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16. Abstract

This report summarizes an assessment of a draft test procedure for confirming the visibility performance of lower beam headlighting systems. Headlighting system performance in this procedure is determined by activating the lower beam headlamps on a production vehicle and measuring the amount of light cast onto the forward roadway over an array of specified locations. Performance levels are then calculated based on measured values for the specified locations.

In this assessment, three vehicles were subjected to three repetitions (sets) of the test procedure. Results showed measured values for visibility and glare measurement locations to be consistent across the three test repetitions. Calculated performance levels based for these same measurement locations were also consistent across the three measurement sets (2015 Cadillac ATS: 5; 2014 Infiniti Q50: 25; 2016 Volvo XC90: 15). Measurement results for an expanded array of measurement locations showed higher coefficient of variation values for the center and left lanes than were seen for the right lane. Performance levels based on the center and left-lane locations were consistent across the three test repetitions for two vehicles, but were not consistent for the third vehicle because one of the measured values was very close to the 3.0 lux cutoff for visibility scoring.

An alternative test procedure was considered that would involve measuring illuminance at only the rearmost points and then calculating the remaining values using the inverse square law of light. Performance levels based on calculated illuminance values matched measurement-based performance levels for two of the three vehicles tested. For the third vehicle, differences resulting in a lower performance level based on calculated illuminance values.

Overall, the test procedure presented no difficulties to execute and was effective in characterizing lower beam performance levels. This test effort also provided valuable information on headlamp illuminance consistency and indicated good test repeatability. The inclusion of center and left lane measurement points to augment the right lane measurement points was informative, but also showed more variance in measured values which may result in different performance level values across multiple test repetitions. The use of alignment aids such as those used in this test effort can help to achieve accurate and repeatable test vehicle and receptor head positioning.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This report summarizes an effort to evaluate a draft test procedure for confirming the visibility performance of lower beam headlighting systems. The draft test procedure differs from the existing equipment-based Federal Motor Vehicle Safety Standard (FMVSS) No.108 requirements in that it examines headlighting system performance as installed on a production light vehicle.

Lower beam headlighting system performance is determined by activating the lower beam headlamps on a production vehicle and measuring the amount of light that is cast onto the forward roadway over an array of specified locations. Two sets of visibility measurement location arrays were examined consisting of visibility and glare measurement points. One array, "Array 1," included forward measurement points to the right and left of the vehicle, while the second array, "Array 2," included the Array 1 points as well as points in the same lane as the test vehicle and additional points in the left lane. For each measurement location, the ambient illumination value was subtracted from the headlamp illumination value to determine the net illuminance provided by the test vehicle's headlighting system at that point. Performance levels were calculated based on measured values for the specified locations. The performance level was calculated using the following equation:

$$\text{Level} = [5 * \Sigma N_v] - [10 * N_g]$$

For determining the lower beam headlighting system's performance level, net illuminance measurements of 3.000 lux or greater are given an N_v value of 1. A net glare measurement of greater than or equal to 0.634 lux is given an N_g value of 1. The best possible performance level rating is 25 and the lower possible rating is 0.

In this effort to assess the draft test procedure, three vehicles were subjected to three repetitions (sets) of the test procedure. Results of these tests showed measured values to be consistent across the three test repetitions, indicating that the draft test procedure produces reliable results. Calculated performance levels based on the Array 1 measurement locations were also consistent across the three measurement sets (2015 Cadillac ATS: 5; 2014 Infiniti Q50: 25; 2016 Volvo XC90: 15). Measurement results for Array 2 showed higher coefficient of variation values for the center and left lanes than were seen for the right lane (NHTSA visibility location). Performance levels based on the Array 2 locations were consistent across the three test repetitions for two vehicles, but were not consistent for the third vehicle because one of the measured values was very close to the 3.0 lux cutoff for visibility scoring.

