
2	Steady	ADB	61	Met	Met	Met	Met
3	Steady	Lower	61	Exceeded	Exceeded	Met	Met
3	Steady	ADB	28	Exceeded	Met (<LB)	Met (<LB)	Met
3	Steady	ADB	61	Met (<LB)	Met (<LB)	Met (<LB)	Met

The following table provides test results for the second repetition of the SAE J3069 test procedure using the opposing car/truck headlamps.

Table 121. SAE J3069 Glare Limit Conformance - Opposing, Car/Truck Headlamps, ADB (Lexus NX300), Second Repetition

SAE Fixture Location	Lamp Presentation	Lamp Mode	Test Vehicle Speed (mph)	155 m	120 m	60 m	30 m
1	Steady	Lower	61	Met	Met	Met	Met
1	Steady	ADB	28	Met	Met	Met	Met
1	Steady	ADB	61	Met	Met	Met	Met
2	Steady	Lower	61	Met	Met	Met	Met
2	Steady	ADB	28	Met	Met	Met	Met
2	Steady	ADB	61	Met	Met	Met	Met
3	Steady	Lower	61	Exceeded	Exceeded	Met	Met
3	Steady	ADB	28	Met (<LB)	Met (<LB)	Met (<LB)	Met
3	Steady	ADB	61	Met (<LB)	Met (<LB)	Met (<LB)	Met

Most first and second repetition SAE opposing scenario test trials performed with car/truck stimulus headlamps met glare limits and matched across repetitions. The Lexus NX300 lower beams exceeded two of four glare limits for the SAE fixture position 3 scenario with steady lamps and 61 mph speed. The Lexus NX300 ADB system met all glare limits for scenarios run with car/truck headlamps except for one condition for which there was disagreement between the first and second repetitions:

- SAE fixture location 3 with steady lamps in ADB mode at 28 mph, measurement distance 155 m

This difference in results for this test scenario was associated with a difference in test outcome for this test scenario condition.

The following tables provide test results for the first (Table 122) and second (Table 123) repetitions of the SAE J3069 test procedure using the car/truck taillamps.

Table 122. *SAE J3069 Glare Limit Conformance - Preceding, Car/Truck Taillamps, ADB (Lexus NX300), First Repetition*

SAE Fixture Location	Lamp Presentation	Lamp Mode	Test Vehicle Speed (mph)	155 m	120 m	60 m	30 m
1	Steady	Lower	61	Met	Met	Met	Met
1	Steady	ADB	28	Met	Met	Met	Met
1	Steady	ADB	61	Met	Met	Met	Met
2	Steady	Lower	61	Met	Met	Met	Met
2	Steady	ADB	28	Met	Met	Met	Met
2	Steady	ADB	61	Met	Met	Met	Met
3	Steady	Lower	61	Met	Met	Met	Met
3	Steady	ADB	28	Met	Met	Met	Met
3	Steady	ADB	61	Met	Met	Met	Met

Table 123. *SAE J3069 Glare Limit Conformance - Preceding, Car/Truck Taillamps, ADB (Lexus NX300), Second Repetition*

SAE Fixture Location	Lamp Presentation	Lamp Mode	Test Vehicle Speed (mph)	155 m	120 m	60 m	30 m
1	Steady	Lower	61	Met	Met	Met	Met
1	Steady	ADB	28	Met	Met	Met	Met
1	Steady	ADB	61	Met	Met	Met	Met
2	Steady	Lower	61	Met	Met	Met	Met
2	Steady	ADB	28	Met	Met	Met	Met
2	Steady	ADB	61	Met	Met	Met	Met
3	Steady	Lower	61	Met	Met	Met	Met
3	Steady	ADB	28	Met	Met	Met	Met
3	Steady	ADB	61	Met	Met	Met	Met

The Lexus NX300 lower beams and ADB met glare limits in all SAE preceding scenarios and both repetitions run with car/truck taillamps.

6.6.2 ADB-Equipped Vehicle Results for SAE J3069 Test Procedure with Motorcycle Stimulus Lamps

The following tables provide results for testing of the ADB-equipped Lexus NX300 per the SAE J3069 test procedure opposing test scenarios using the motorcycle stimulus headlamp. Table 124 contains results of the first test repetition and Table 125 contains results of the second repetition.

Table 124. *SAE J3069 Glare Limit Conformance - Opposing, Motorcycle Headlamp, ADB (Lexus NX300), First Repetition*

SAE Fixture Location	**Lamp Presentation**	**Lamp Mode**	**Test Vehicle Speed (mph)**	**155 m**	**120 m**	**60 m**	**30 m**
1	Steady	Lower	61	Met	Met	Met	Met
1	Steady	ADB	28	Exceeded	Exceeded	Met	Met
1	Steady	ADB	61	Exceeded	Exceeded	Exceeded	Met
1	**Sudden**	ADB	28	Exceeded	Exceeded	Met	Met
1	**Sudden**	ADB	61	Exceeded	Exceeded	Exceeded	Met
2	Steady	Lower	61	Met	Met	Met	Met
2	Steady	ADB	28	Exceeded	Exceeded	Met	Met
2	Steady	ADB	61	Exceeded	Exceeded	Exceeded	Met
2	**Sudden**	ADB	28	Exceeded	Exceeded	Met	Met
2	**Sudden**	ADB	61	Exceeded	Exceeded	Met	Met
3	Steady	Lower	61	Exceeded	Exceeded	Met	Met
3	Steady	ADB	28	Exceeded	Exceeded	Met	Met
3	Steady	ADB	61	Exceeded	Exceeded	Exceeded	Exceeded
3	**Sudden**	ADB	28	Exceeded	Exceeded	Met	Met
3	**Sudden**	ADB	61	Exceeded	Exceeded	Exceeded	Exceeded

The first test repetition found the ADB system to exceed at least two glare limits in all tested scenarios, including six sudden appearance trials, except one (Fixture location 1 at 61 mph). The NX300 in lower beam mode met all glare limits for two test scenarios.

Table 125. *SAE J3069 Glare Limit Conformance - Opposing, Motorcycle Headlamp, ADB (Lexus NX300), Second Repetition*

SAE Fixture Location	**Lamp Presentation**	**Lamp Mode**	**Test Vehicle Speed (mph)**	**155 m**	**120 m**	**60 m**	**30 m**
1	Steady	Lower	61	Met	Met	Met	Met
1	Steady	ADB	28	Exceeded	Exceeded	Met	Met
1	Steady	ADB	61	Exceeded	Exceeded	Exceeded	Met
1	**Sudden**	ADB	28	Exceeded	Exceeded	Met	Met
1	**Sudden**	ADB	61	Exceeded	Exceeded	Met	Met
2	Steady	Lower	61	Met	Met	Met	Met
2	Steady	ADB	28	Met	Met	Met	Met
2	Steady	ADB	61	Exceeded	Exceeded	Exceeded	Met
2	**Sudden**	ADB	28	Exceeded	Exceeded	Met	Met
2	**Sudden**	ADB	61	Exceeded	Exceeded	Met	Met
3	Steady	Lower	61	Exceeded	Exceeded	Met	Met
3	Steady	ADB	28	Exceeded	Exceeded	Met	Met
3	Steady	ADB	61	Exceeded	Exceeded	Exceeded	Exceeded
3	**Sudden**	ADB	28	Exceeded	Exceeded	Met	Met
3	**Sudden**	ADB	61	Exceeded	Exceeded	Exceeded	Exceeded

In general, the first and second repetitions matched for SAE opposing scenarios using motorcycle headlamp and ADB-equipped Lexus NX300. Disagreement between the first and second repetitions were present in the following scenarios:

- SAE fixture location 1 with sudden appearance lamps in ADB mode at 61 mph at measurement distance 60 m
- SAE fixture location 2 with steady lamps in ADB mode at 28 mph at measurement distances 155 m and 120 m

The following figure illustrates illuminance versus distance for the opposing SAE scenario with test fixture in location 2 and steady motorcycle headlamp stimulus run with the Lexus NX300 in ADB mode traveling at 28 mph. The system exceeded two glare limits in the first repetition where the stimulus was not recognized until midway between 100 and 50 m from the test fixture but passed the second repetition. However, if this trial data were evaluated per the NHTSA glare limit criteria and approach, both trials would have exceeded glare limits.

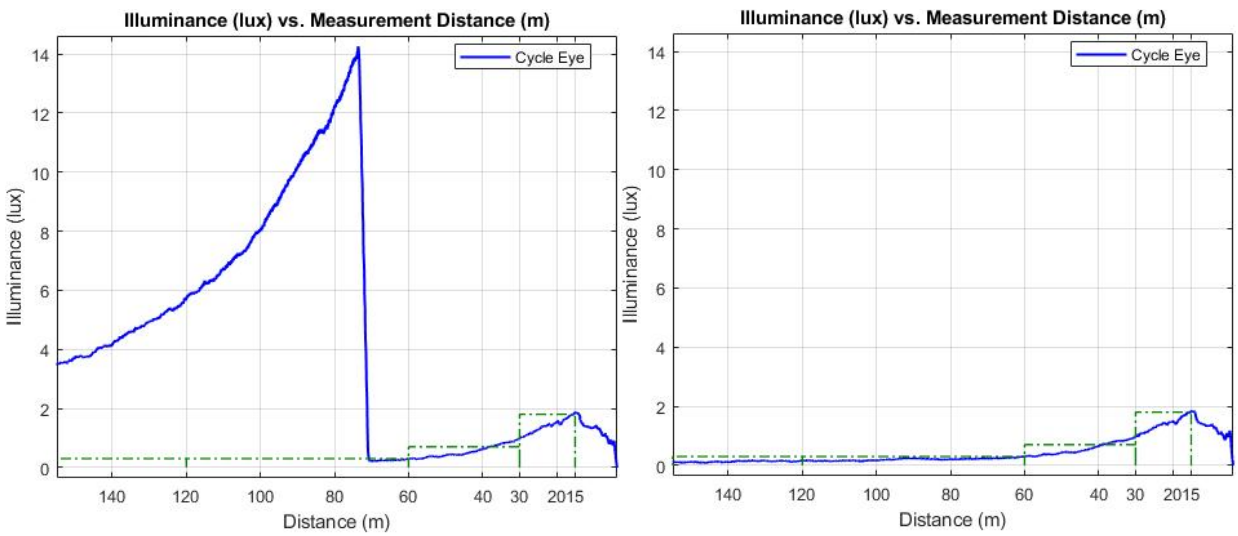

Figure 53. *Plots for Opposing Straight, SAE Fixture Position 2, Steady Motorcycle Stimulus Headlamp, ADB (Lexus NX300), at 28 mph, Both Repetitions (LexusSAEADB_0030, LexusSAE2_0124)*

The following figures illustrate results shown in Tables 124 and 125 for the Fixture Position 3 scenario with sudden lamp presentation. Both the first and second repetitions showed the pattern of 60 and 30 m glare limit exceedances for the 28 mph trials and all glare limits exceeded for the 61 mph trials.

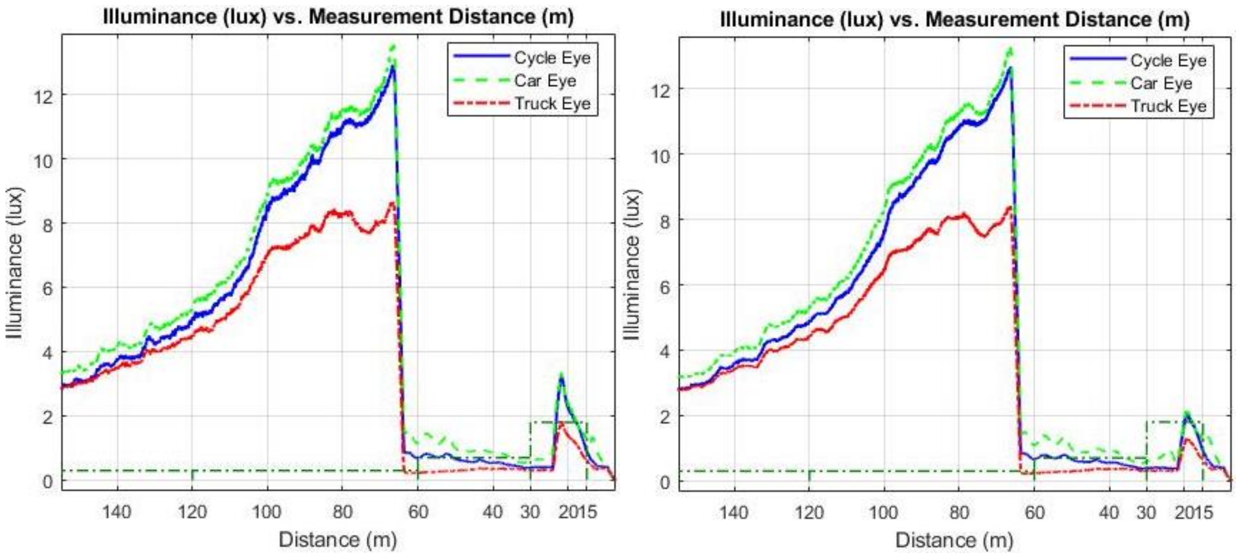

Figure 54. *Plots for SAE J3069 Opposing, Motorcycle Headlamp Sudden Appearance, ADB (Lexus NX300), 28 mph, First and Second Repetitions (LexusSAE2_132, LexusSAEADB_0038)*

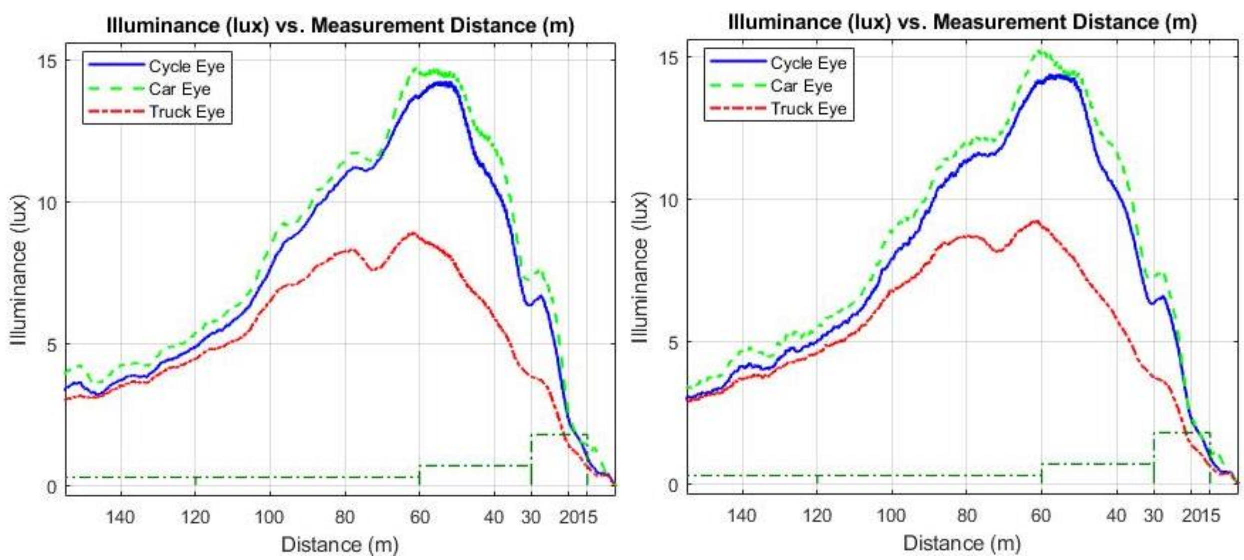

Figure 55. *Plots for SAE J3069 Opposing, Motorcycle Headlamp Sudden Appearance, ADB (Lexus NX300), 61 mph, First and Second Repetitions (LexusSAEADB_0039, LexusSAE2_0133)*

The following table provides test results for the first repetition of the SAE J3069 test procedure using the preceding motorcycle taillamp.

Table 126. *SAE J3069 Glare Limit Conformance - Preceding, Motorcycle Taillamp, ADB (Lexus NX300), First Repetition*

SAE Fixture Location	Lamp Presentation	Lamp Mode	Test Vehicle Speed (mph)	155 m	120 m	60 m	30 m
1	Steady	Lower	61	Met	Met	Met	Met
1	Steady	ADB	28	Met	Met	Met	Met
1	Steady	ADB	61	Met	Met	Met	Met
1	**Sudden**	ADB	28	Met	Exceeded	Exceeded	Met
1	**Sudden**	ADB	61	Met	Exceeded	Exceeded	Met
2	Steady	Lower	61	Met	Met	Met	Met
2	Steady	ADB	28	Met	Met	Met	Met
2	Steady	ADB	61	Met	Met	Met	Met
2	**Sudden**	ADB	28	Met	Exceeded	Exceeded	Exceeded
2	**Sudden**	ADB	61	Met	Exceeded	Exceeded	Exceeded
3	Steady	Lower	61	Met	Met	Met	Met
3	Steady	ADB	28	Met	Exceeded	Exceeded	Met
3	Steady	ADB	61	Met	Exceeded	Exceeded	Met
3	**Sudden**	ADB	28	Met	Exceeded	Exceeded	Met
3	**Sudden**	ADB	61	Met	Exceeded	Exceeded	Met

The following table provides test results for the second repetition of the SAE J3069 test procedure using the preceding motorcycle taillamp.

Table 127. *SAE J3069 Glare Limit Conformance - Preceding, Motorcycle Taillamp, ADB (Lexus NX300), Second Repetition*

SAE Fixture Location	Lamp Presentation	Lamp Mode	Test Vehicle Speed (mph)	155 m	120 m	60 m	30 m
1	Steady	Lower	61	Met	Met	Met	Met
1	Steady	ADB	28	Met	Exceeded	Exceeded	Met
1	Steady	ADB	61	Met	Met	Met	Met
1	**Sudden**	ADB	28	Met	Exceeded	Exceeded	Met
1	**Sudden**	ADB	61	Met	Exceeded	Exceeded	Met
2	Steady	Lower	61	Met	Met	Met	Met
2	Steady	ADB	28	Met	Met	Met	Met
2	Steady	ADB	61	Met	Met	Met	Met
2	**Sudden**	ADB	28	Met	Exceeded	Exceeded	Exceeded
2	**Sudden**	ADB	61	Met	Exceeded	Exceeded	Exceeded
3	Steady	Lower	61	Met	Met	Met	Met
3	Steady	ADB	28	Met	Exceeded	Exceeded	Met
3	Steady	ADB	61	Met	Exceeded	Exceeded	Met
3	**Sudden**	ADB	28	Met	Exceeded	Exceeded	Met
3	**Sudden**	ADB	61	Met	Exceeded	Exceeded	Met

Test results for the Lexus N300 ADB in the preceding SAE fixture position 1 scenario with steady motorcycle taillamps at 28 mph, the system met all glare limits for the first trial, but exceeded two of three glare limits in the second repetition. The following figure illustrates the data from those two test repetitions for comparison.

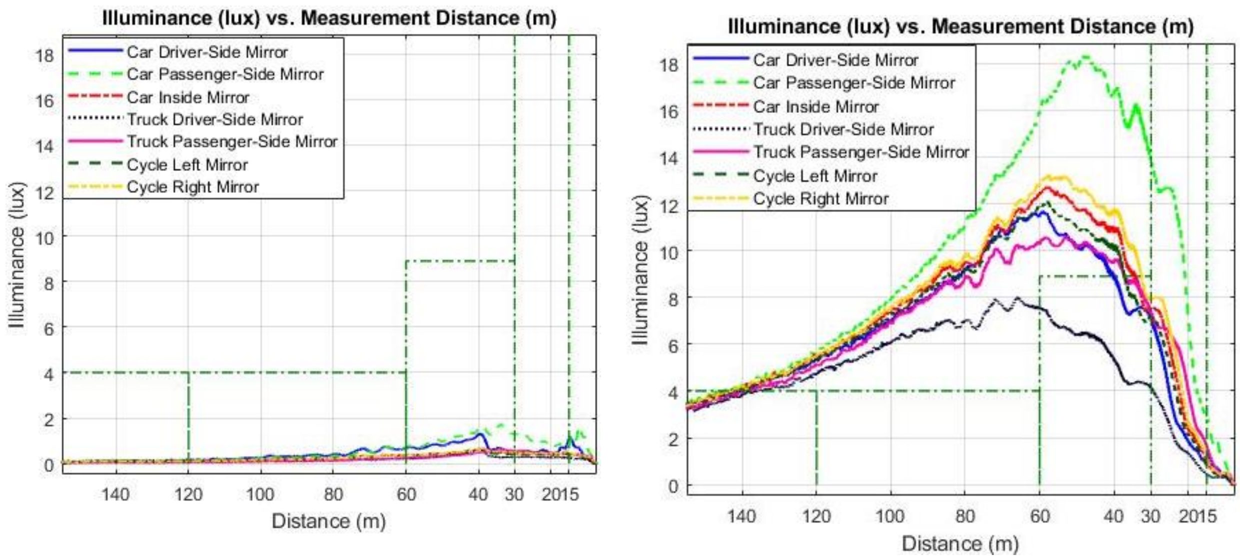

Figure 56. *Plots for SAE J3069 Preceding SAE Fixture Position 1, Motorcycle Taillamp Steady Presentation, ADB (Lexus NX300), 28 mph, First and Second Repetitions (LexusSAEADB_0040, LexusSAE2_0134)*

Test results for the same scenario and conditions but run at 61 mph showed all glare limits met in both repetitions. The following figure illustrates data from those two test repetitions for comparison.

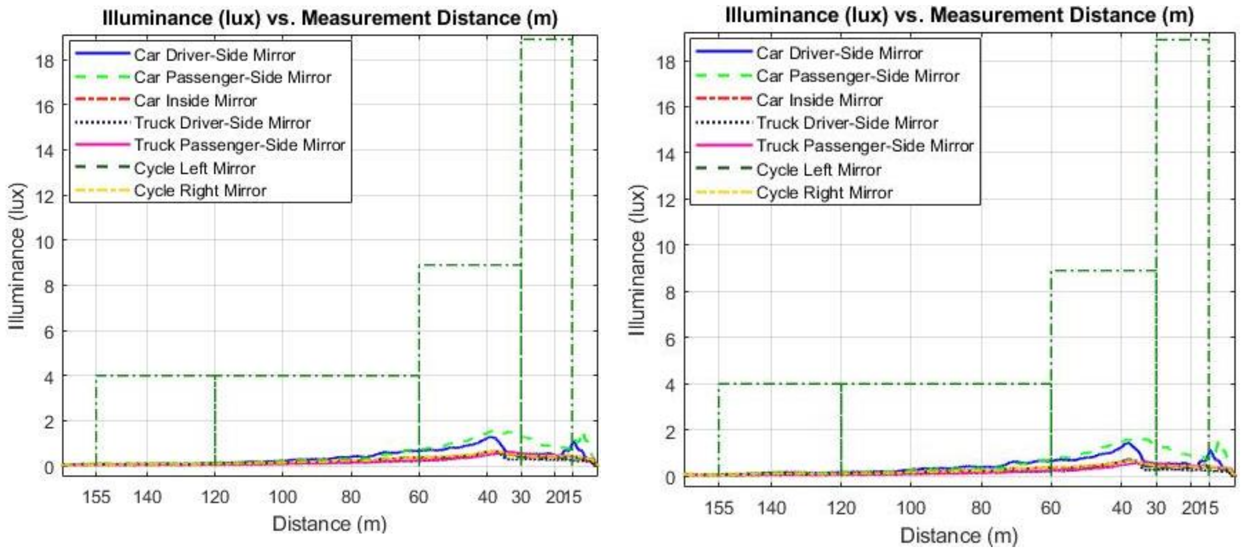

Figure 57. *Plots for SAE J3069 Preceding SAE Fixture Position 1, Motorcycle Taillamp Steady Presentation, ADB (Lexus NX300), 61 mph, First and Second Repetitions (LexusSAEADB_0041, LexusSAE2_0135)*

Lexus NX300 lower beams met glare limits for all trials of SAE preceding scenarios performed with the motorcycle taillamp stimulus. The vehicle's ADB system met glare limits for both repetitions with SAE fixture position 2 and for one of two repetitions with SAE fixture position 1. The first and second repetitions of SAE preceding scenarios performed with motorcycle taillamp stimulus matched for all test conditions except SAE fixture position 1 with steady lamps for ADB mode at 28 mph, with glare limit exceedances at measurement distances of 120 m and 60 m, as was illustrated in the prior figures.

The tables in this section showed results by measurement distance, with a mix of compliance outcomes varying by fixture location, test vehicle speed, and measurement distance. While performing this set of tests using an ADB-equipped test vehicle in both lower beam and ADB modes, two aspects of the test procedure were identified as possible issues: the open-ended test vehicle speed selection and the variable sudden reveal distance. Both factors could affect test outcome unknowingly during the performance of a single test. For example, in the table above, the ADB mode trial results for SAE Fixture Location 1 with steady lamp presentation at 28 and 61 mph, where test vehicle speed was the only difference, did not agree. There are glare exceedances at both 120 m and 60 m measurement distances for the 28-mph trial, while the higher speed trial met the glare limits at those distances.

6.7 Comparison of ADB Test Procedure Results For Testing Using a Test Fixture Versus Stimulus Vehicle

Testing was also conducted using a production stimulus vehicle rather than a test fixture as the stimulus to assess how those results would compare to test fixture based results. Ideally, the measured illuminance values would be the same or at least very similar and test outcomes from the two stimulus types would agree. For lower beam mode, similar results would confirm that vehicle body reflections did not substantially impact illuminance values. For ADB mode, similar results would confirm that the test vehicle's ADB recognition system was not performing differently in response to the test fixture as it would in response to a real vehicle.

For all test fixture trials, the stimulus lamps were either the NHTSA Ford F-150 headlamps or taillamps or the SAE car/truck headlamps or taillamps, as appropriate for the test procedure being conducted. Test scenarios were performed using one test vehicle, a Lexus NX300 in both lower beam and ADB modes.

6.7.1 Stimulus Vehicle (Ford F-150) Description

A U.S. market production vehicle provided the "other/stimulus vehicle" headlighting system for eliciting the ADB response. It was a 2018 Ford F-150 Super Crew 4x4 with a 145-inch wheelbase, XLT package, and 5.5-ft bed. The truck was equipped with Halogen headlamps, a 5.0L V8, and a 10-speed automatic transmission.

Five illuminance receptor heads were installed on the 2018 Ford F-150 stimulus vehicle.[12] Receptor heads were installed on the exterior of the vehicle to represent the F-150 driver's eye point, F-150 inside rearview mirror, and F-150 passenger-side rearview mirror locations. Two additional receptor heads were used in locations that replicated the heights of test fixture car and truck passenger-side rearview mirror measurement points (i.e., receptor head locations). Additional details of the positions of receptor heads are presented in the following table.

[12] Only five illuminance receptor heads were installed on the 2018 Ford F-150 stimulus vehicle due to limited equipment availability and limitations of the data acquisition equipment being used.

Table 128. *Illuminance Meter Receptor Head Locations for F-150 Truck Stimulus Vehicle*

Stimulus	Scenario	Receptor Head (RH) Number	Receptor Head (RH) Name	Location
Ford F-150	Oncoming	11	F-150 Eye Point	50th Percentile male driver's eye point projected forward to the exterior surface of the windshield
	Same Direction	12	F-150 Inside Rearview Mirror	Mounted at height of, and laterally in line with, center of F-150 inside mirror surface, but with longitudinal position at exterior side of rear window
		13	Car Passenger-Side Rearview Mirror	Mounted at height corresponding to test fixture car passenger-side rearview mirror measurement point, but with lateral and longitudinal dimensions of F-150 passenger-side rearview mirror
		14	F-150 Passenger-Side Rearview Mirror	Mounted at the center of the F-150 passenger-side mirror surface
		15	Truck Passenger-Side Rearview Mirror	Mounted at height corresponding to test fixture truck passenger-side rearview mirror measurement point, but with lateral and longitudinal dimensions of F-150 passenger-side rearview mirror

An illuminance receptor head for the drivers' eye point was attached to the outside of the windshield using a small suction cup. A receptor head for the inside mirror location was similarly attached to the rear window of the pickup cab. One receptor head was positioned at the center of the reflective surface of the F-150 passenger-side rearview mirror. Two additional receptor heads were positioned to represent test fixture measurement point locations for car and truck passenger-side rearview mirrors.

The following figure shows the forward-facing receptor head (RH11) mounted on the F-150 truck, in front of the driver's eye point.

Figure 58. *NHTSA Stimulus Vehicle With Forward-Facing Receptor Head (RH11)*

Figure 58 shows the four rear-facing receptor heads, one mounted on the back window of the truck (RH12) and three mounted on the right side of the truck (RH13, RH14, and RH15). The three passenger-side mirror receptor heads were mounted to a ‘sliding leg C-stand’. For consistent mounting, a bracket was made to attach the C-stand to the mounting bolts of the passenger-side step bar. A large suction cup was used to keep the top of the C-stand stable. The analog outputs of the five receptor heads attached to the Ford F-150 were connected to the VCDAS and converted to CAN inside the system.

Figure 59. *NHTSA Stimulus Vehicle With Rear-Facing Receptor Heads*

For test trials with the F-150 vehicle as the stimulus, the vehicle was positioned such that the vehicle's lamps were in the same longitudinal location as the test fixture's truck lamps.

The following two figures contain drawings that show the relative positions of the illuminance receptor heads on the stimulus vehicle as compared to the receptor heads on the test fixture. As shown in Figure 60, the F-150 stimulus vehicle driver eye point was 0.617 m lower, 0.31 m to the right (toward the driver side), and 0.69 m forward of the truck eye point receptor head on the test fixture. As shown in Figure 61, the car passenger-side mirror receptor head on the F-150 stimulus vehicle was at the same height, 11 cm to the right, and 29 cm aft of the car passenger-side mirror receptor head on the test fixture. The truck passenger-side mirror receptor head on the F-150 stimulus vehicle was at the same height, 11 cm to the right, and 29 cm aft of the truck passenger-side mirror receptor head on the test fixture.

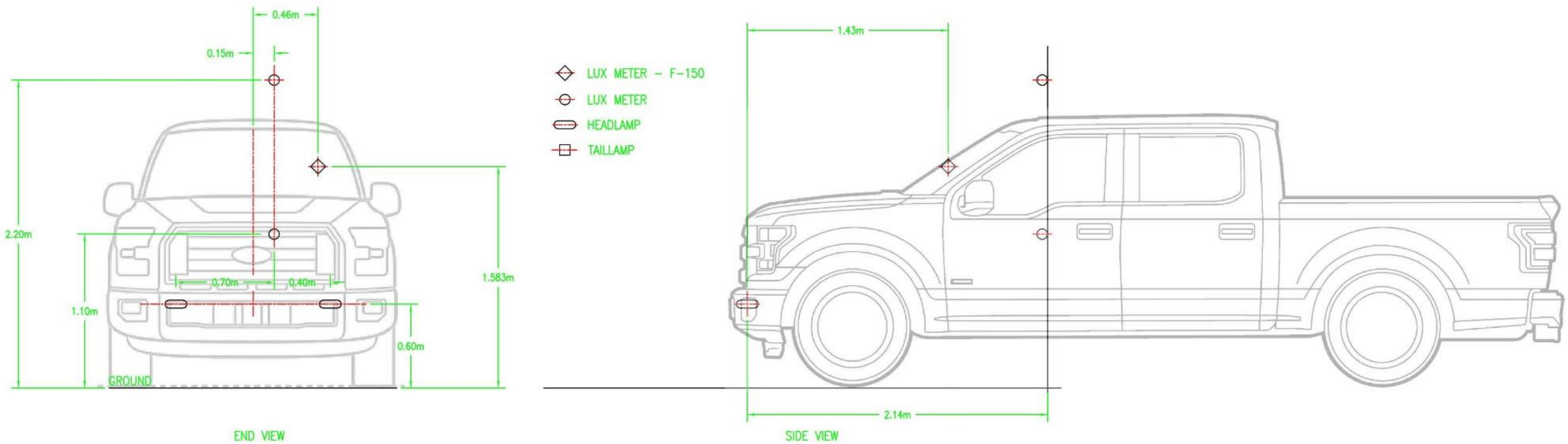

Figure 60. *Dimensioned Drawing of Oncoming Illuminance Receptor Heads as Mounted on F-150 Stimulus Vehicle [9, 10]*

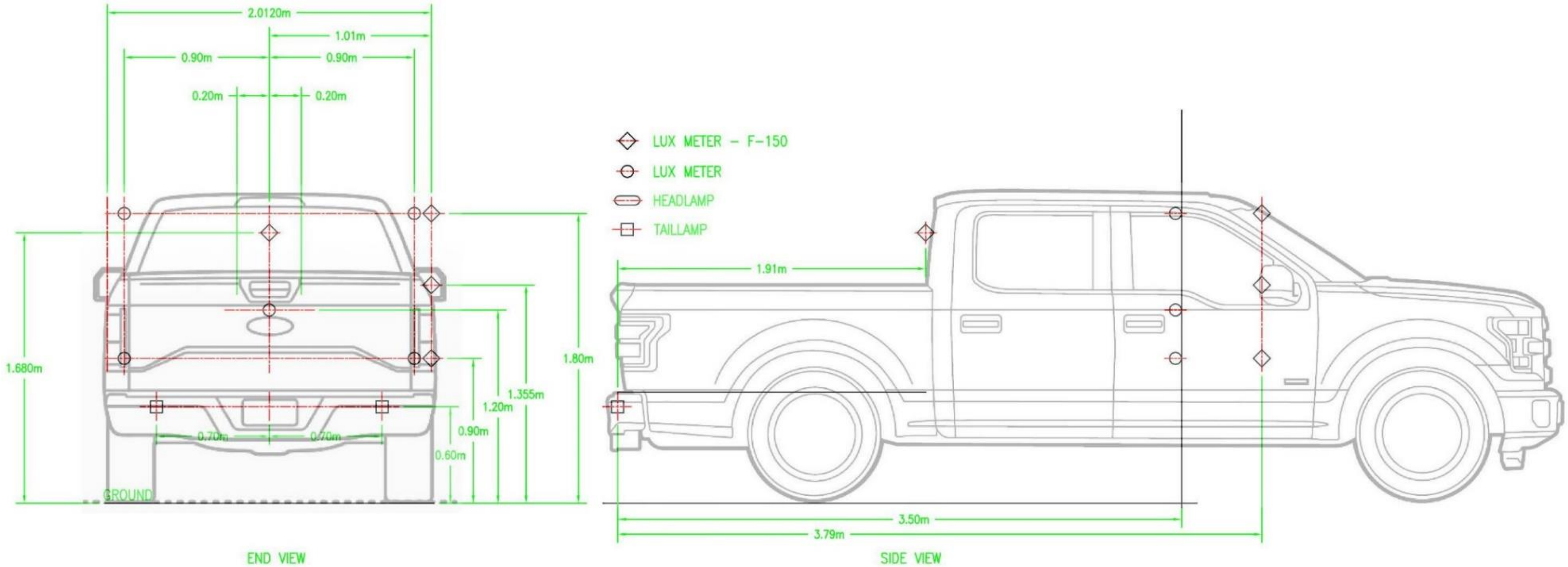

Figure 61. *Dimensioned Drawing of Same Direction Illuminance Receptor Heads as Mounted on F-150 Stimulus Vehicle [9, 10]*

6.7.2 Stimulus Vehicle Versus Test Fixture Comparison, Test Matrix Description

The following tables show the test matrices used to make this comparison. Lower beam trials were run at higher speeds, while ADB trials were run at both a low and higher speed.

Table 129. *Test Matrix For NHTSA Test Procedure With F-150 Stimulus Vehicle*

Lamps	Orientations / Lamp Type	Curve Direction	Radius of Curvature (m)	Vehicle Speed (mph)
Ford F-150 Stimulus Vehicle with OE Lamps	Oncoming (Headlamps) and Same Direction (Taillamps)	Right	210	41
			210	44
			250	41
			250	44
			335	51
			335	54
			400	51
			400	54
		Left	85	26
			85	29
			115	26
			115	29
			210	41
			210	44
			250	41
			250	44
			335	51
			335	54
			400	51
			400	54
		Straight	NA	61
			NA	69

Table 130. *Test Matrix For SAE J3069 Test Procedure With F-150 Stimulus Vehicle*

Orientation	Lamp Type	F-150 in SAE Fixture Location	Lamp Presentation
Opposing	F-150 Truck Headlamps	1 (2 lanes left of ADB test lane)	Steady
			Sudden Reveal
		2 (1 lane left of ADB test lane)	Steady
			Sudden Reveal
		3 (2 lanes right of ADB test lane)	Steady
			Sudden Reveal
Preceding	F-150 Truck Taillamps	1 (2 lanes left of ADB test lane)	Steady
			Sudden Reveal
		2 (1 lane left of ADB test lane)	Steady
			Sudden Reveal
		3 (2 lanes right of ADB test lane)	Steady
			Sudden Reveal

In the test outcome comparison tables in the following sections, results are presented to indicate whether a receptor head's illuminance value "met" or "exceeded" the glare limits associated with each measurement distance sub-range. The last table column indicates whether the test scenario outcome obtained for testing using the F-150 stimulus vehicle was in agreement ("Agree") with the outcome from trials involving use of the test fixture or whether they were in disagreement ("Disagree").

6.7.3 NHTSA ADB Test Procedure Illuminance Results Comparison: Stimulus Vehicle Versus Test Fixture

A single ADB-equipped vehicle (Lexus NX300) was available for testing to assess whether the ADB system performed differently in test trials with the test fixture outfitted with F-150 truck OEM vehicle headlamps and taillamps versus test trials performed with an actual F-150 stimulus vehicle. Trials were run with each of the NHTSA test fixture lamps and the original equipment lamps on the 2018 Ford F-150 that served as the stimulus vehicle. Scenarios were performed using the Lexus NX300 in ADB mode as well as in lower beam mode. Results for test scenarios or groups of scenarios for which test outcomes were in full agreement are not presented in tables.

6.7.3.1 NHTSA Stimulus Vehicle Versus Test Fixture Comparison - Lower Beam

For oncoming NHTSA test scenarios run with Lexus NX300 in lower beam mode, there was complete agreement in test outcomes between the F-150 stimulus vehicle and the test fixture for all test scenarios except the 400-m right curve. As shown in the table below, results for the Lexus in lower beam mode for the 400-m curve showed the F-150 eye point receptor head recorded a maximum illuminance value that exceeded the 70 - 60 m measurement distance sub-range glare limit for the F-150 stimulus vehicle trial, but the truck eye point receptor head on the test fixture did not exceed the glare limit. However, it should be noted that the test fixture truck eye point was 28.42 cm higher and 49.97 cm to the left of the F-150 driver eye point, and this difference in measurement point location likely had the truck eye point exposed to a the outer, less bright area of the beam pattern.

Table 131. Glare Limit Conformance Comparison for F-150 Stimulus Vehicle and Test Fixture, Oncoming Right Curve 400 m Radius of Curvature, Lexus NX300 (Lower Beams)

Measurement Distance Sub-Range (m)	Radius of Curvature (m)	Curve Direction	Speed (mph)	F-150 Stimulus Vehicle	Test Fixture	Outcome Agreement
				RH11 F-150 Eye Point	RH8 Truck Eye Point	
				Glare Limit	Glare Limit	
70-60	400	Right	54	Exceeded	Met	Disagree
59.9-30	400	Right	54	Met	Met	Agree
29.9-15	400	Right	54	Met	Met	Agree

For same direction NHTSA scenarios with Lexus NX300 in lower beam mode, there was complete agreement in all test outcomes between the F-150 stimulus vehicle and the test fixture. The same direction left curve test scenario illuminance comparison results for the Lexus NX300 operating in lower beam mode are shown in the figures below, providing a closer look at how the stimulus vehicle and test fixture compare when similar receptor head locations are matched up for each radius of curvature test scenario. Figures 61 - 66 show separate plots for each set of comparable or approximately comparable test fixture and stimulus vehicle illuminance receptor heads. In each of these figures, the top plot shows that the F-150 stimulus vehicle inside mirror receptor head tended to have lower illuminance values than the inside mirror receptor head on the test fixture, which was at a height to represent a car inside mirror. The lower F-150 stimulus vehicle inside mirror illuminance values may have been due to the 48 cm difference in height between the two measurement points. Another possible reason for the lower F-150 stimulus vehicle inside mirror illuminance values could be that the body of the stimulus vehicle was partially obstructing the test vehicle lamps from illuminating that measurement point. However, given that a majority of the test scenarios showed the same test outcomes for both stimulus methods with a test vehicle in lower beam mode, vehicle body reflections or obstruction of light from shining on receptor heads did not substantially impact test results.

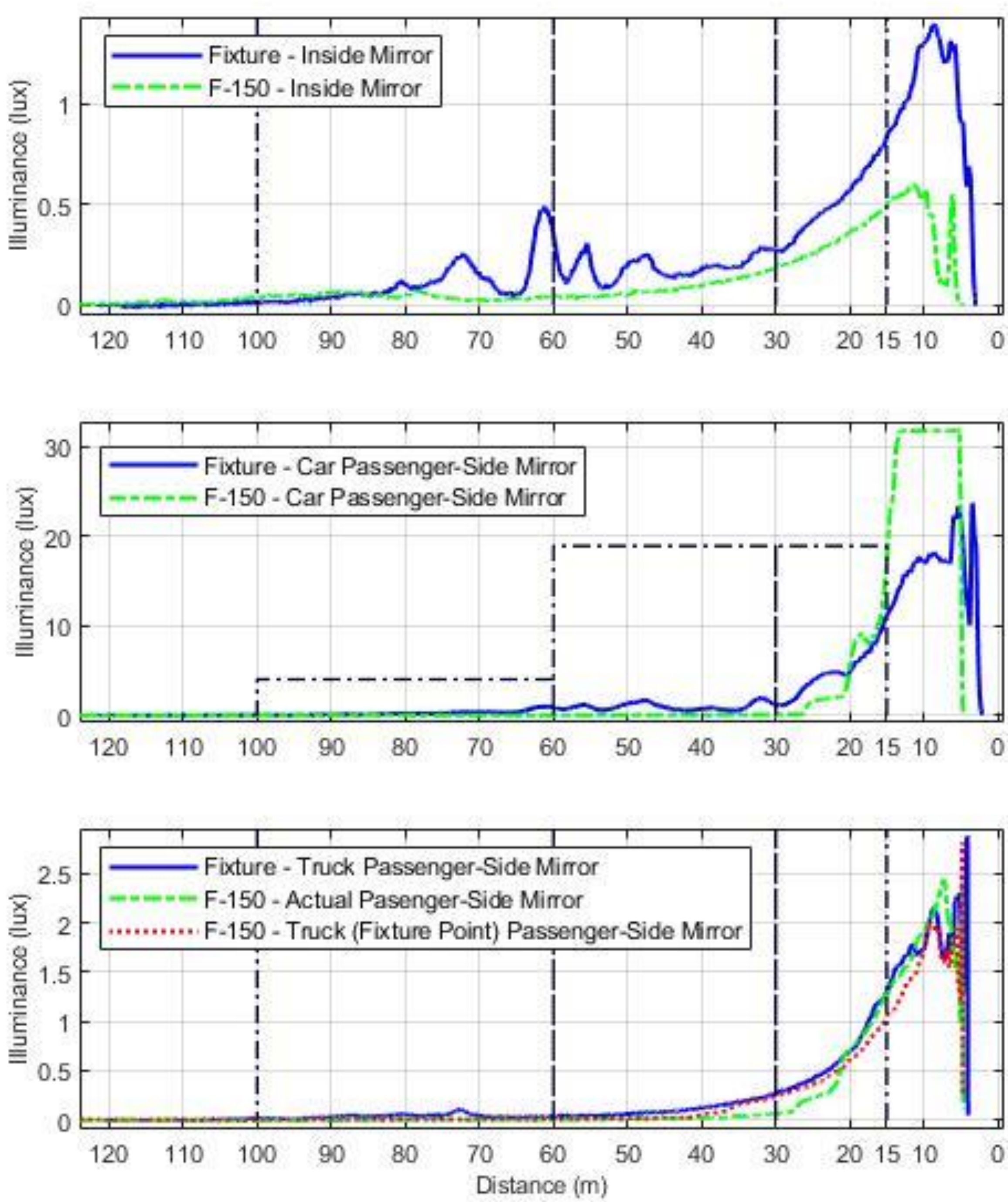

Figure 62. *Fixture Versus F-150, Same Direction Left Curve 85 m Radius of Curvature, Lower Beam (Lexus NX300), at 29 mph (Lexus2_0035, LexusF-150_0053)*

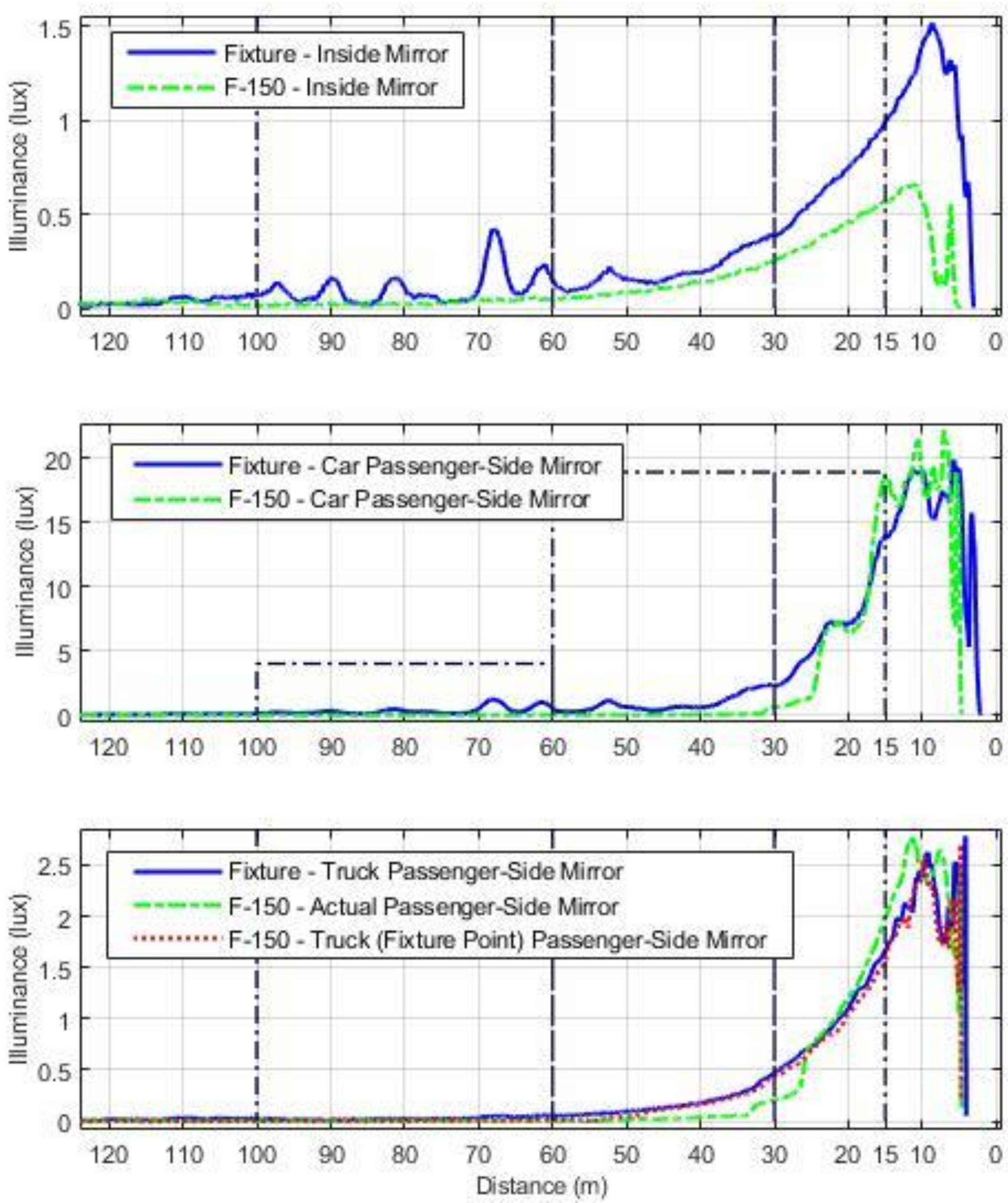

Figure 63. *Fixture Versus F-150, Same Direction Left Curve 115 m Radius of Curvature, Lower Beam (Lexus NX300), at 29 mph (Lexus2_0039, LexusF-150_0056)*

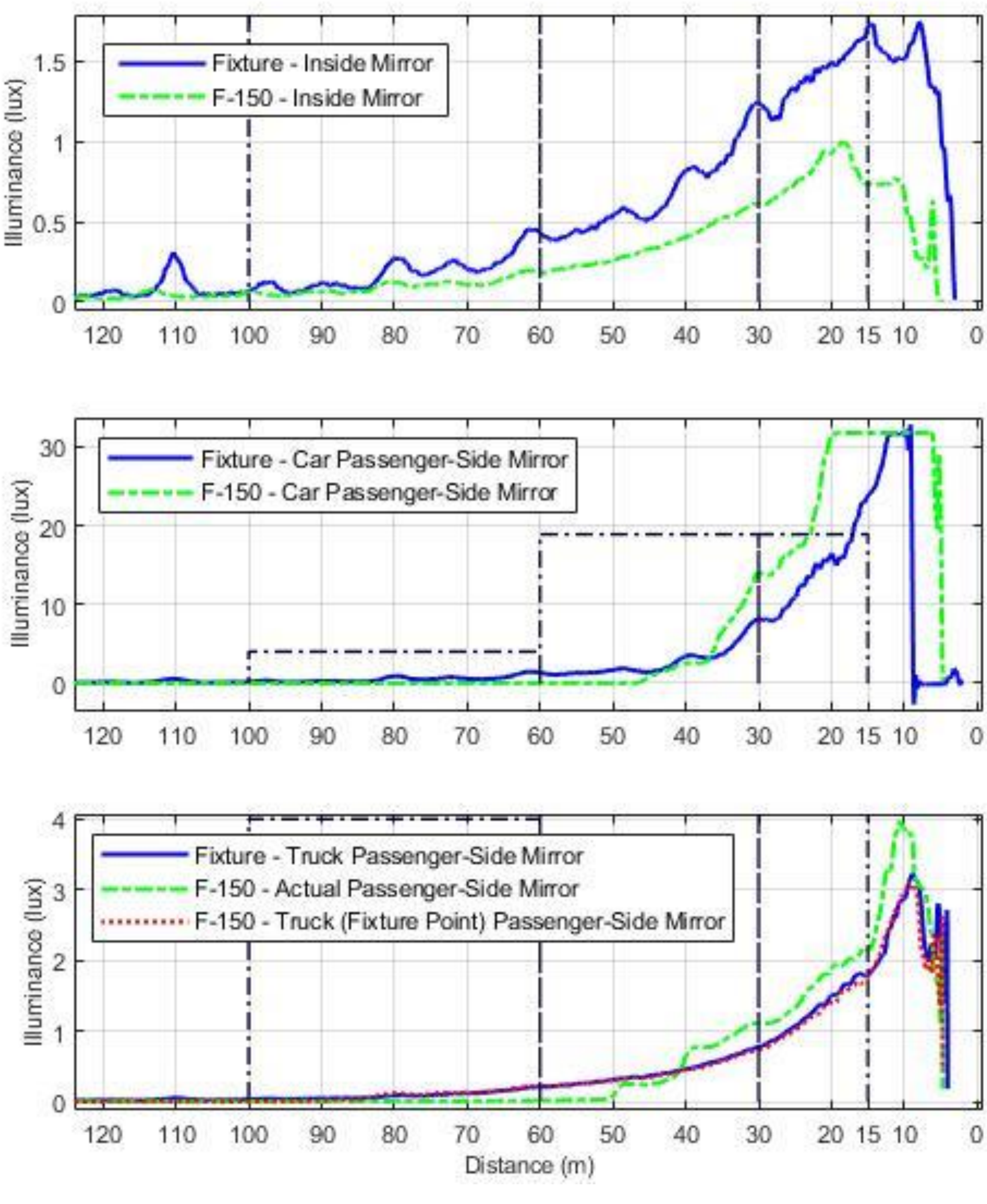

Figure 64. *Fixture Versus F-150, Same Direction Left Curve 210 m Radius of Curvature, Lower Beam (Lexus NX300), at 44 mph (Lexus2_0043, LexusF-150_0059)*

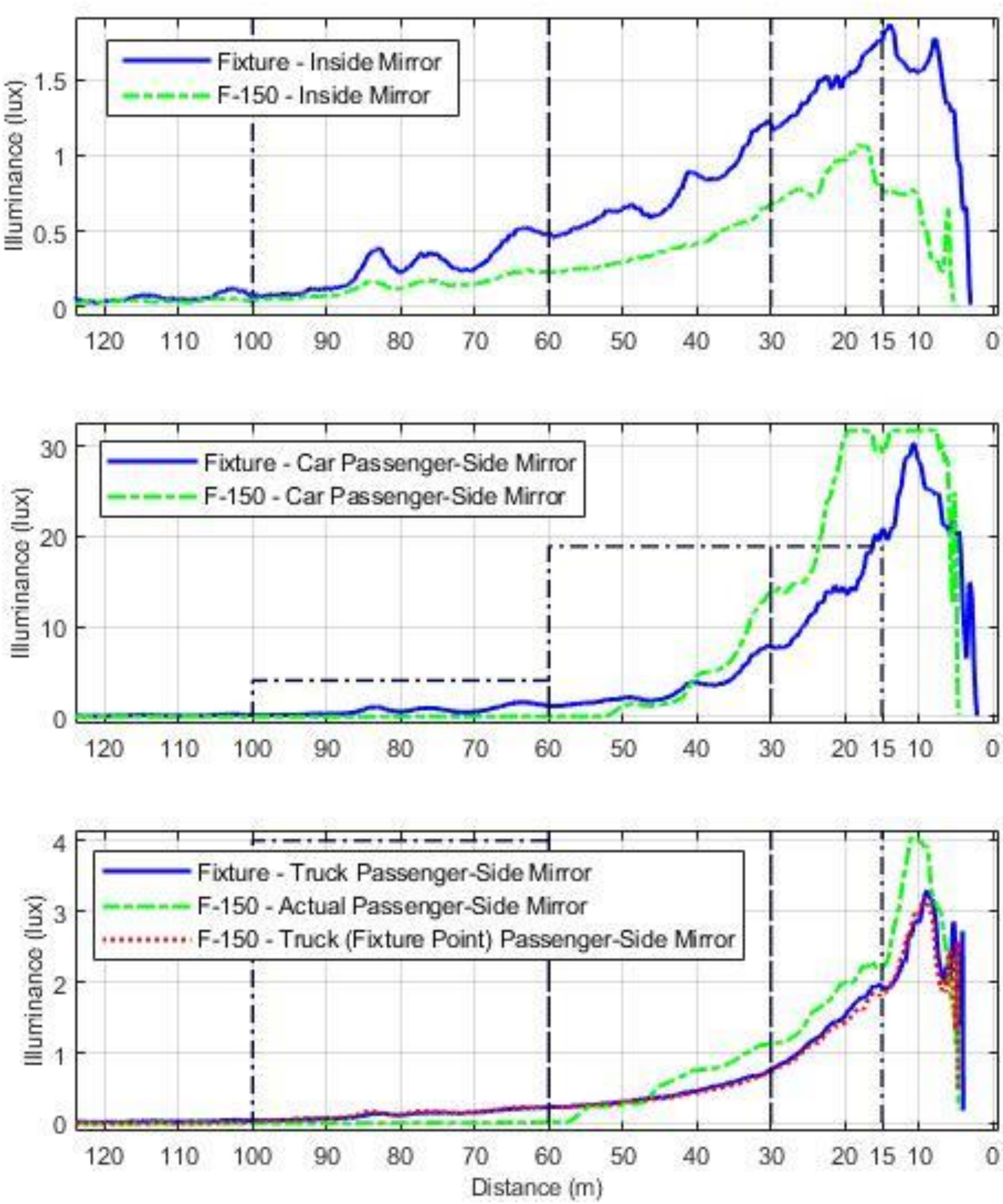

Figure 65. *Fixture Versus F-150, Same Direction Left Curve 250 m Radius of Curvature, Lower Beam (Lexus NX300), at 44 mph (Lexus2_0048, LexusF-150_0062)*

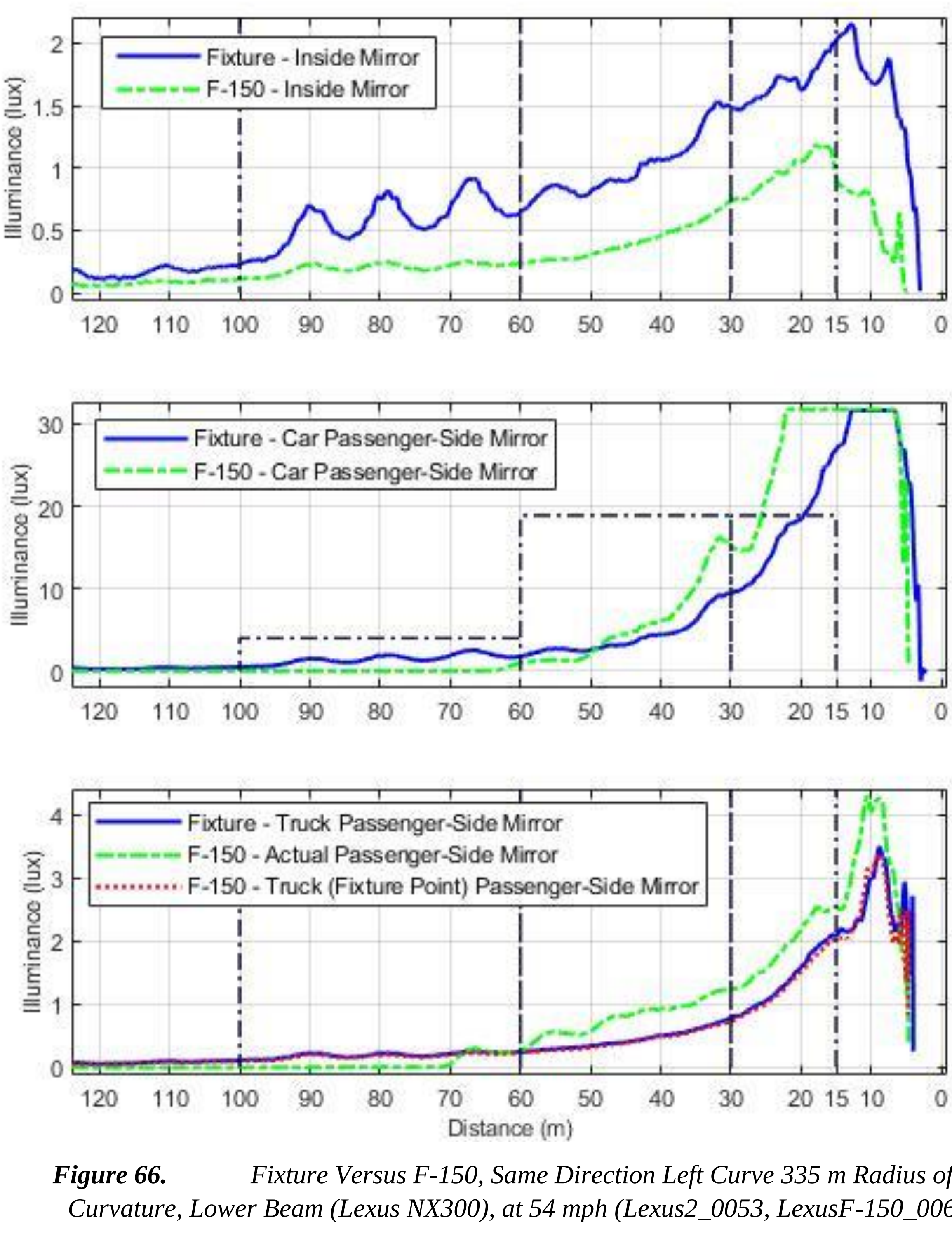

Figure 66. *Fixture Versus F-150, Same Direction Left Curve 335 m Radius of Curvature, Lower Beam (Lexus NX300), at 54 mph (Lexus2_0053, LexusF-150_0065)*

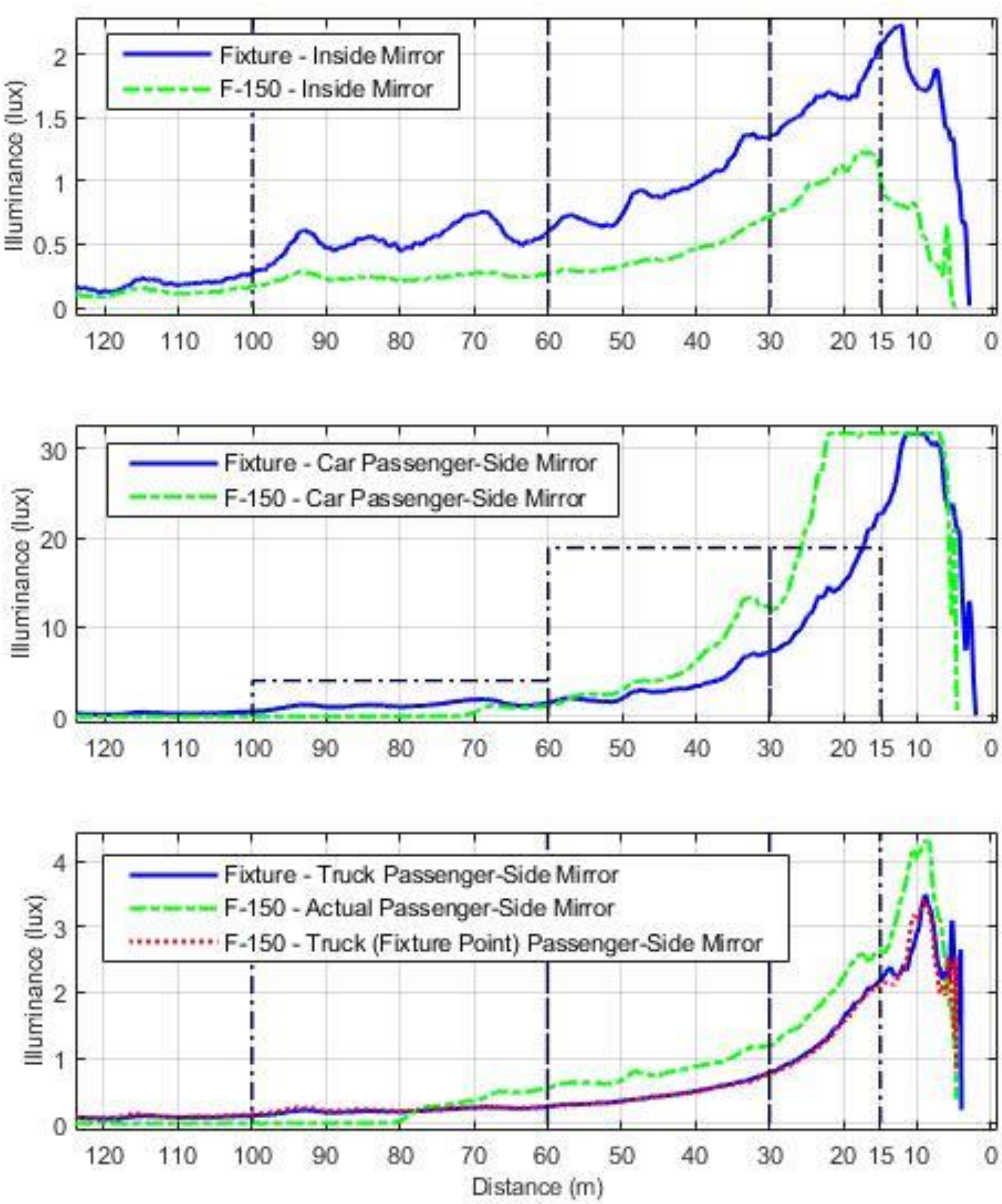

Figure 67. *Fixture Versus F-150, Same Direction Left Curve 400 m Radius of Curvature, Lower Beam (Lexus NX300), at 54 mph (Lexus2_0060, LexusF-150_0068)*

6.7.3.2 NHTSA Stimulus Vehicle Versus Test Fixture Comparison - ADB

For the following oncoming NHTSA scenarios with the Lexus NX300 in ADB mode, there was complete agreement in test outcomes between the F-150 stimulus vehicle and the test fixture for all repetitions:

- left curve with radius of 115 m,
- left curve with radius of 210 m,
- right curve with radius of 210 m,
- left curve with radius of 250 m,
- right curve with radius of 250 m,
- left curve with radius of 335 m,
- left curve with radius of 400 m, and
- straight path.

For the NHTSA oncoming scenarios with the Lexus NX300 in ADB mode, there was outcome disagreement for the following scenarios:

- left curve with a radius of 85 m and a measurement distance sub-range of 59.9 - 30 m,
- right curve with a radius of 335 m and a measurement distance sub-range of 70 - 60 m and a speed of 54 mph, and
- right curve with a radius of 400 m and a measurement distance sub-range of 70 - 60 m.

Tables 132 - 134 summarize the test outcome difference results for oncoming test scenarios conducted with the NHTSA test fixture and F-150 stimulus vehicle for the ADB-equipped Lexus NX300 operated in ADB mode. The truck eye point is the only test fixture measurement point relevant for these test scenarios. For the F-150 stimulus vehicle, the driver's eye point (RF11) is the closest measurement point to the test fixture truck driver eye point (RH8), but does not provide a direct comparison since the position of the F-150 driver eye point did not directly correspond to the RH8 test fixture truck eye point. The test fixture truck driver eye point was 0.617 m higher (and 0.31 m to the right) as it represents a larger size truck than the F-150. In these three oncoming scenarios where outcome disagreement was present, the F-150 eye point receptor head on the stimulus vehicle resulted in a maximum illuminance value which exceeded a glare limit, but the truck eye point receptor head on the test fixture did not exceed a glare limit. The difference in receptor head heights likely meant that the test fixture truck driver eye point receptor head was illuminated by a dimmer portion of the test vehicle's lighting pattern, which increases the likelihood that it would meet glare limits. Separate tables are shown below for oncoming test scenarios in which there was test outcome disagreement.

Table 132. *Glare Limit Conformance Comparison for F-150 Stimulus Vehicle and NHTSA Test Fixture With F-150 Stimulus Headlamps, Oncoming Left Curve 85 m Radius of Curvature, Lexus NX300 (ADB)*

Measurement Distance Sub-Range (m)	Radius of Curvature (m)	Curve Direction	Speed (mph)	F-150 Stimulus Vehicle	Test Fixture	Outcome Agreement
				RH11 F-150 Eye Point	RH8 Truck Eye Point	
				Glare Limit	Glare Limit	
59.9-30	85	Left	26	Exceeded	Met	Disagree
59.9-30	85	Left	29	Exceeded	Met	Disagree
29.9-15	85	Left	26	Met	Met	Agree
29.9-15	85	Left	29	Met	Met	Agree

Table 133. *Glare Limit Conformance Comparison for F-150 Stimulus Vehicle and NHTSA Test Fixture With F-150 Stimulus Headlamps, Oncoming Right Curve 335 m Radius of Curvature, Lexus NX300 (ADB)*

Measurement Distance Sub-Range (m)	Radius of Curvature (m)	Curve Direction	Speed (mph)	F-150 Stimulus Vehicle	Test Fixture	Outcome Agreement
				RH11 F-150 Eye Point	RH8 Truck Eye Point	
				Glare Limit	Glare Limit	
70-60	335	Right	51	Met	Met	Agree
70-60	335	Right	54	Exceeded	Met	Disagree
59.9-30	335	Right	51	Met	Met	Agree
59.9-30	335	Right	54	Met	Met	Agree
29.9-15	335	Right	51	Met	Met	Agree
29.9-15	335	Right	54	Met	Met	Agree

Table 134. *Glare Limit Conformance Comparison for F-150 Stimulus Vehicle and NHTSA Test Fixture With F-150 Stimulus Headlamps, Oncoming Right Curve 400 m Radius of Curvature, Lexus NX300 (ADB)*

Measurement Distance Sub-Range (m)	Radius of Curvature (m)	Curve Direction	Speed (mph)	F-150 Stimulus Vehicle	Test Fixture	Outcome Agreement
				RH11 F-150 Eye Point	RH8 Truck Eye Point	
				Glare Limit	Glare Limit	
70-60	400	Right	51	Exceeded	Met	Disagree
70-60	400	Right	54	Exceeded	Met	Disagree
59.9-30	400	Right	51	Met	Met	Agree
59.9-30	400	Right	54	Met	Met	Agree
29.9-15	400	Right	51	Met	Met	Agree
29.9-15	400	Right	54	Met	Met	Agree

Measurement points of interest for same direction test scenarios were the car (Camry) passenger-side mirror, truck passenger-side mirror, and inside mirror locations. As stated previously, the measurement points on the stimulus vehicle were close but not identical to the measurement points on the test fixture. The car passenger-side mirror receptor head on the F-150 stimulus vehicle was at the same height, 11 cm further to the right, and 29 cm aft of the car passenger-side mirror receptor head on the test fixture. The truck passenger-side mirror receptor head on the F-150 stimulus vehicle was at the same height, 11 cm to the right, and 29 cm aft of the car passenger-side mirror receptor head on the test fixture compared to the truck passenger-side mirror receptor head on the test fixture. These differences in measurement point locations may contribute to differences between test outcomes for the test fixture and stimulus vehicle.

For the following same direction NHTSA scenarios with the Lexus NX300 in ADB mode, there was complete agreement in test outcomes between the F-150 stimulus vehicle and the test fixture for all trials of these conditions:

- left curve with radius of 210 m,
- right curve with radius of 210 m,
- right curve with radius of 250 m,
- left curve with radius of 335 m,
- right curve with radius of 335 m, and
- right curve with radius of 400 m.

For the NHTSA same direction scenarios with the Lexus NX300 in ADB mode, there was outcome disagreement for the following scenarios:

- left curve with radius of 85 m, measurement distance sub-range of 29.9 - 15 m,
- left curve with radius of 115 m, measurement distance sub-range of 29.9 - 15 m and speed of 29 mph,
- left curve with radius of 250 m, measurement distance of 29.9 - 15 m,
- left curve with radius of 400 m, measurement distance sub-range of 29.9 - 15 m and speed of 51 mph, and
- straight path, measurement distance sub-range of 29.9 - 15 m and speed of 69 mph.

Tables 135 - 139 summarize the test outcome difference results for same direction test scenarios conducted with the NHTSA test fixture and F-150 stimulus vehicle. In these same direction scenarios where outcome disagreement was present, with the exception of the left curve with 85 m radius of curvature, the car passenger-side mirror receptor head on the stimulus vehicle resulted in a maximum illuminance value which exceeded the glare limit, while the car passenger-side mirror receptor head on the test fixture did not exceed the glare limit. For the left curve with 85 m radius of curvature and a measurement distance sub-range of 29.9 - 15 m and a speed of 26 mph, the car passenger-side mirror receptor head exceeded the glare limit on the test fixture, but not on the F-150 stimulus vehicle. Additionally, for the left curve with 85 m radius of curvature and a measurement distance sub-range of 29.9 - 15 m and a speed of 29 mph, the truck passenger-side mirror receptor head on the F-150 stimulus vehicle resulted in a maximum illuminance value which exceeded the glare limit, while the truck passenger-side mirror receptor head on the test fixture did not exceed the glare limit.

Table 135. *Glare Limit Conformance Comparison for F-150 Stimulus Vehicle and NHTSA Test Fixture With F-150 Stimulus Taillamps, Same Direction Left Curve 85 m Radius of Curvature, Lexus NX300 (ADB)*

Measurement Distance Sub-Range (m)	Radius of Curvature (m)	Curve Direction	Speed (mph)	F-150 Stimulus Vehicle			Test Fixture			Outcome Agreement		
				RH13 Car PSM	RH12 F-150 Inside Mirror	RH15 Truck PSM	RH7 Car PSM	RH6 Car Inside Mirror	RH10 Truck PSM			
				Glare Limit	Glare Limit	Glare Limit	Glare Limit	Glare Limit	Glare Limit	Car PSM	Inside Mirror	Truck PSM
59.9-30	85	Left	26	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
59.9-30	85	Left	29	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
29.9-15	85	Left	26	Met	Met	Met	Exceeded	Met	Met	Disagree	Agree	Agree
29.9-15	85	Left	29	Exceeded	Met	Exceeded	Exceeded	Met	Met	Agree	Agree	Disagree

Table 136. *Glare Limit Conformance Comparison for F-150 Stimulus Vehicle and NHTSA Test Fixture With F-150 Stimulus Taillamps, Same Direction Left Curve 115 m Radius of Curvature, Lexus NX300 (ADB)*

Measurement Distance Sub-Range (m)	Radius of Curvature (m)	Curve Direction	Speed (mph)	F-150 Stimulus Vehicle			Test Fixture			Outcome Agreement		
				RH13 Car PSM	RH12 F-150 Inside Mirror	RH15 Truck PSM	RH7 Car PSM	RH6 Car Inside Mirror	RH10 Truck PSM			
				Glare Limit	Glare Limit	Glare Limit	Glare Limit	Glare Limit	Glare Limit	Car PSM	Inside Mirror	Truck PSM
59.9-30	115	Left	26	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
59.9-30	115	Left	29	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
29.9-15	115	Left	26	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
29.9-15	115	Left	29	Exceeded	Met	Met	Met	Met	Met	Disagree	Agree	Agree

Table 137. *Glare Limit Conformance Comparison for F-150 Stimulus Vehicle and NHTSA Test Fixture With F-150 Stimulus Taillamps, Same Direction Left Curve 250 m Radius of Curvature, Lexus NX300 (ADB)*

Measurement Distance Sub-Range (m)	Radius of Curvature (m)	Curve Direction	Speed (mph)	F-150 Stimulus Vehicle			Test Fixture			Outcome Agreement		
				RH13 Car PSM	RH12 F-150 Inside Mirror	RH15 Truck PSM	RH7 Car PSM	RH6 Car Inside Mirror	RH10 Truck PSM			
				Glare Limit	Glare Limit	Glare Limit	Glare Limit	Glare Limit	Glare Limit	Car PSM	Inside Mirror	Truck PSM
59.9-30	250	Left	41	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
59.9-30	250	Left	44	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
29.9-15	250	Left	41	Exceeded	Met	Met	Met	Met	Met	Disagree	Agree	Agree
29.9-15	250	Left	44	Exceeded	Met	Met	Met	Met	Met	Disagree	Agree	Agree

Table 138. *Glare Limit Conformance Comparison for F-150 Stimulus Vehicle and NHTSA Test Fixture With F-150 Stimulus Taillamps, Same Direction Left Curve 400 m Radius of Curvature, Lexus NX300 (ADB)*

Measurement Distance Sub-Range (m)	Radius of Curvature (m)	Curve Direction	Speed (mph)	F-150 Stimulus Vehicle			Test Fixture			Outcome Agreement		
				RH13 Car PSM	RH12 F-150 Inside Mirror	RH15 Truck PSM	RH7 Car PSM	RH6 Car Inside Mirror	RH10 Truck PSM			
				Glare Limit	Glare Limit	Glare Limit	Glare Limit	Glare Limit	Glare Limit	Car PSM	Inside Mirror	Truck PSM
59.9-30	400	Left	51	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
59.9-30	400	Left	54	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
29.9-15	400	Left	51	Exceeded	Met	Met	Met	Met	Met	Disagree	Agree	Agree
29.9-15	400	Left	54	Exceeded	Met	Met	Exceeded	Met	Met	Agree	Agree	Agree

Table 139. Glare Limit Conformance Comparison for F-150 Stimulus Vehicle and NHTSA Test Fixture With F-150 Stimulus Taillamps, Same Direction Straight, Lexus NX300 (ADB)

Measurement Distance Sub-Range (m)	Radius of Curvature (m)	Curve Direction	Speed (mph)	F-150 Stimulus Vehicle			Test Fixture			Outcome Agreement		
				RH13 Car PSM	RH12 F-150 Inside Mirror	RH15 Truck PSM	RH7 Car PSM	RH6 Car Inside Mirror	RH10 Truck PSM			
				Glare Limit	Glare Limit	Glare Limit	Glare Limit	Glare Limit	Glare Limit	Car PSM	Inside Mirror	Truck PSM
100-60	Straight	Straight	61	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
100-60	Straight	Straight	69	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
59.9-30	Straight	Straight	61	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
59.9-30	Straight	Straight	69	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
29.9-15	Straight	Straight	61	Met	Met	Met	Met	Met	Met	Agree	Agree	Agree
29.9-15	Straight	Straight	69	Exceeded	Met	Met	Met	Met	Met	Disagree	Agree	Agree

The following figures are examples of how the ADB system reacted to the F-150 truck stimulus vehicle versus the fixture with F-150 headlamps. Figures 67 and 68 show that in straight oncoming and preceding test scenarios, the ADB system recognized both the stimulus vehicle and test fixture before either stimulus entered the measurement range.

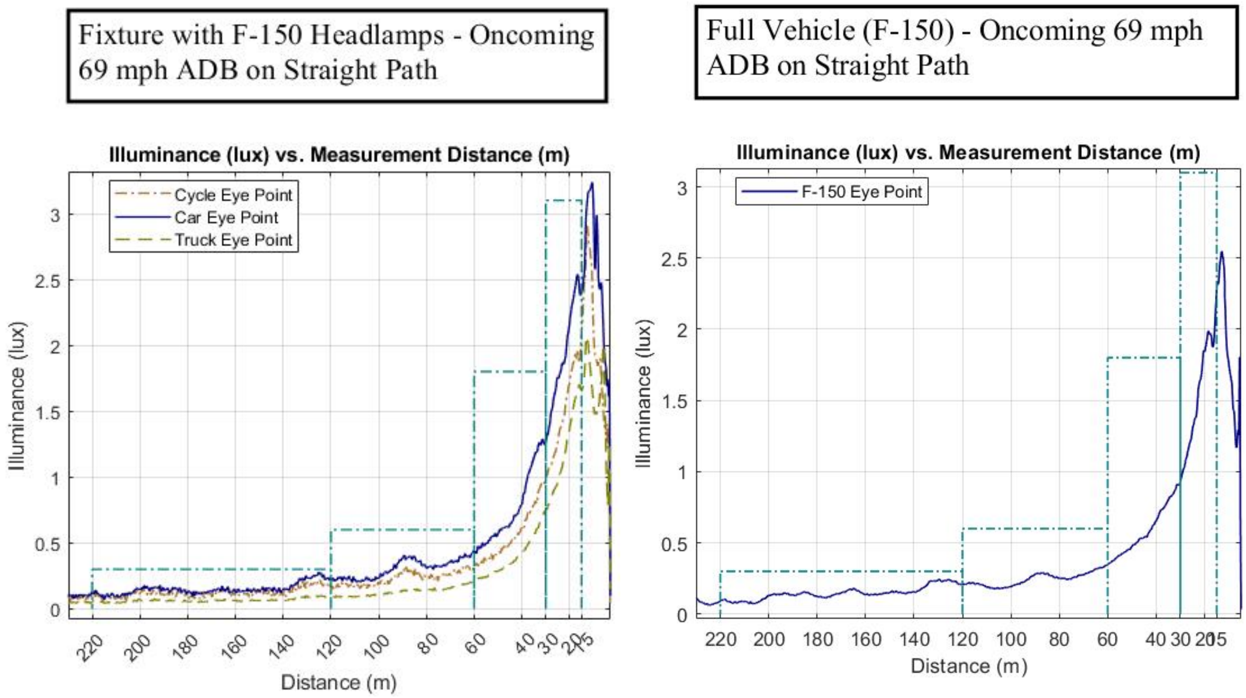

Figure 68. *Test Fixture Versus Stimulus Vehicle, Oncoming Straight, ADB (Lexus NX300), at 69 mph (LexusNHTSAADB3_0019, LexusF-150_0046)*

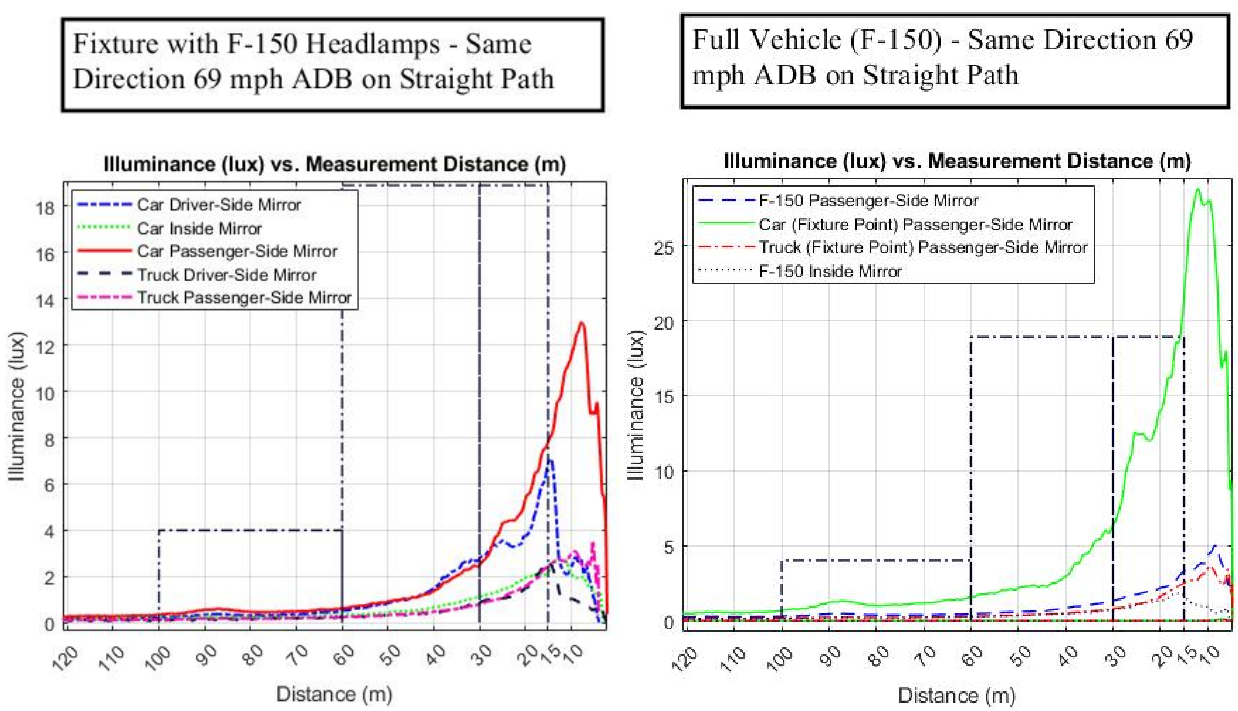

Figure 69. *Test Fixture Versus Stimulus Vehicle, Same Direction Straight, ADB (Lexus NX300), at 69 mph (LexusNHTSAADB3_0020, LexusF-150_0049)*

While for the most part, differences in test results were not observed between the test fixture and stimulus vehicle for comparable test conditions, one exception to this was observed. For the oncoming left 85-m curve at 29 mph, the ADB system seemed to respond earlier to the test fixture. For this test scenario conducted with the test fixture, the test vehicle adjusted its light output at around 44 m and did not exceed the glare limits. For this test scenario conducted with the stimulus vehicle, the ADB system later, which resulted in a glare exceedance. These trials are illustrated in Figure 69 below. This difference in response may be due to differences in headlamp mounting heights between the test fixture and the stimulus vehicle, as can be seen in Figure 60. Furthermore, the F-150 stimulus vehicle driver's eye point (RF11) was 0.617 m lower and 0.31 m to the right of the test fixture truck driver eye point. As such, the F-150 driver eye point was closer to the bright part of the test vehicle's beam pattern. This difference in response may be due both to the differences in headlamp mounting heights and differences in measurement point locations between the test fixture and the stimulus vehicle.

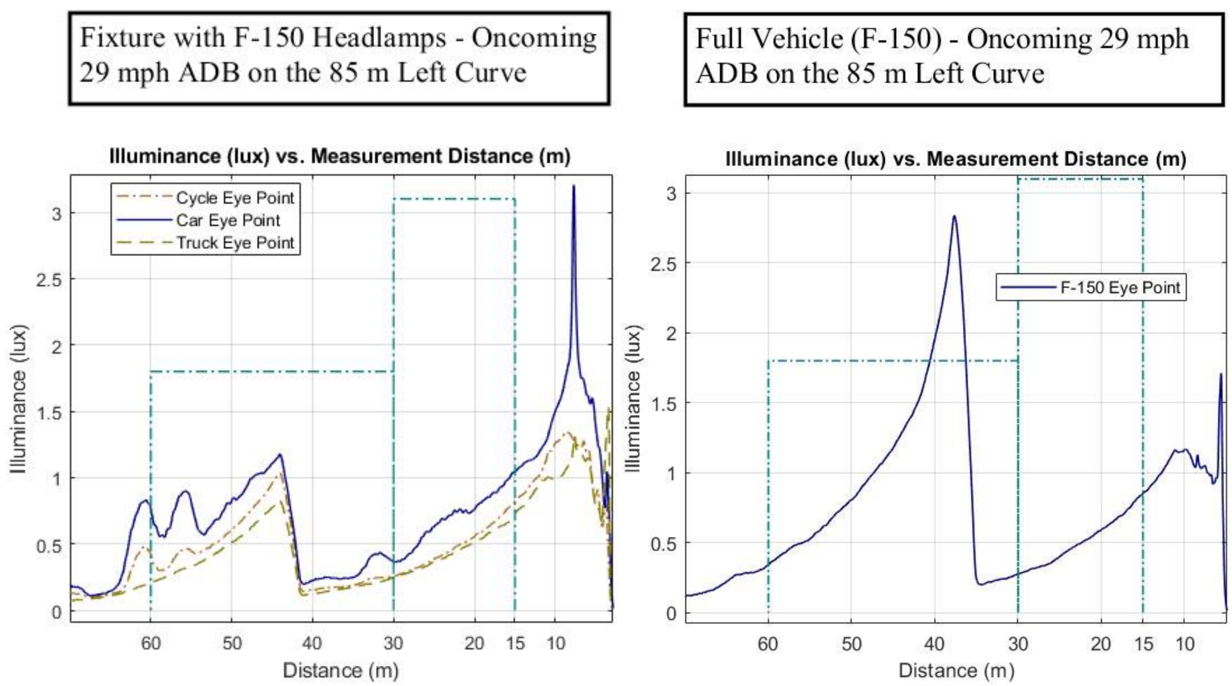

Figure 70. *Test Fixture Versus Stimulus Vehicle, Oncoming Left Curve 85 m Radius of Curvature, ADB (Lexus NX300), at 29 mph (Lexus2_0002, LexusF-150_0028)*

6.7.4 SAE J3069 Test Procedure Illuminance Results Comparison: Stimulus Vehicle Versus Test Fixture

Trials were run with the SAE test fixture and related lamps as well as the original equipment lamps on the 2018 Ford F-150 that served as the stimulus vehicle. Scenarios were performed using the Lexus NX300 in ADB mode as well as in lower beam mode. Overall, results between the F-150 stimulus vehicle and the test fixture for SAE J3069 test scenarios were similar.

6.7.4.1 SAE J3069 Stimulus Vehicle Versus Test Fixture Comparison – Opposing Scenarios

For SAE J3069 opposing scenario SAE fixture location test drives there was complete test outcome agreement between the F-150 stimulus vehicle and the test fixture for these lower beam and ADB conditions:

- SAE fixture location 1 (2 lanes left of ADB test lane) at all measurement distances, and
- SAE fixture location 2 (1 lane left of ADB test lane) at all measurement distances.

Table 140 summarizes the test outcome difference results for the opposing SAE Fixture Location 3 test scenario conducted with the SAE test fixture and F-150 stimulus vehicle for the Lexus NX300 in lower beam mode. At measurement distances of 155 m and 120 m, the F-150 eye point receptor head resulted in a maximum illuminance value which exceeded the glare limit on the F-150 stimulus vehicle, but the truck eye point receptor head on the test fixture did not. As noted previously, F-150 stimulus vehicle driver's eye point (RF11) was 0.617 m lower and 0.31 m to the right of the test fixture truck driver eye point. As such, the F-150 driver eye point was closer to the bright part of the test vehicle's beam pattern. This the difference in height between the F-150 driver eye point and the test fixture truck driver eye point was the likely reason for the discrepancy in test outcome agreement.

Table 140. *Glare Limit Conformance Comparison for F-150 Stimulus Vehicle and SAE Test Fixture With Car/Truck Stimulus Headlamps, Opposing, SAE Fixture Location 3 (2 lanes right of ADB test lane), Lexus NX300 (Lower Beams)*

SAE Fixture Location	Measurement Distance (m)	Speed (mph)	F-150 Stimulus Vehicle	Test Fixture	Outcome Agreement
			RH11 F-150 Eye Pt	RH8 Truck Eye Pt	
			Glare Limit	Glare Limit	
3 (2 lanes right of ADB test lane)	155	61	Exceeded	Met	Disagree
	120	61	Exceeded	Met	Disagree
	60	61	Met	Met	Agree
	30	61	Met	Met	Agree

The following figure illustrates data for the Lexus NX300 in lower beam mode in the opposing SAE Fixture Location 3 test scenario conducted at 61 mph with the SAE test fixture and F-150 stimulus vehicle.

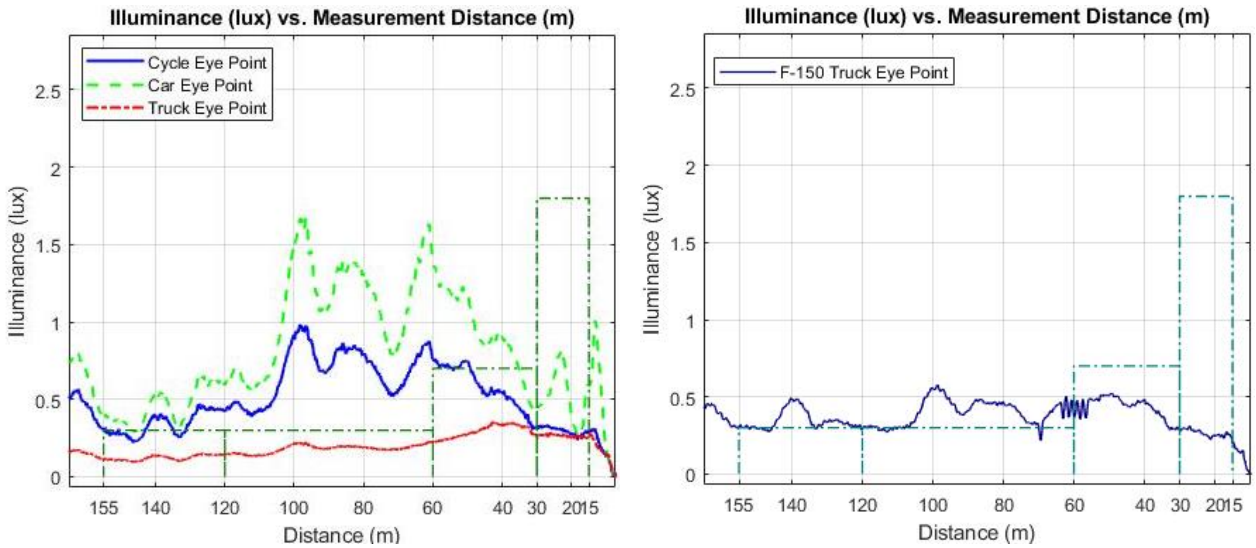

Figure 71. *Test Fixture Versus Stimulus Vehicle, Preceding SAE Fixture Location 3, Lower Beam (Lexus NX300), at 61 mph (LexusSAEF-150_0020, LexusSAEADB_0015.mat)*

Table 141 summarizes the test outcome difference results for the ADB-equipped Lexus NX300 in SAE opposing Fixture Location 3 test scenario conducted with the SAE test fixture and F-150 stimulus vehicle. The F-150 stimulus vehicle eye point receptor head resulted in a maximum illuminance value which exceeded the glare limit, but the truck eye point receptor head on the test fixture did not exceed any glare limit in these cases:

- At a measurement distance of 155 m with speeds of 28 mph and 61 mph, and
- at a measurement distance of 120 m with speed of 61 mph.

As stated previously, the difference in height between the F-150 driver eye point and the test fixture truck driver eye point was the likely reason for the discrepancy in test outcome agreement.

Table 141. *Glare Limit Conformance Comparison for F-150 Stimulus Vehicle and SAE Test Fixture With Car/Truck Stimulus Headlamps, Opposing, SAE Fixture Location 3 (2 lanes right of ADB test lane), ADB (Lexus NX300)*

SAE Fixture Location	Measurement Distance (m)	Speed (mph)	F-150 Stimulus Vehicle RH11 F-150 Eye Pt Glare Limit	Test Fixture RH8 Truck Eye Pt Glare Limit	Outcome Agreement
3 (2 lanes right of ADB test lane)	155	28	Exceeded	Met	Disagree
	155	61	Exceeded	Met	Disagree
	120	28	Met	Met	Agree
	120	61	Exceeded	Met	Disagree
	60	28	Met	Met	Agree
	60	61	Met	Met	Agree
	30	28	Met	Met	Agree
	30	61	Met	Met	Agree

The following figure illustrates data for the Lexus NX300 in ADB mode performing the opposing SAE Fixture Location 3 test scenario conducted at 61 mph with the SAE test fixture and F-150 stimulus vehicle.

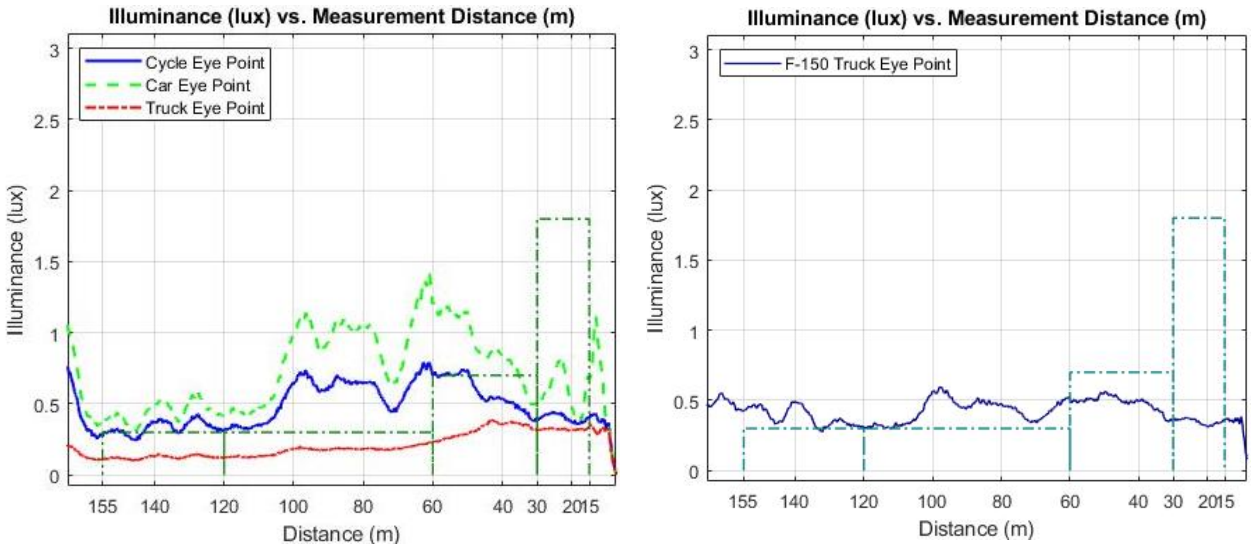

Figure 72. *Test Fixture Versus Stimulus Vehicle, Opposing SAE Fixture Location 3, Car/Truck Stimulus Headlamps, ADB (Lexus NX300), at 61 mph*

6.7.4.2 SAE J3069 Stimulus Vehicle Versus Test Fixture Comparison – Preceding Scenarios

For all SAE J3069 preceding scenario trials, there was complete test outcome agreement between the F-150 stimulus vehicle and the test fixture for both lower beam and ADB for all three SAE fixture location locations and all measurement distances.

7.0 SUMMARY

This report summarized testing of and test procedure development for a type of advanced headlighting system called “adaptive driving beam,” or ADB. This effort by the National Highway Traffic Safety Administration (NHTSA) supports a rulemaking effort initiated by a 2018 Notice of Proposed Rule Making (NPRM) [1] that outlined a proposal to allow Adaptive Driving Beam (ADB) headlighting systems on light vehicles in the United States. The work described in this report involved 1) modifying the test procedure proposed in the NPRM to use stimulus test fixtures instead of stimulus vehicles, 2) revising the set of test scenarios to reduce the number of scenarios and revise the radii of curvature for curved-road test scenarios, and 3) carrying out testing to permit evaluation of the test procedure. Testing per that test procedure was conducted to provide needed data to support resolution of comments on NHTSA’s proposal. Testing based on SAE’s Surface Vehicle Recommended Practice J3069 “Adaptive Driving Beam” test procedure [3] was also conducted.

Test procedure implementation information, testing performed, and analysis results are summarized below according to the following numbered objectives. Findings for each objective are summarized accordingly.

1. **Design, build, and assess a test fixture that could serve as a stationary stimulus vehicle surrogate for use in ADB testing.**

   A test fixture was designed and built that could accommodate both the NHTSA and SAE test procedures. The test fixture layout included a vertical array of illuminance meter light sensors (i.e., receptor heads) along with structure for accurately positioning the various NHTSA and SAE lamp conditions that included: Ford F-150 headlamps and taillamps, Toyota Camry headlamps and taillamps, a Harley Davidson motorcycle headlamp and taillamp, and SAE headlamps and taillamps (custom lamps built by a vendor to meet the SAE J3069 specifications). Testing was conducted using the developed fixture to assess both the viability of test fixture use and viability/need for SAE-style stimulus lamps.

2. **Develop detailed ADB compliance test procedure documentation.**

   A detailed test procedure document was written that outlines dynamic test procedure details, test fixture characteristics, example instrumentation, test vehicle preparations, test execution, data processing, and test result determination. Testing conducted in support of this effort allowed for further assessment of the test procedure to determine if there were any problems or gaps in the NHTSA test procedures when running an ADB-equipped vehicle through the test protocols. No problems or gaps were found in any of the test procedures, with the results of each test procedure showing a mix of pass and fail outcomes when the illuminance data were compared to the glare limits.

3. **Evaluate the stability of illuminance meter outputs over time without a test run (checking for any noise in the system that is not dependent on the tested vehicle).**

   An important initial step performed was to evaluate the stability of the measured illuminance values, without a test vehicle present, to determine if there was any noise in the measurement system that was not dependent on the vehicle being tested or some aspect of the test procedure. This was performed to confirm that the measurement system would provide consistent and stable data before beginning any vehicle testing. For each stimulus lamp condition, illuminance data were recorded for a period of 30 seconds in typical test conditions. The results indicated that both the analog and digital data measured value standard deviations were low for each of the receptor heads for each of the 10 test lamp conditions, suggesting very little system noise or fluctuation. In fact, each lamp condition had at least two receptor heads that exhibited no variability (standard deviation = 0) in the digital data. Thus, the illuminance meter outputs were found to be stable and the measurement system could be ruled out as a source of any data noise or variability in measured values.

4. **Ensure validity of dynamic illuminance measurements through comparison to static measurements.**

   Tests were performed to assess whether test scenarios could be executed with sufficiently steady vehicle dynamics such that, in lower beam mode, headlamp illumination measured during dynamic test scenario performance would match that measured in the same location with the vehicle stationary. Measured illuminance and pitch angle data values were extracted for both dynamic and static test trials at specific scenario path points corresponding to an end of a glare limit distance range. Illuminance results indicated dynamic and static measurements were comparable in most scenarios; however, there were some receptor head locations in some scenarios in which the dynamic and static measurements were not similar. Pitch angle results indicated dynamic and static measurements were comparable in most scenarios. Overall, analysis of vehicle pitch data showed that pitch could be monitored and controlled as part of the test procedure conditions.

5. **Verify that the proposed NHTSA test provides accurate results for multiple light source types.**

   Tests were performed using the three vehicle models with headlighting systems operating in lower beam mode. Results demonstrated that the headlamp types tested, halogen and LED, were compatible with the test procedure.

6. **Evaluate a late-model vehicle's lower beam performance with respect to NHTSA-proposed ADB glare limit criteria.**

   Three test vehicles with headlighting systems operating in lower beam mode were subjected to the NHTSA ADB compliance test procedure. The vehicles included a 2019 Ford Fusion with halogen headlamps, a 2018 Lexus NX300 European mass production model with LED headlamps and lower and upper beams modified to be FMVSS No. 108 compliant, and a 2016 Volvo XC90 with LED headlamps. Measured illuminance values were evaluated with respect to the glare limit criteria. The Ford Fusion lower beam headlamps had passing results below the glare limits in all test scenarios, while the Lexus NX300 lower beam headlamps did not pass several of the test scenarios when illuminance values were compared to the glare limits. The Volvo XC90 lower beam headlamps passed most but not all the test scenarios.

7. **Test an ADB-equipped vehicle per the NHTSA draft test procedure.**

An ADB-equipped European market 2018 Lexus NX300 with LED headlamps and lower beam headlamp pattern modified to United States VOR (visually optically aligned right) standards was subjected to the draft NHTSA ADB compliance test procedure. As noted above, the lower beams of this vehicle did not pass several of the test scenarios when illuminance values were compared to the glare limits, therefore, as expected, the ABD test results also showed a mix of pass / fail outcomes varying by radius of curvature and measurement distance sub-range, providing a good breakdown of where the vehicle's headlamps may need improvement in performance in order to pass the test procedure. In performing this set of tests using an ADB-equipped test vehicle, no problems or gaps were found in the NHTSA test procedure.

8. **Test an ADB-equipped vehicle per the SAE J3069 test procedure.**

   The objective of this test was to gather information on the SAE test procedure. More specifically, testing was conducted to aid discussion of differences between the NHTSA and SAE test procedures. Data and information were needed to facilitate effective discussion of the trade-offs between gains in realism of test scenarios versus repeatability and efficiency of testing. Test results for the ADB-equipped Lexus test vehicle for both lower beam and ADB modes showed a mix of test outcomes varying by fixture location, test vehicle speed, and measurement distance. Two aspects of the SAE test procedure, the open-ended test vehicle speed selection and variable stimulus lamp sudden appearance distance were identified as possible contributors to test outcome variability.

9. **Assess whether ADB-equipped vehicles respond similarly when tested using the modified NHTSA test procedure with a stimulus test fixture as when using a FMVSS-compliant vehicle.**

   The Lexus NX300 with headlighting system operating in ADB mode was subjected to both the NHTSA and SAE ADB test procedures once with the specified stimulus test fixture and again with a 2018 Ford F-150 production vehicle serving as a stimulus vehicle in place of the test fixture. Measured values and system performance outcomes for the stimulus vehicle versus the test fixture were compared for both test procedures. The results showed that the Lexus NX300's ADB system generally responded similarly to the test fixture as it did to the full stimulus vehicle. Results for the Lexus NX300 operated in lower beam mode showed complete agreement for oncoming NHTSA test scenarios test outcomes between the F-150 stimulus vehicle and the test fixture for all test scenarios except the 400-m right curve and complete agreement for all same direction test scenarios. For the Lexus NX300 operated in ADB mode, test outcomes agreed for most oncoming test scenarios and approximately half of the same direction test scenarios. For the SAE J3069 test procedure, there was test outcome agreement between the test fixture and stimulus vehicle results for most test scenarios for both lower beam and ADB trials. For both test procedures, any differences in test outcomes between the test fixture and stimulus vehicle were likely due both to differences in headlamp mounting heights and the measurement point between the test fixture and the stimulus vehicle.

In summary, to assess the objectives above, a test fixture was designed and constructed to serve as a reasonable surrogate for an actual vehicle to provide a stimulus needed to observe the performance of an ADB headlighting system. The NHTSA test procedure was found to be suitable for FMVSS use and effective in determining whether an ADB headlighting system limits glare to other motorists to specified criteria levels as determined by the evaluations and verifications performed. In addition, the test procedure adequately accounted for test surface conditions and other sources of test variability.

8.0 REFERENCES

1. Federal Register/ Vol. 83, No. 198/pp. 51766-51813. Federal Motor Vehicle Safety Standards; Lamps, Reflective Devices, and Associated Equipment. Notice of Proposed Rulemaking (NPRM).
2. 49 CFR Sec. 571.108, Standard No. 108; Lamps, reflective devices, and associated equipment.
3. SAE J3069, Surface Vehicle Recommended Practice: Adaptive Driving Beam, Issued June 2016, www.sae.org/standards/content/j3069_201606/.
4. Mazzae, E. N., Baldwin, G. H. S., Andrella, A., & Smith, L. A. (2015, July). *Adaptive driving beam headlighting system glare assessment*. (Report No. DOT HS 812 174). Washington, DC: National Highway Traffic Safety Administration.
5. Source of VDA image used in Figure 24: http://maps.googleapis.com/maps/api/staticmap?center=40.30775077,-83.5453102&zoom=17&scale=2&size=640x640&maptype=satellite&format=jpg&markers=&sensor=false&key=AIzaSyDrZxBItfEoib5Ppyo8jaE-GvwdEtagd2U
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10. Ford Motor Company. Ford F-150 Model Year 2018 Brochure. (2018). Retrieved from https://cdn.dealereprocess.org/cdn/brochures/ford/2018-f150.pdfhttps://cdn.dealereprocess.org/cdn/brochures/ford/2018-f150.pdf. Accessed January 19, 2022.

Appendix A. Additional Test Fixture Information

The following are additional drawings and renderings of the test fixture, receptor heads and lamps, for more details and specifications.

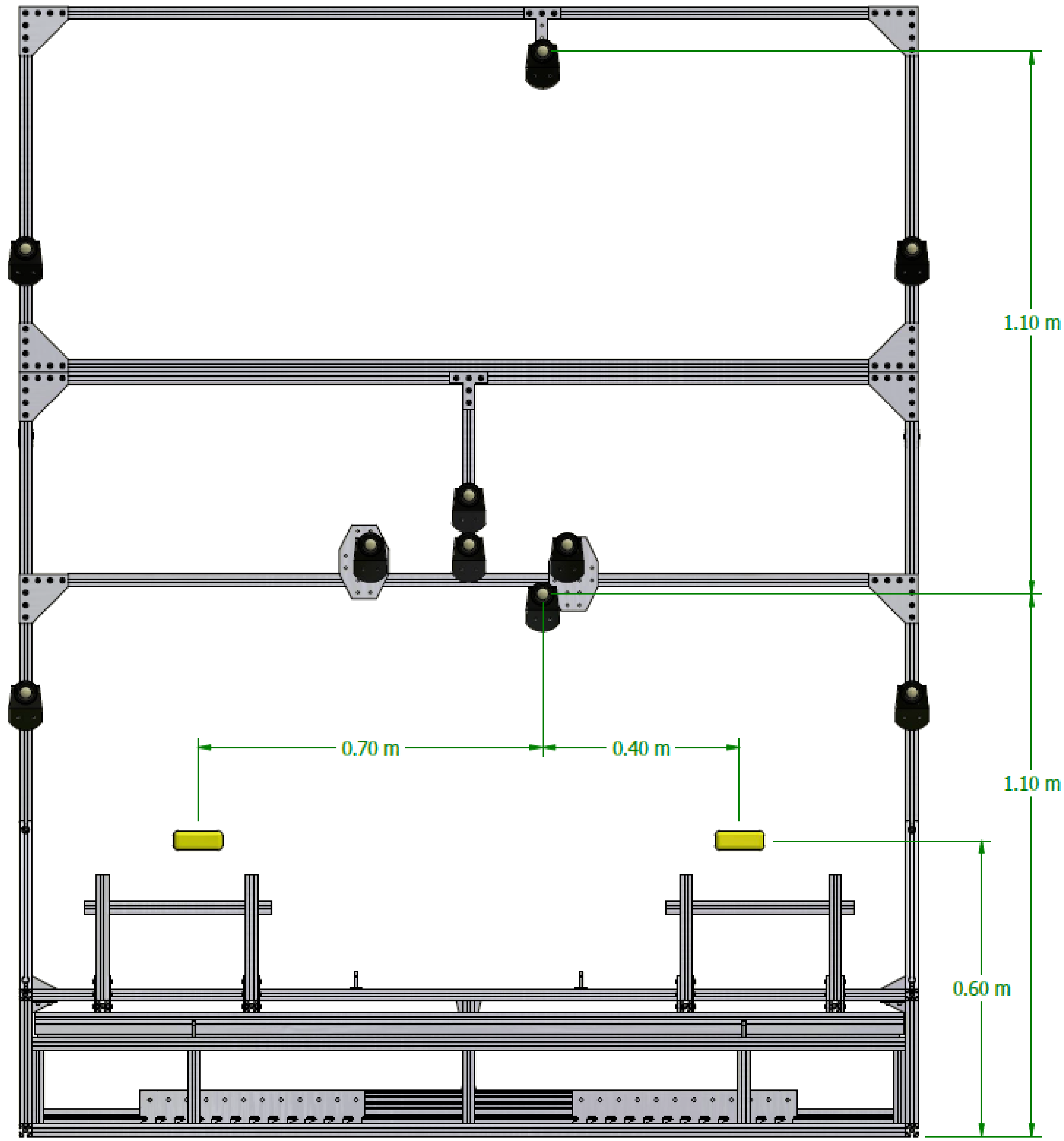


Figure 73. *NHTSA Test Fixture End View, Camry Headlamps*

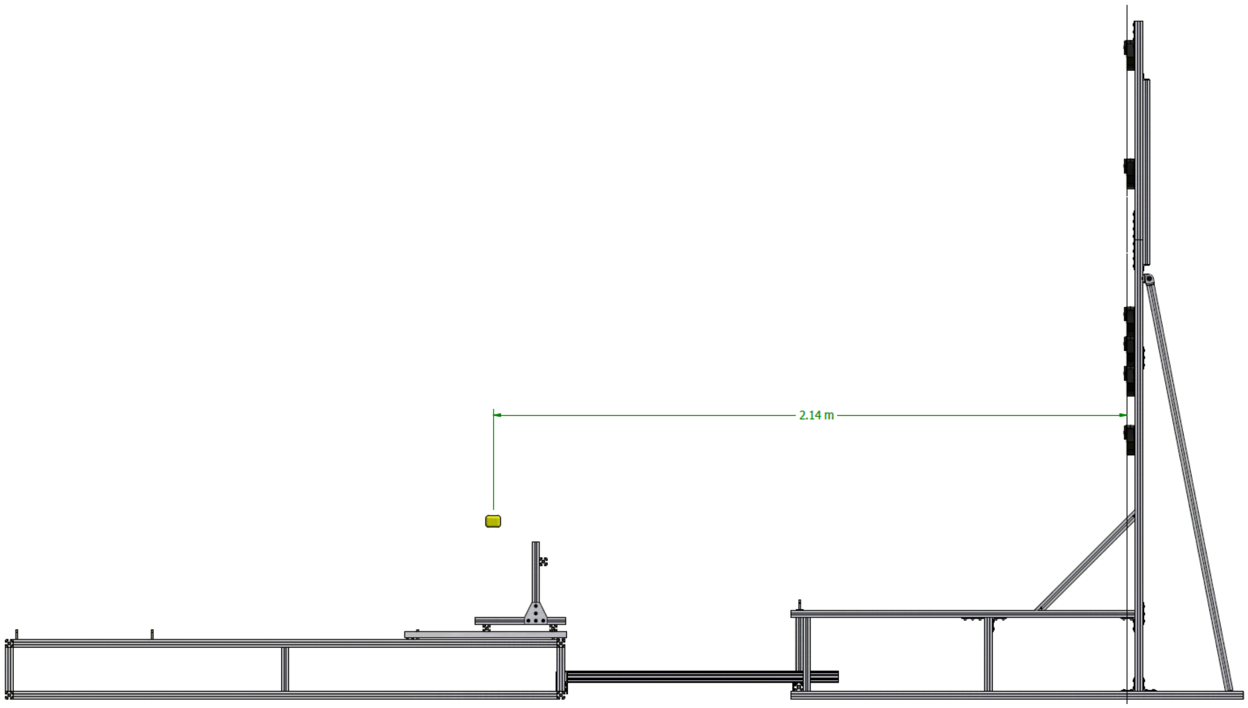


Figure 74. *NHTSA Test Fixture Side View, Camry Headlamps*

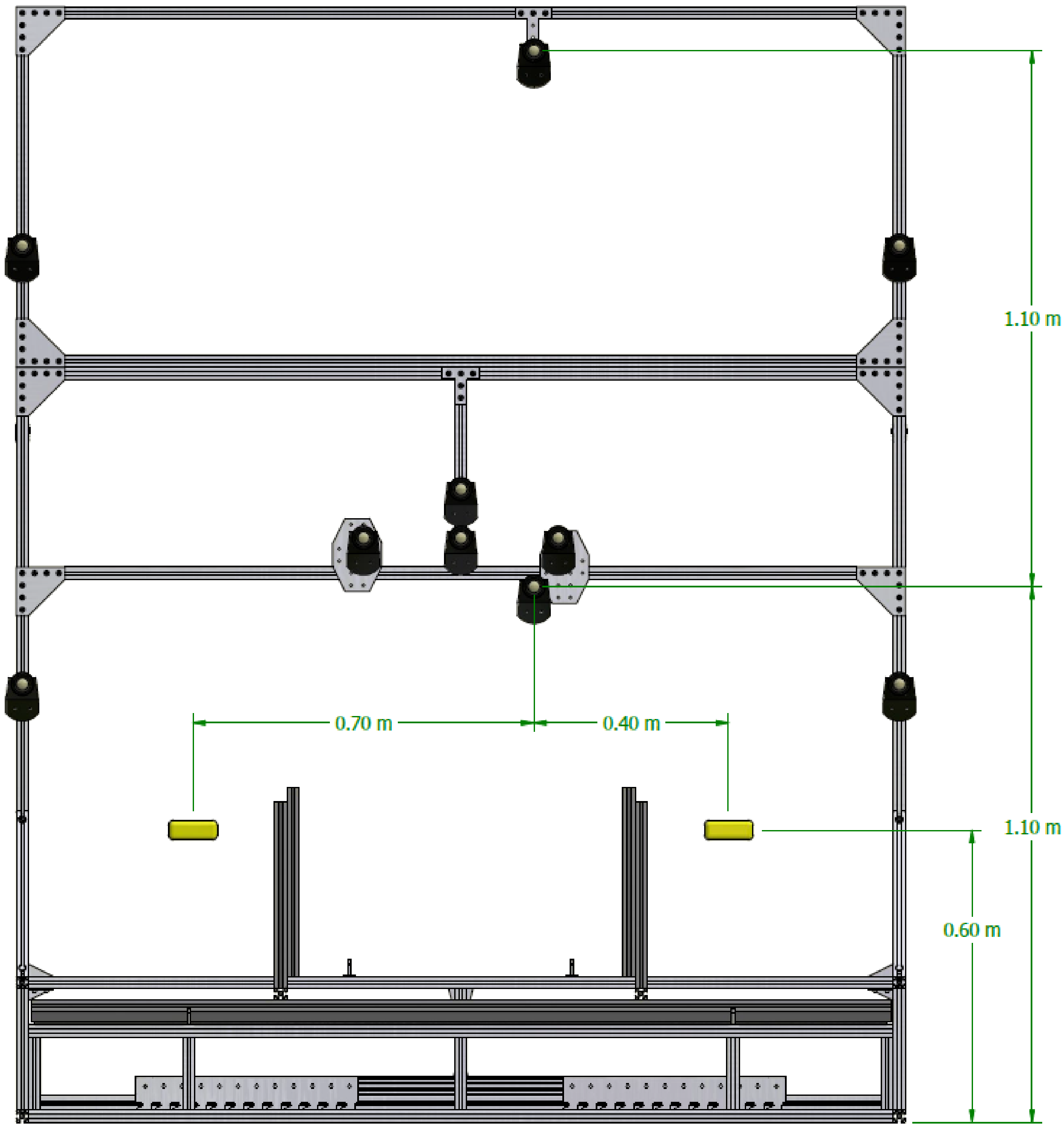


Figure 75. *NHTSA Test Fixture End View, F-150 Truck Headlamps*

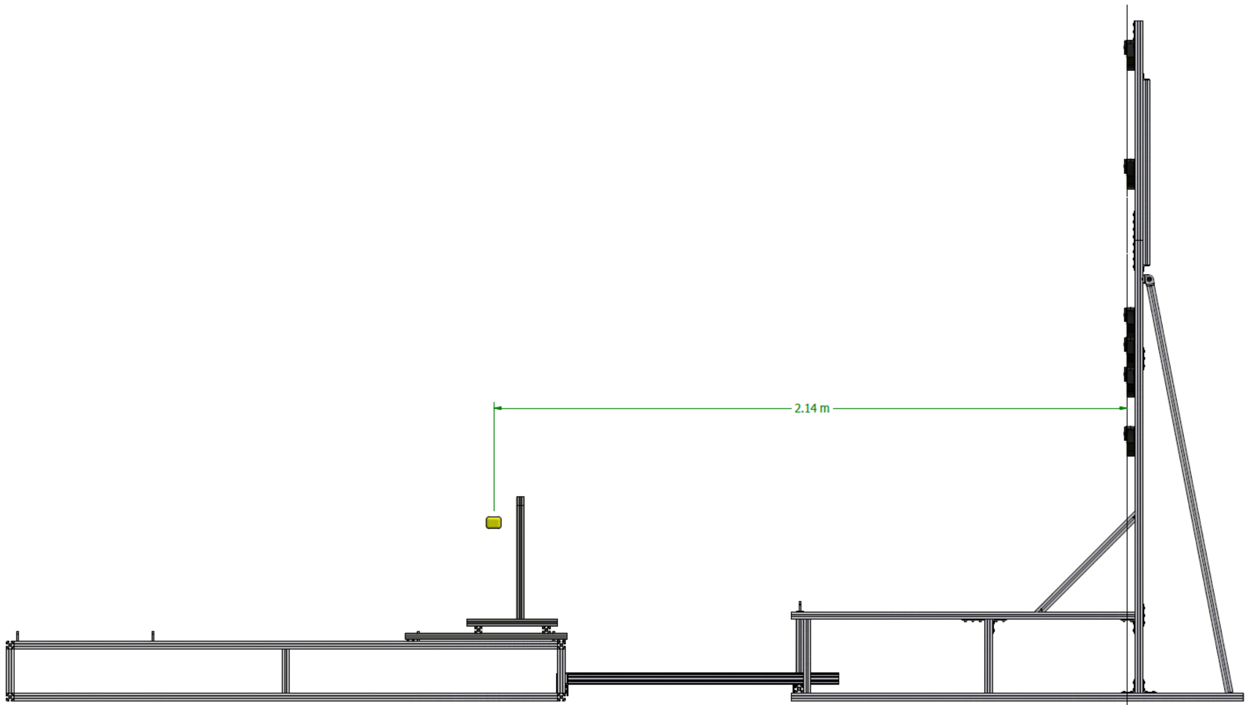


Figure 76. *NHTSA Test Fixture Side View, F-150 Truck Headlamps*

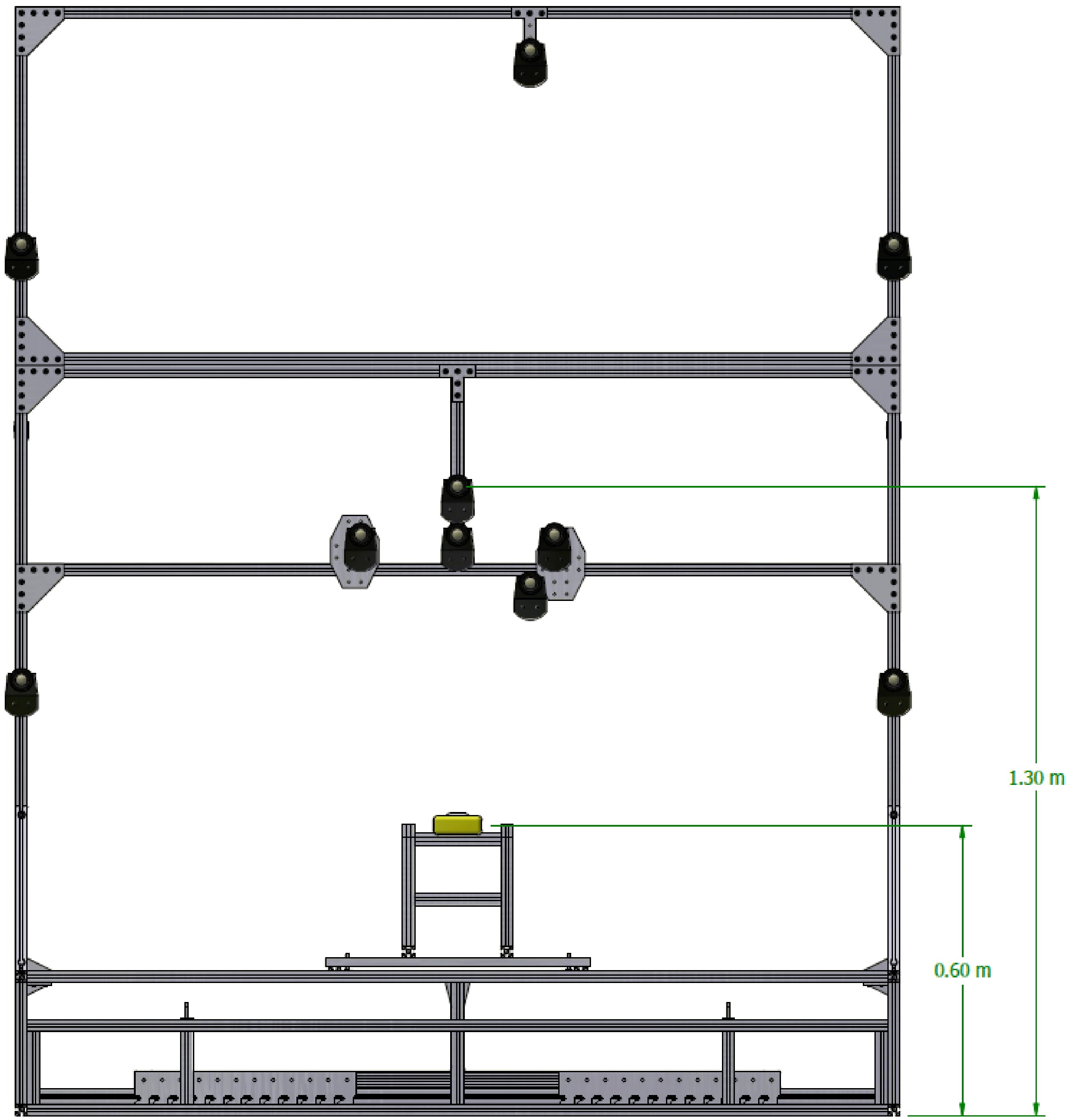


Figure 77. *NHTSA Test Fixture End View, Motorcycle Headlamp*

Figure 78. *NHTSA Test Fixture Side View, Motorcycle Headlamp*

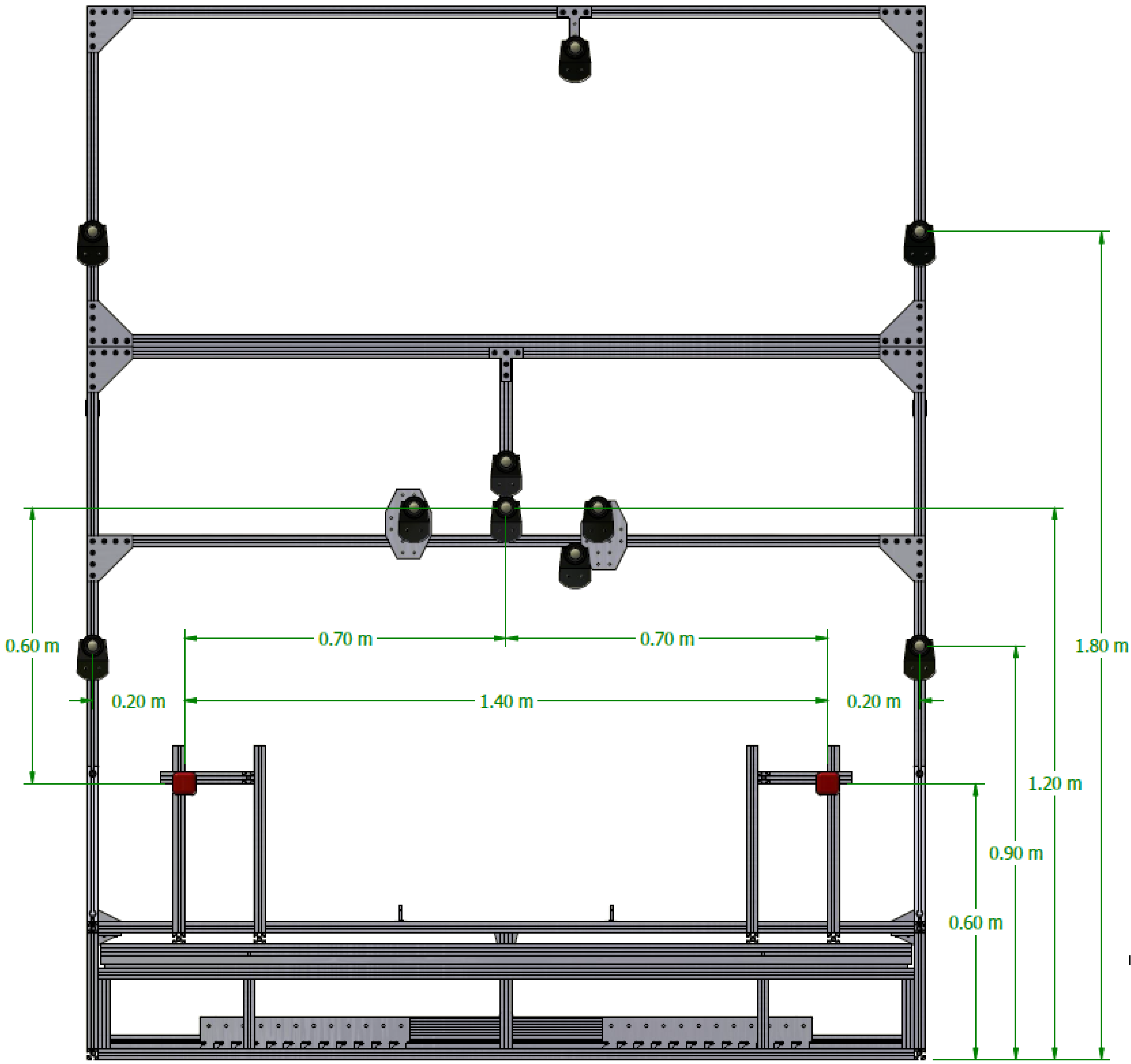


Figure 79. *NHTSA Test Fixture End View, Car Taillamps*

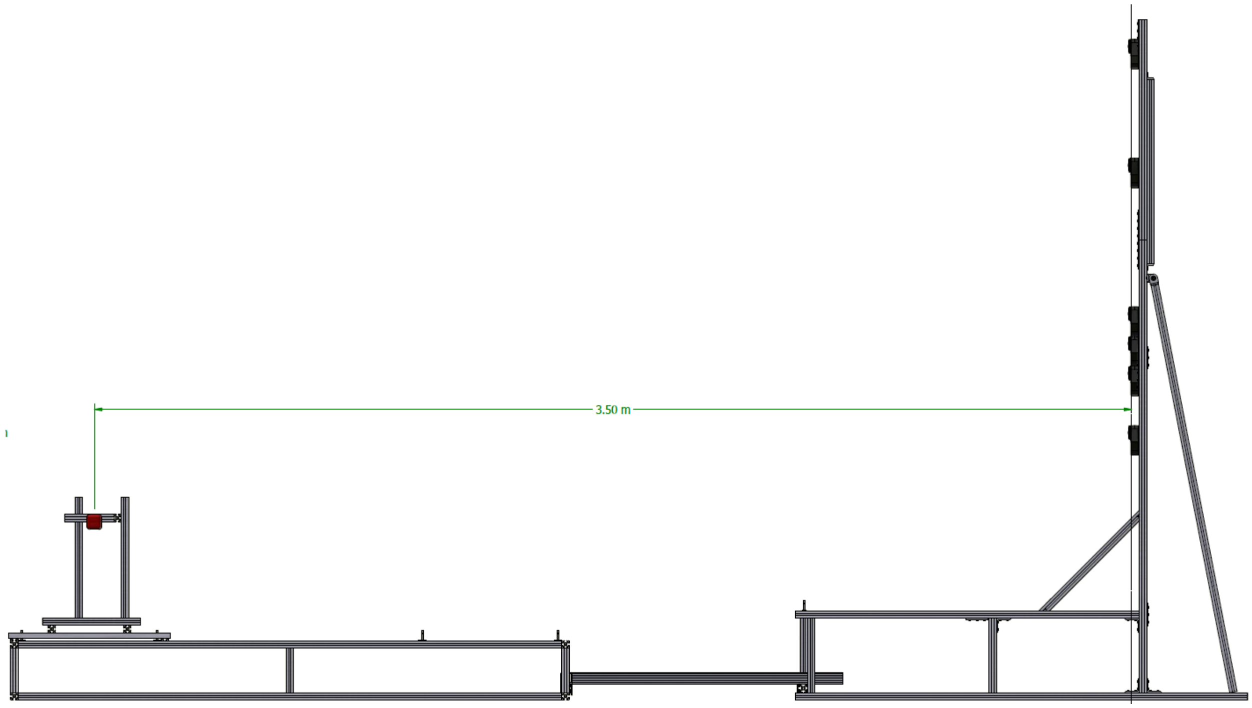


Figure 80. *NHTSA Test Fixture Side View, Car Taillamps*

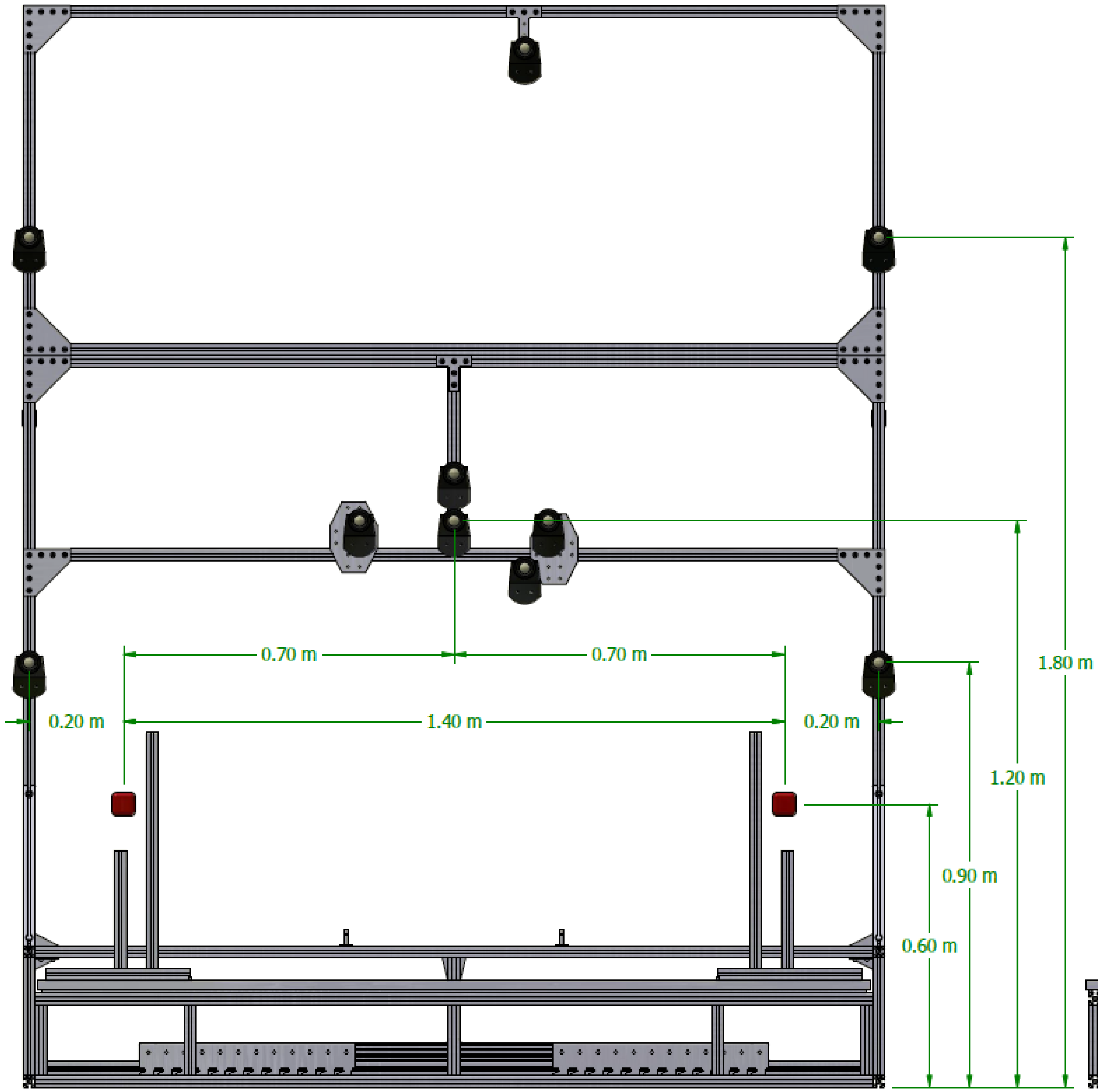


Figure 81. *NHTSA Test Fixture End View, F-150 Truck Taillamps*

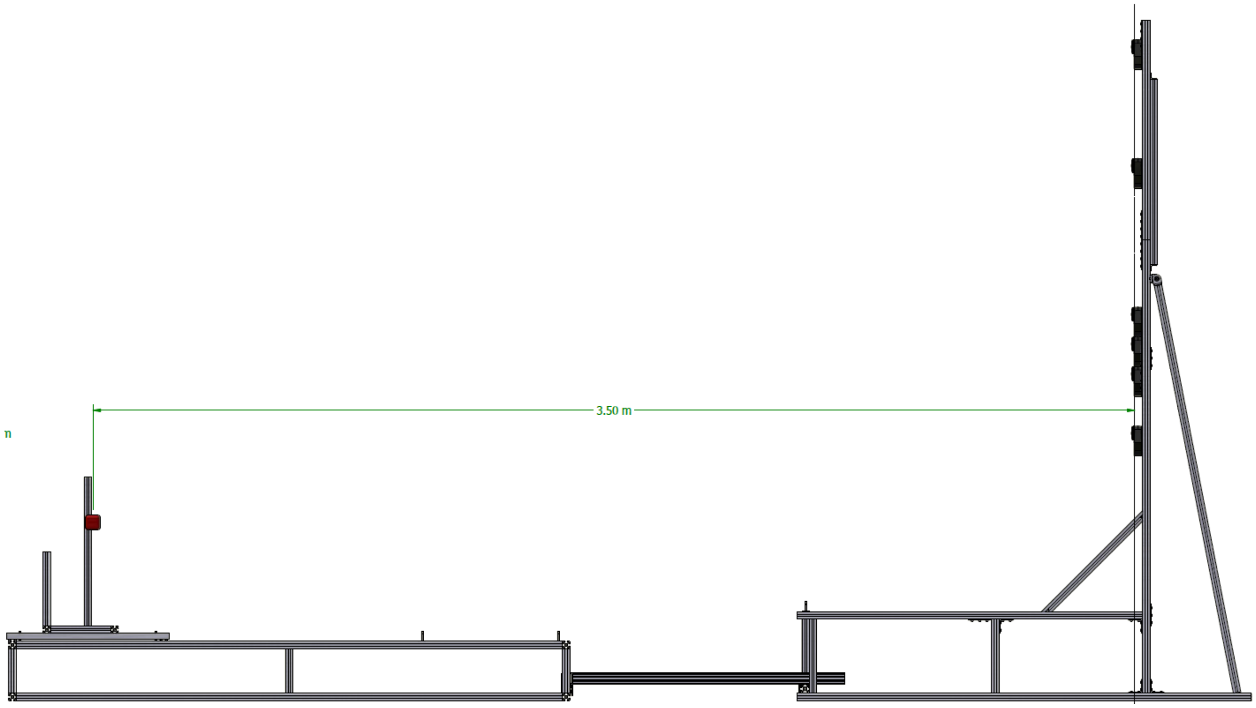


Figure 82. *NHTSA Test Fixture Side View, F-150 Truck Taillamps*

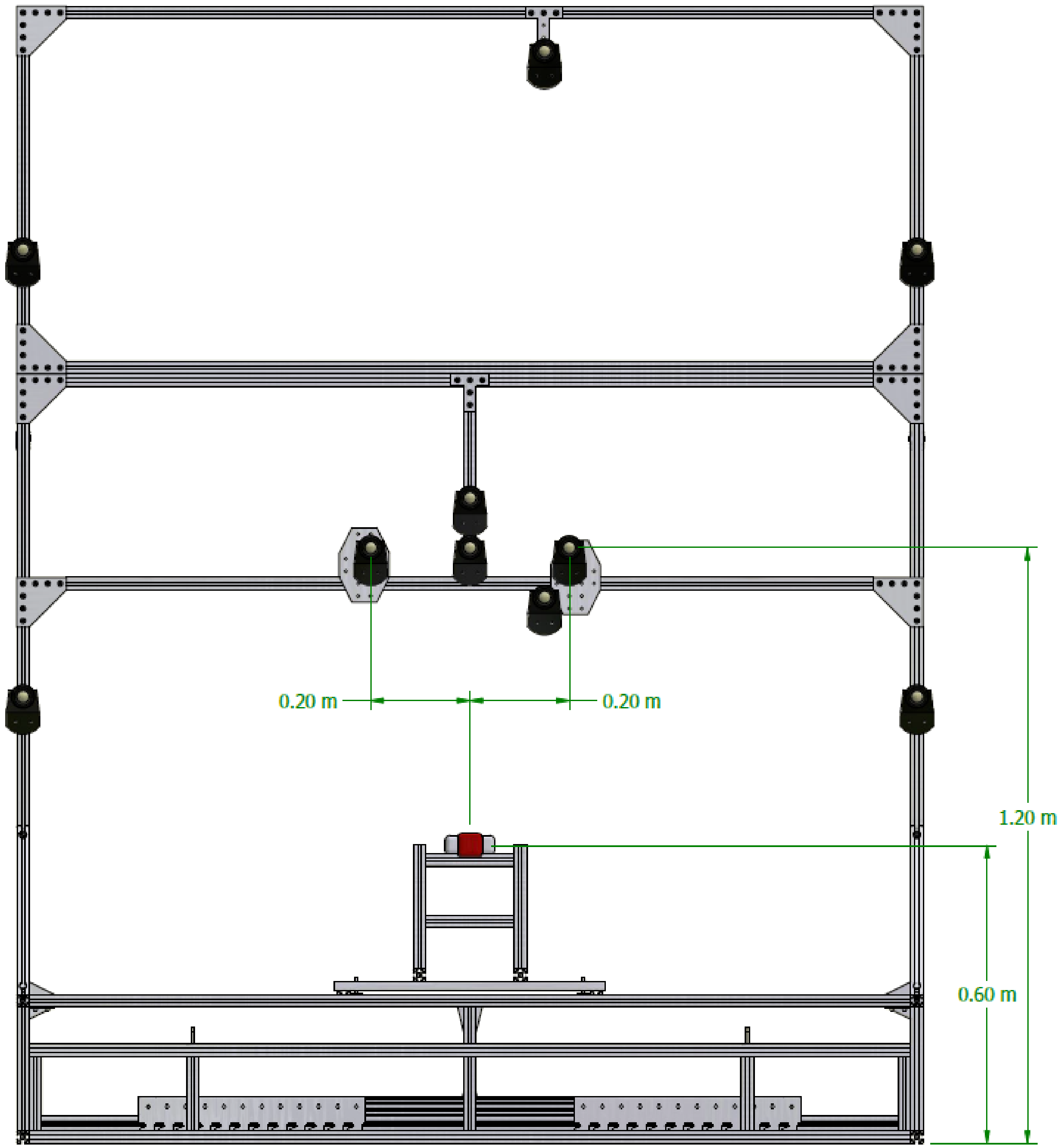


Figure 83. *NHTSA Test Fixture End View, Motorcycle Taillamp*

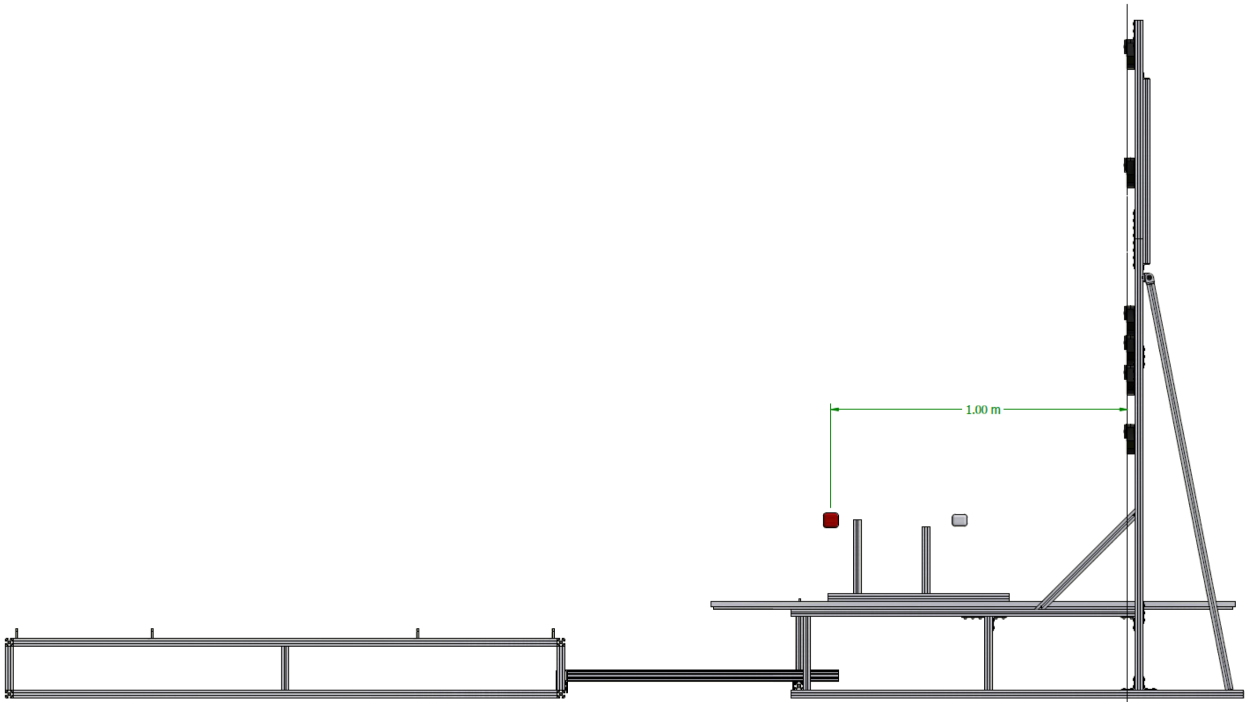


Figure 84. *NHTSA Test Fixture Side View, Motorcycle Taillamp*

The following is an image showing the entire structure of the fixture with receptor heads and test lamp mounting locations.

Figure 85. *Test Fixture Structure With Receptor Heads*

The following is an image showing the side view of the receptor head locations on the fixture structure.

Figure 86. *Fixture With Receptor Heads, Side View*

Appendix B. Instrumentation and Equipment Information

Table 142. Measurement System Components

Manufacturer	Name	Model Number	Description
NHTSA VRTC	VCDAS	N/A	Video CAN Data Acquisition System
Oxford Technical Solutions (OXTS)	RT Hunter	RT-Range S Hunter	Relative position
(OXTS)	RT-XLAN	RT-XLAN	Long range wireless LAN
(OXTS)	RT-XLAN	RT-XLAN	Long range wireless LAN, could be eliminated with TrackFI
(OXTS)	RT- 3003	RT-3003	Inertial Measurement Unit
NovAtel Inc.	NovAtel	GPS-702-GG-HV	Dual-frequency GPS antenna
Free Wave	Freewave	FGR-115RC	Wireless Data Transceiver
esd electronics	CAN cables	Assorted lengths	CAN extension cables
Grid Connect	CAN terminator	GC-CAN-TERM-GC	120Ohm CAN Terminator
Konica-Minolta	T-10a	T-10a	Illuminance meter
Konica-Minolta	T-A20	T-A20	Main body adapter
Konica-Minolta	T-A21	T-A21	Receptor head adapter
Konica-Minolta	T-10A Receptor head	T-10A	Receptor head
Konica-Minolta	AC power adapter	AC_A308 (120v)	120v power adapter for Konica hardware
80/20 Inc.	80/20	Assorted angles, straights, and corners	Fixture built with mostly 25Series components
Various	LAN Cables	Assorted lengths	To connect Receptor heads together
Multicomp	Phone plug	SPC15154	3.5mm, 2 contact, phone audio connector for analog output of receptor heads
Belden	Audio sound and control cable	9452-010-U500	Shielded 2 conductor cable for analog out of receptor heads

Table 143. Power-Related Components

Manufacturer	Name	Model Number	Description
Honda	Generator	EU6500is A	Gasoline generator with inverter
Lithium Battery Power,LLC	Lithium Batteries	12V 50AH	12-volt 50 Amp hour batteries, wired in parallel
Peak Systems	PCAN-MicroMod Analog 2	IPEH-002207	Analog to CAN Module
Perko	Battery selector switch	8511	Battery selector/disconnect switch
Carol Brand	Carolprene 4GA 600V cable	1UGT2	Carolprene EPDM welding cable, used for battery cables
Shenzhen Yi Yunda Technology Co.Ltd	Thermal Circuit Breaker	T Tocas 30 Amp Surface-Mount Circuit Breakers	12V 30Amp circuit protection with manual reset
Sorensen	Power supply	SRL 40-25	regulated power supply for lights

Table 144. *Other Apparatus and Vehicle Control Items*

Manufacturer	Name	Model Number	Description
AB Dynamics	Steering controller	SR15 Orbit	steering robot
AB Dynamics	Sync Omni		Converts telemetry data to CAN
AB Dynamics	TrackFI radio		wireless telemetry
Sapphire Technical Solutions	Calibrated light source	LS-301-1	kit included 2 lamps, red lenses, remote trigger, power source, cables

Appendix C. Headlamp Aiming

This appendix presents the photos taken of the headlamp aiming test-ready status for each of the three test vehicles and each of the four NHTSA stimulus headlamps used in the testing documented in the NHTSA Adaptive Driving Beam (ADB) reports titled:

1. Adaptive Driving Beam Headlighting Systems Rulemaking Support Testing
2. Adaptive Driving Beam (ADB) Headlamps Test Repeatability Assessment

The three test vehicles are:

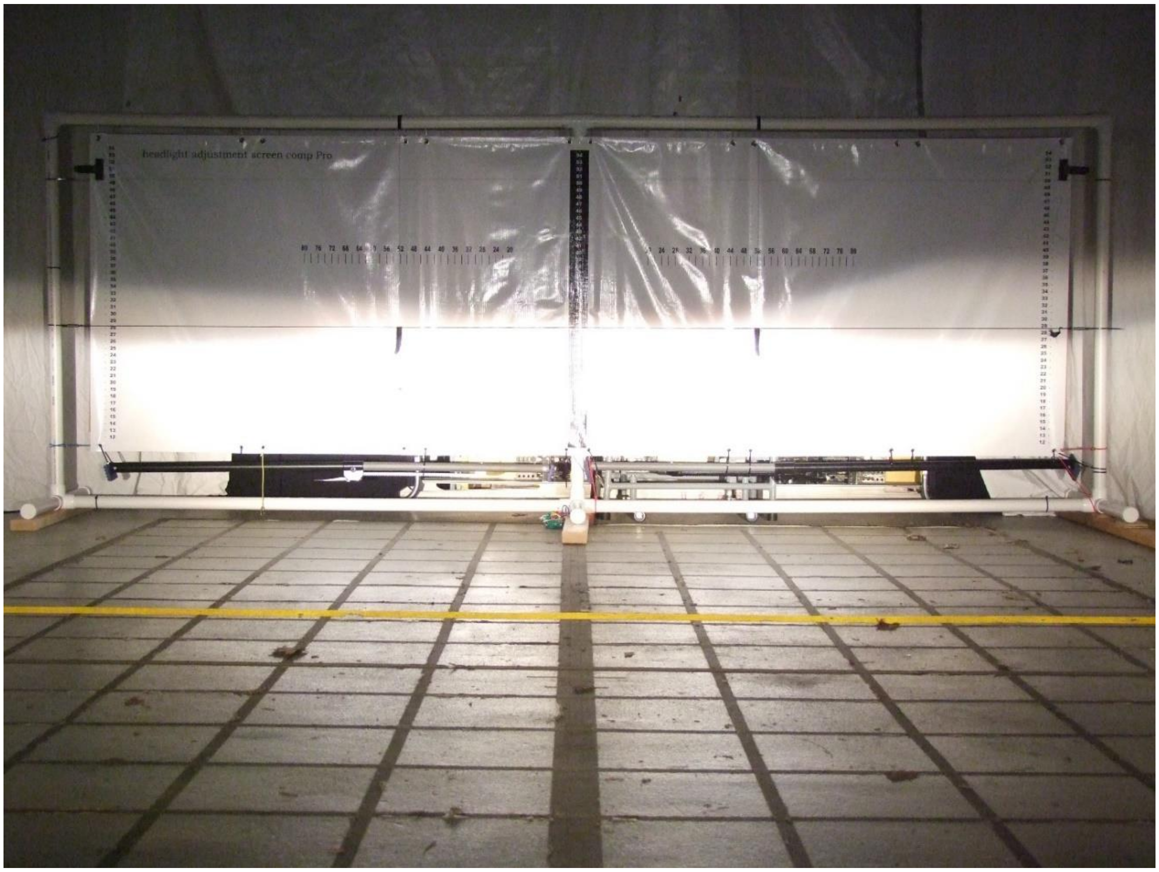
- 2019 Ford Fusion (halogen headlamps, FMVSS certified)
- 2018 Lexus NX300 (European mass production model), ADB-equipped (LED headlamps)
- 2016 Volvo XC90 (LED headlamps, FMVSS certified)

Three of the four NHTSA stimulus headlamps were part of a NHTSA test fixture, with the fourth being the headlamps on an actual Ford F-150 pickup truck. The four NHTSA stimulus headlamps are:

- Stimulus car headlamps: Toyota Camry headlamp pair on test fixture (LED)
- Stimulus truck headlamps: Ford F-150 headlamp pair on test fixture (Halogen)
- Stimulus motorcycle headlamps: Harley Davidson motorcycle headlamp on test fixture (Halogen)
- Ford F-150 pickup truck (with Halogen headlamps)

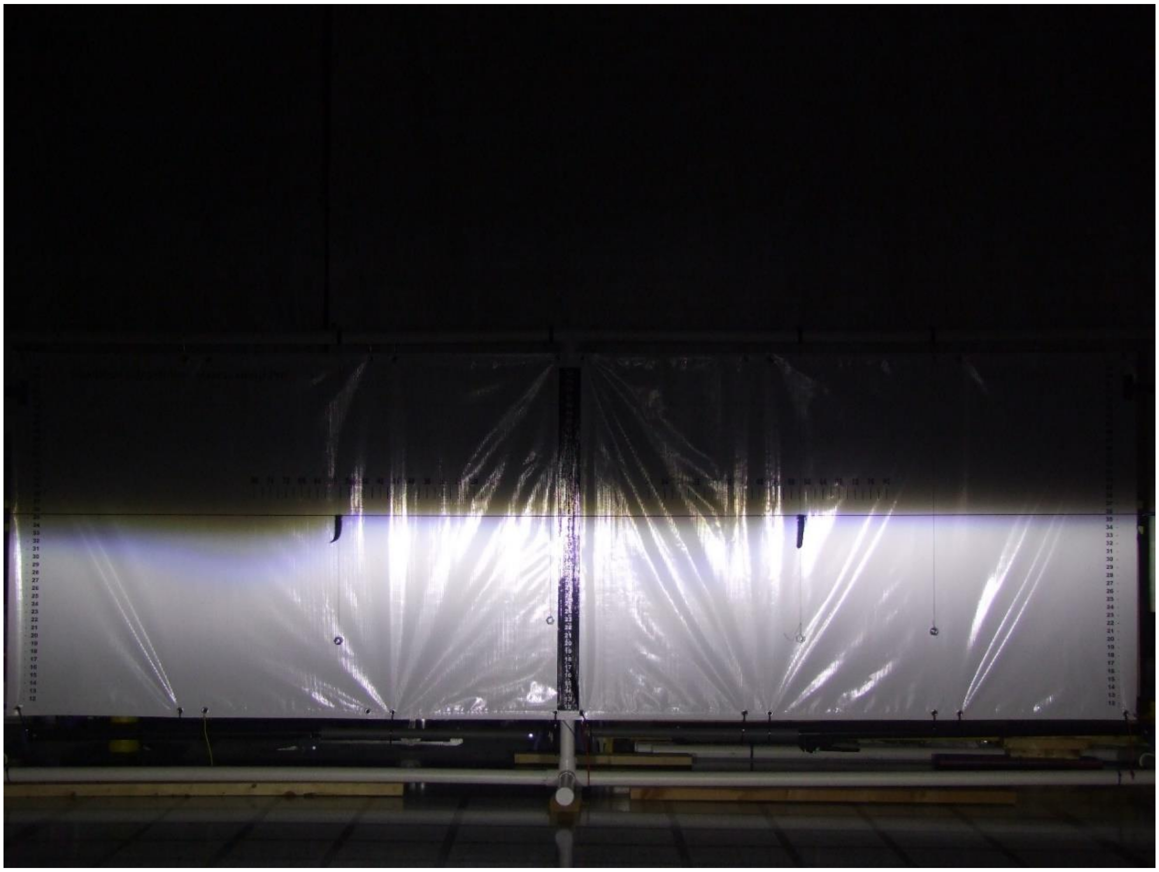
The following figure is a photo of the headlamp aim setting of the Ford Fusion test vehicle.

__Figure 87.__ Ford Fusion Headlamp Adjustment (Adjusted_Fusion_Both_Lights.jpg)



The following figure is a photo of the headlamp aim setting of the Lexus NX300 test vehicle.

Figure 88. *Lexus NX300 Headlamp Adjustment (Lexus_Both_Headlights_Adjustment_Final.jpg)*



Next are figures of the NHTSA stimulus lamps. Since the Volvo XC90 test vehicle intentionally had its headlamps adjusted several times as part of a repeatability test, those figures are located last with more details to document the different adjustments performed by different aimers (staff members).

The following figure is a photo of the headlamp aim setting of the NHTSA stimulus car (Camry) headlamps.

Figure 89. *NHTSA Stimulus Camry Headlamp Adjustment (Adjusted_Camry_Headlights2.jpg)*

The following figure is a photo of the headlamp aim setting of the NHTSA stimulus truck headlamps.

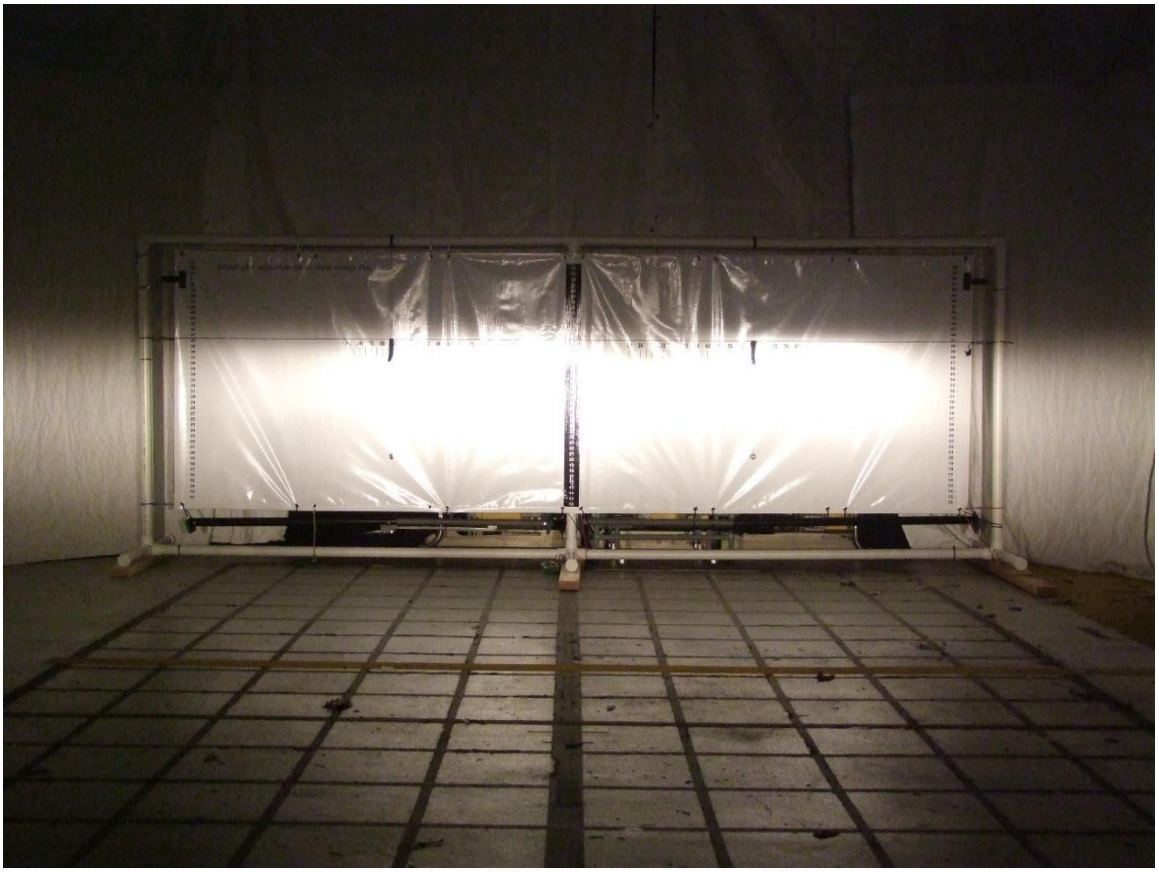
Figure 90. *NHTSA Stimulus F-150 Truck Headlamp Adjustment (Adjusted_Truck_Headlights.JPG)*

The following figure is a photo of the headlamp aim setting of the NHTSA stimulus motorcycle headlamp.

Figure 91. *NHTSA Stimulus Motorcycle Headlamp Adjustment (Adjusted_MC_Headlight.jpg)*

The following figure is a photo of the headlamp aim setting of the NHTSA F-150 pickup truck headlamp.

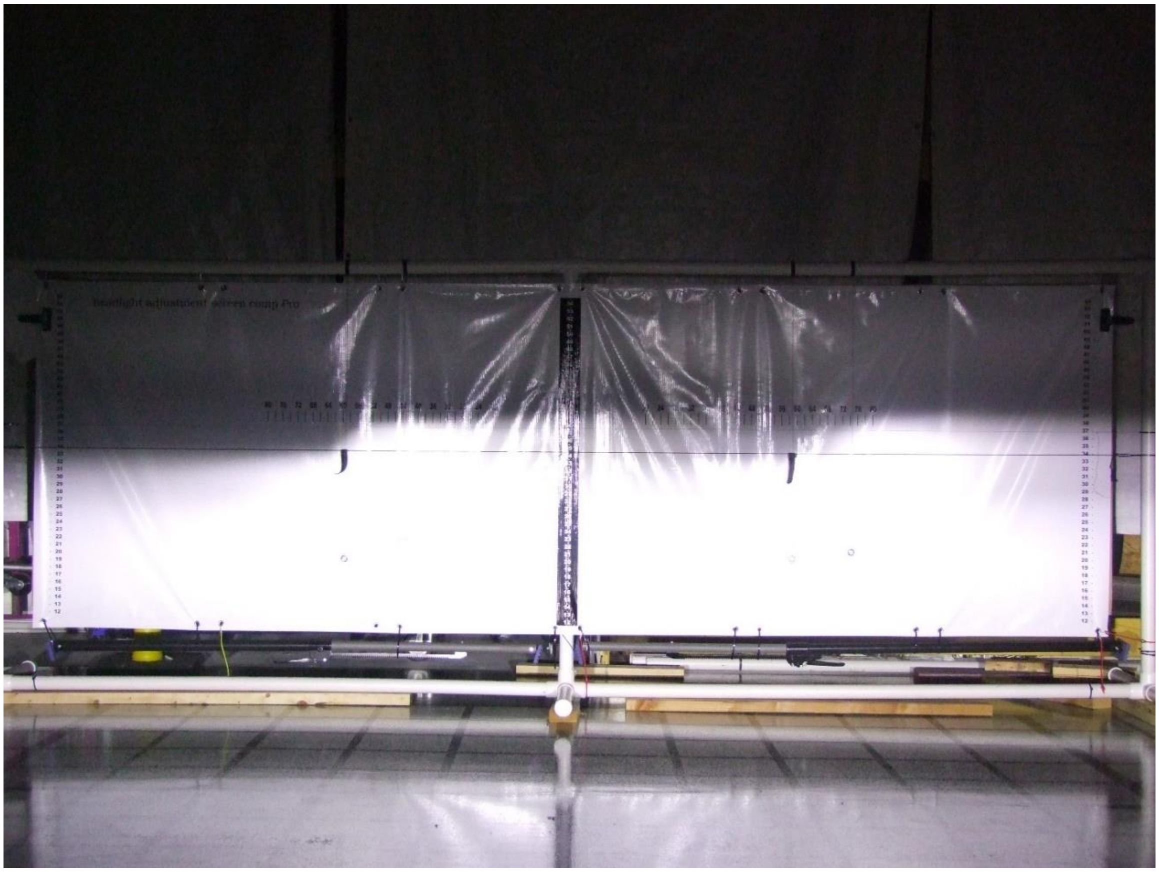
Figure 92. *NHTSA F-150 Pickup Truck Headlamp Adjustment (Adjusted_Pickup_Both_Lights.jpg)*



For repeatability testing, the Volvo test vehicle's headlights were adjusted six different times, twice each by three different members of the research staff, to assess any potential effects of different aimers.

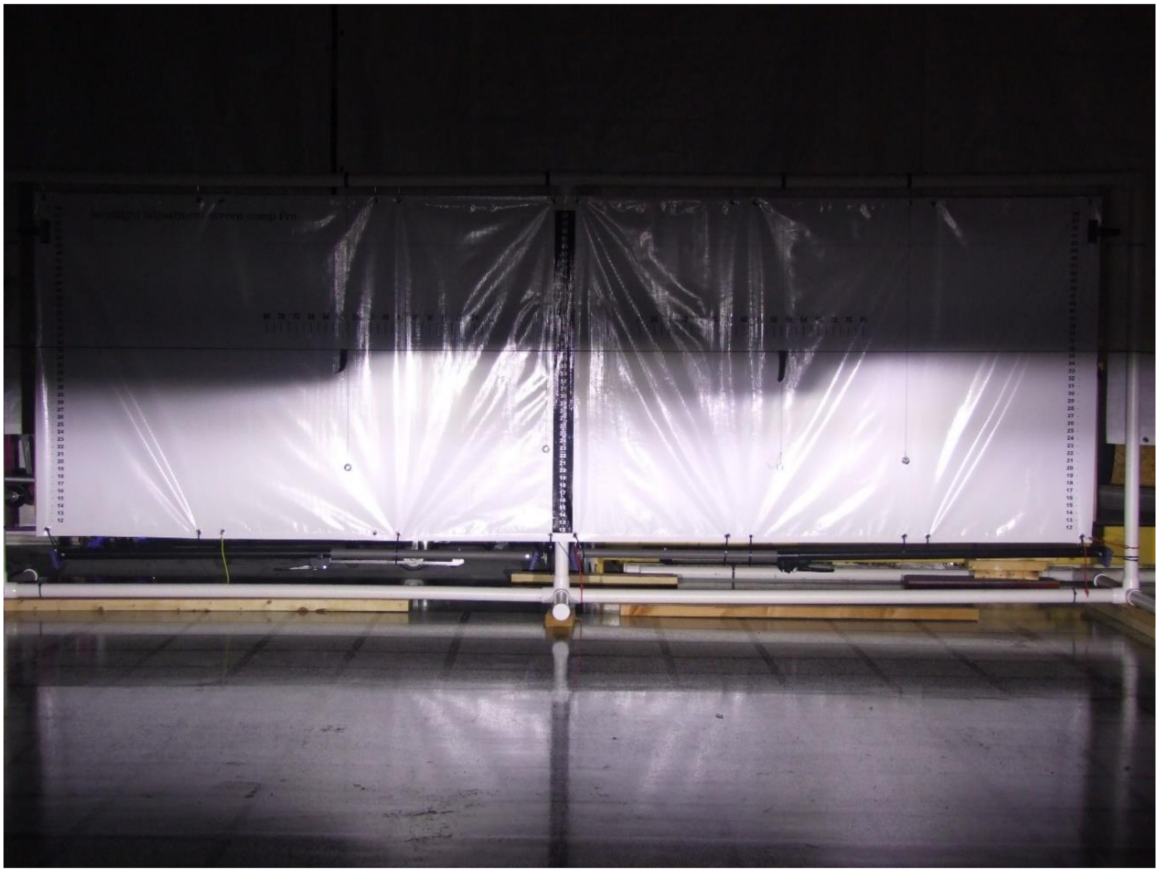
The following figure is a photo of the headlamp aim setting of the Volvo XC90 by the first staff member's first headlamp adjustment.

Figure 93. *Volvo XC9 Headlamp Adjustment, Aimer A, Adjustment 1 (Volvo_Both_Headlights_Alignment_(Initial)_D1-1.jpg)*



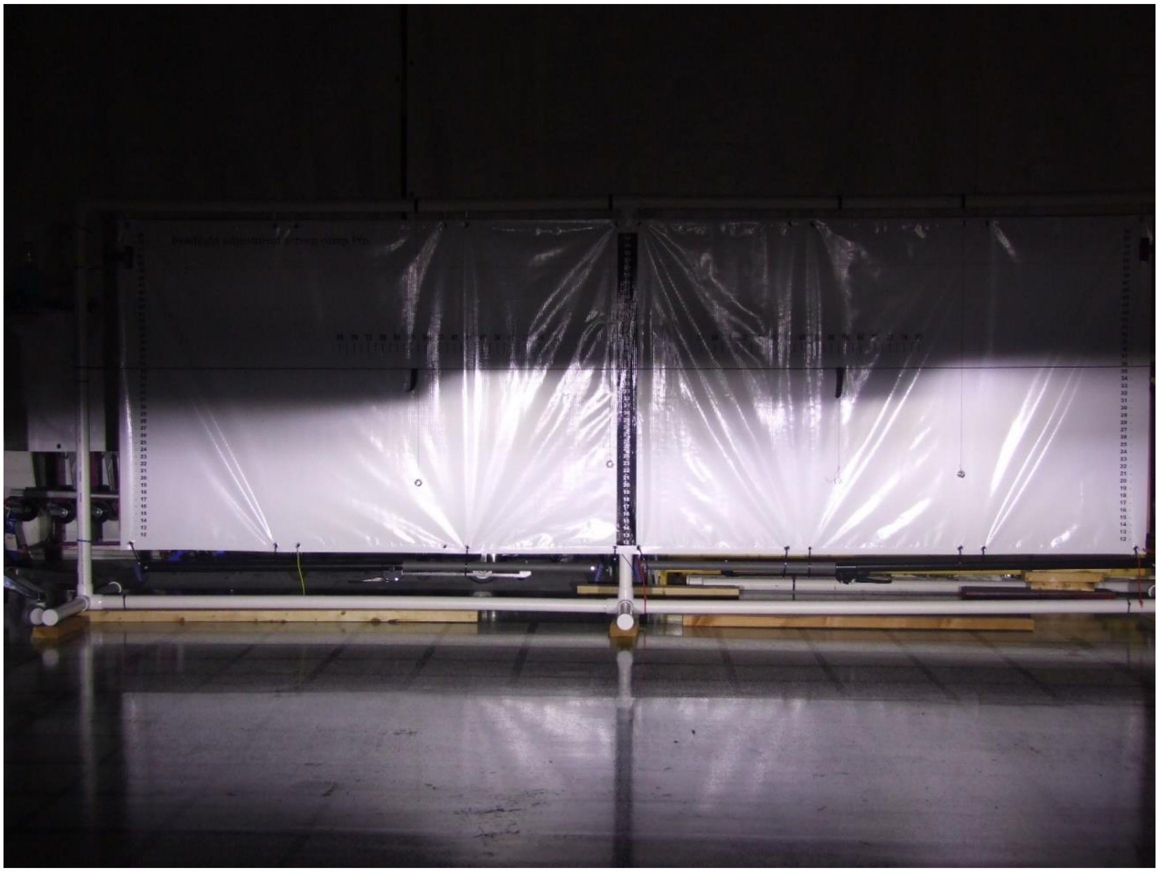
The following figure is a photo of the headlamp aim setting of the Volvo XC90 by the first staff member's second headlamp adjustment.

Figure 94. *Volvo XC9 Headlamp Adjustment, Aimer A, Adjustment 2 (Volvo_Both_Headlight_Adjustments_D1-2.jpg)*



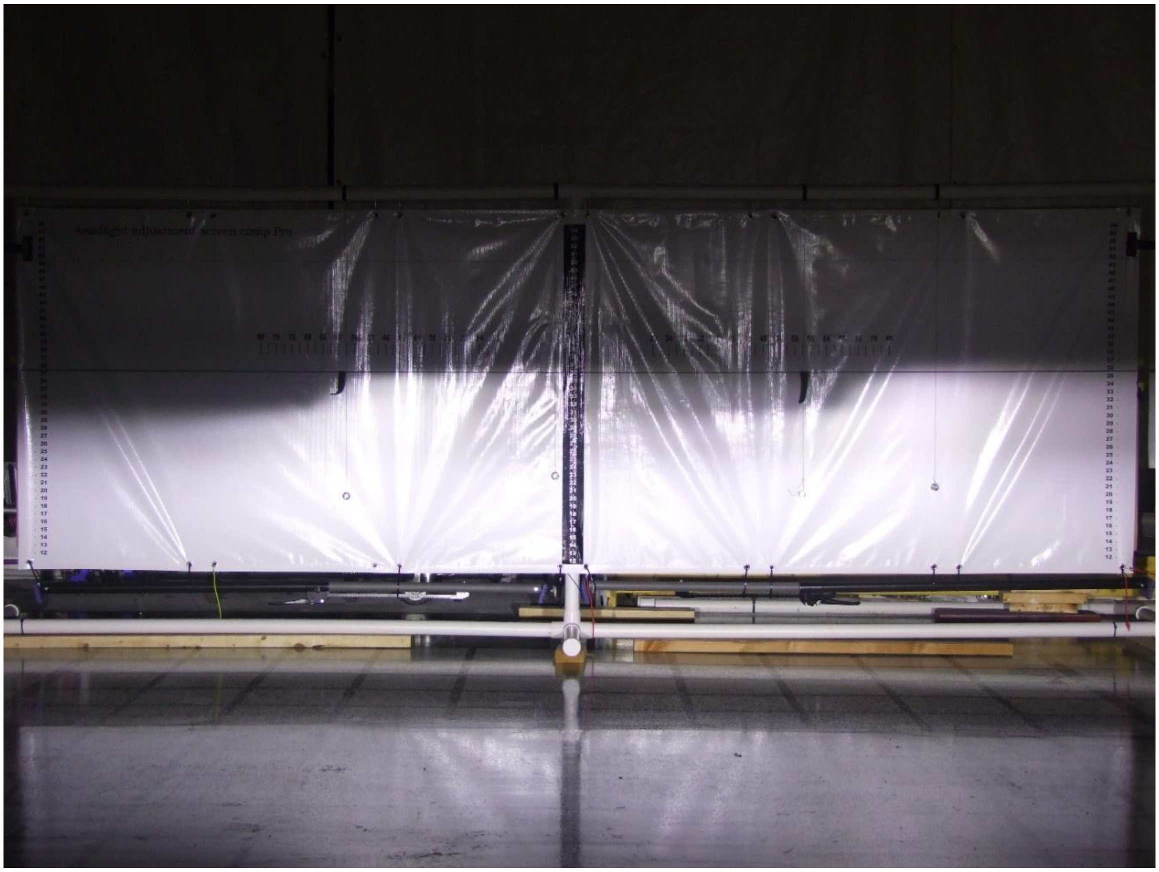
The following figure is a photo of the headlamp aim setting of the Volvo XC90 by the second staff member's first headlamp adjustment.

Figure 95. *Volvo XC9 Headlamp Adjustment, Aimer B, Adjustment 1 (Volvo_Both_Headlight_Adjustments_D2-1.jpg)*



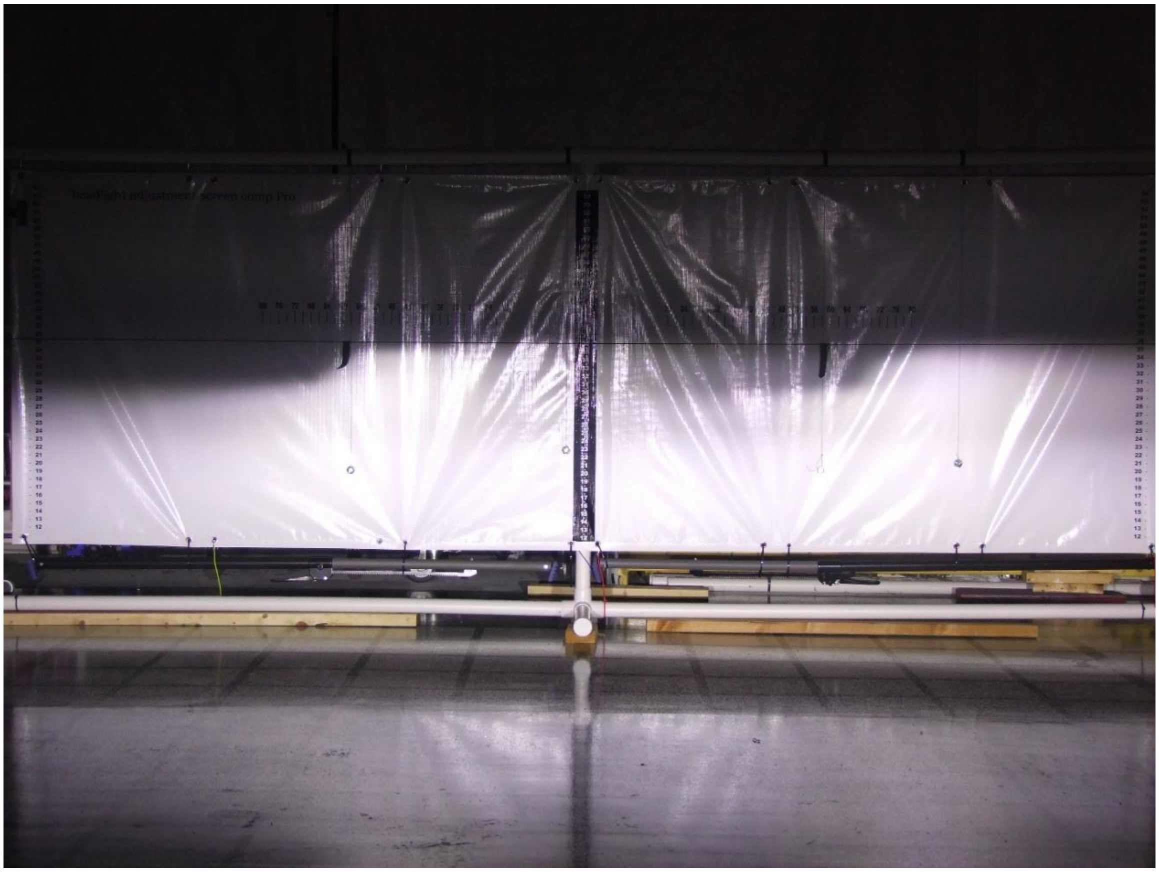
The following figure is a photo of the headlamp aim setting of the Volvo XC90 by the second staff member's second headlamp adjustment.

Figure 96. *Volvo XC9 Headlamp Adjustment, Aimer B, Adjustment 2 (Volvo_Both_Headlight_Adjustments_D2-2.jpg)*



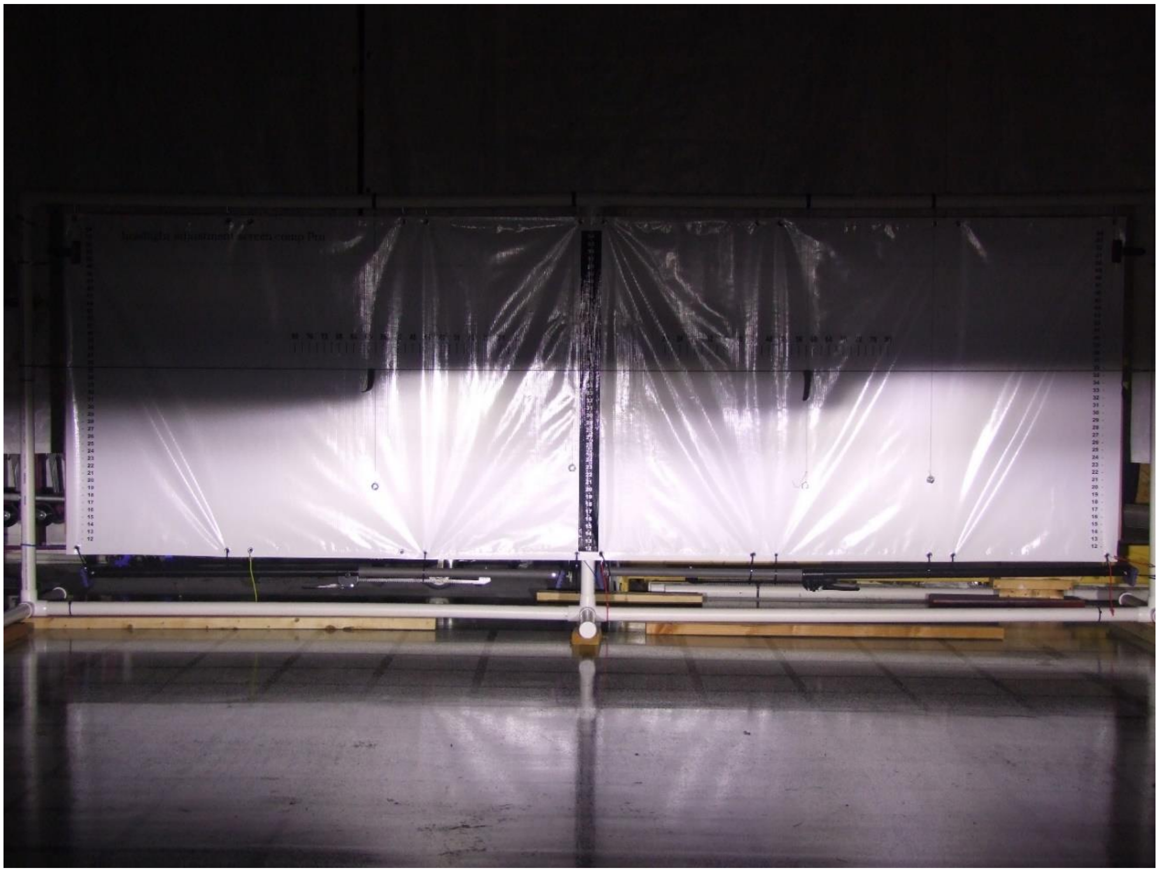
The following figure is a photo of the headlamp aim setting of the Volvo XC90 by the third staff member's first headlamp adjustment.

Figure 97. *Volvo XC9 Headlamp Adjustment, Aimer C, Adjustment 1 (Volvo_Both_Headlight_Adjustments_D3-1.jpg)*



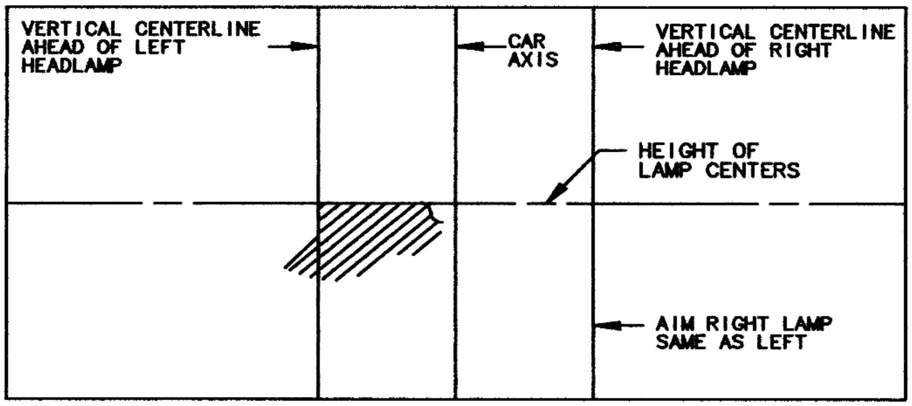
The following figure is a photo of the headlamp aim setting of the Volvo XC90 by the third staff member's second headlamp adjustment.

Figure 98. *Volvo XC9 Headlamp Adjustment, Aimer C, Adjustment 2 (Volvo_Both_Headlight_Adjustments_D3-2.jpg)*



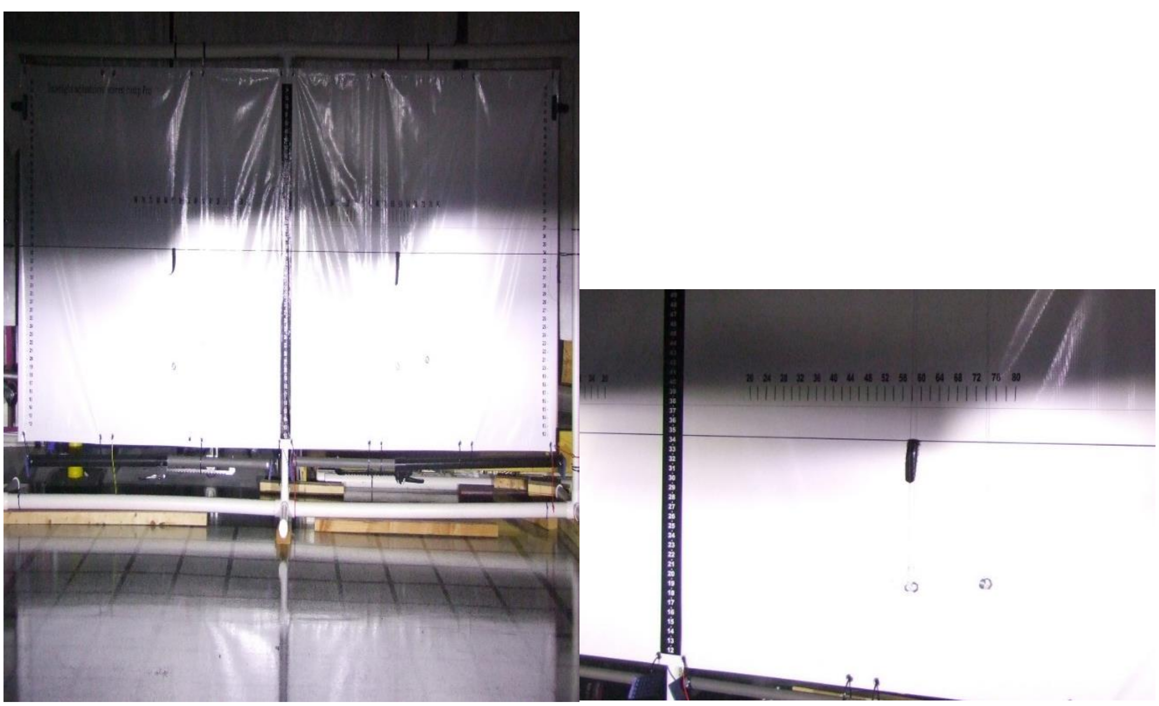
See the reports indicated above for more details. In general, as part of preparation for testing the repeatability of the NHTSA ADB test procedure, the Volvo XC90 test vehicle was initially aimed following the SAE J599 headlamp aiming procedure. SAE J599 details the aiming of the beam in the following diagram:

Figure 99. *SAE J599 Diagram: High-Intensity Zone (Shaded Area) of a Properly Aimed Lower Beam on the Aiming Screen 7.6m (25ft) in Front of the Vehicle*



The headlamp center of the repeatability test vehicle (Volvo XC90) was measured to be at 37.3 inches. The initial aiming condition prior to testing can be seen here with the top guide set to 37.5 inches.

Figure 100. *Volvo XC90 Headlamp Adjustment, Set to 37.5 Inches*



Most of the repeatability testing was done with this initial aiming condition. This includes all 10 night to night repetitions, and all single-night gauge repetitions.

Before the start of the 'bending lights off' repetition, the vehicle had its headlamps re-aimed. Five subsequent repetitions were completed with the headlamps re-aimed between each one.

For the aiming repeatability procedure, the headlamps were misaligned by one person, and then another would reset them using the SAE J559 procedure. The aiming guides were not touched during the re-aiming process. During data analysis, a discrepancy was found in the receptor head readings before and after the aiming process.

Upon investigation of the aiming photos for each re-aiming, it was found that the guides had at some point been moved after the original aiming, and never reset. The guide can be seen to be set at 36 inches, resulting in a headlamp height set 1.5 to 2 inches lower than the original setting in the following figure. This was the setting used for the five re-aimed repetitions; thus, the headlamps are aimed at a different height than the first headlamp setting used for the majority of the other repeatability testing.

Figure 101. *Volvo XC90 Headlamp Adjustment, Set to 36 Inches*

DOT HS 813 xxx

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