An alternate test procedure approach was also examined that involved measuring illuminance at only the rearmost measurement points and then calculating the remaining points based on the measured values using the inverse square law of light. Magnitudes of differences between measured and calculated illuminance values for the Array 1 measurement locations were 0.25 lux or less across sets, while the magnitudes of differences for center and left lane points were larger, up to as much as 3.32 lux. Performance levels based on calculated illuminance values matched measurement-based levels for two of the three vehicles tested. Differences between measured illuminance values and values calculated based on a single measured point in each lane were observed and resulted in different performance levels in some cases. Specifically, two of the three tested vehicles' performance levels based on calculated values were the same as for measured values, but the third vehicle showed differences between performance levels based on measured versus calculated values. The performance level based on calculated illuminance values was lower performance than that based on measured values. Given the detailed steps taken to ensure the accuracy of the positioning of test vehicle and illuminance measurement components, it is possible that differences in measured illuminance values may be related to variations in the intensity of light through this region of the beam pattern.

Overall, the draft test procedure presented no difficulties to execute and was effective in characterizing lower beam performance levels. This effort provided valuable information on headlamp illuminance consistency and test repeatability. The inclusion of center and left lane measurement points to augment the Array 1 right-lane measurement points was informative, but also showed more variance in measured values. The use of alignment aids such as those used in this test effort are recommended to achieve accurate and repeatable test vehicle positioning.

1.0 INTRODUCTION

This report summarizes an effort to evaluate a draft test procedure for confirming the visibility performance of lower beam headlighting systems for light vehicles. The draft test procedure differs from the existing equipment-based Federal Motor Vehicle Safety Standard (FMVSS) No.108 [1] requirements in that it examines headlighting system performance as installed on a production vehicle.

This full-vehicle test procedure is conducted outdoors on a test track in dark conditions with the test vehicle stationary. The lower beam headlighting system is activated and the amount of light cast onto the roadway over a set of specific locations forward of the vehicle is measured. The ability of the lower beam headlighting system to illuminate the forward roadway in these locations is evaluated and a performance level is calculated using a performance level equation.

2.0 METHOD

Testing was performed based on a draft test procedure for measuring lower beam headlighting system performance in illuminating the forward roadway.

2.1 Test Procedure Approach

This test procedure assessment effort involved measuring lower beam performance outdoors in darkness on a test track. Illumination across various measurement locations forward of the test vehicle was measured while controlling for ambient light levels. Illuminance measurement locations included multiple “visibility measurement points” and a “glare measurement point.”

2.1.1 Measurement Locations

Two sets of illuminance measurement locations were examined. Measurement locations included visibility and glare measurement points at various distances from the test vehicle at which the illuminance from the lower beam headlamps was measured. These points for the first set of locations, “Array 1,” were as follows:

A. Five lux meters are placed with the center of the sensor 200 mm vertically above the test pad surface, facing the vehicle at the following locations from the longitudinal centerline of the vehicle (left/right) and from the front bumper (down road)
   a. Visibility Detector v_{75}: 4 m right, 75 m down road
   b. Visibility Detector v_{85}: 4 m right, 85 m down road
   c. Visibility Detector v_{95}: 4 m right, 95 m down road
   d. Visibility Detector v_{105}: 4 m right, 105 m down road
   e. Visibility Detector v_{115}: 4 m right, 115 m down road

B. One lux meter is placed with the center of the sensor 1.0 m vertically above the test pad surface, facing the vehicle at the following location from the longitudinal centerline of the vehicle (left/right) and from the front bumper (down road)
   a. Glare Detector g_{60}: 4 m left, 60 m down road

Two additional glare point locations were examined to permit assessment of alternative heights for the glare measurement location. These heights were 1.1 m and 1.2 m and are shown in Figure 1 as locations 2 and 3, respectively.

The specified measurement locations at which illuminance receptor heads were placed are shown in Figure 4 and are numbered 1 and 4 to 8.

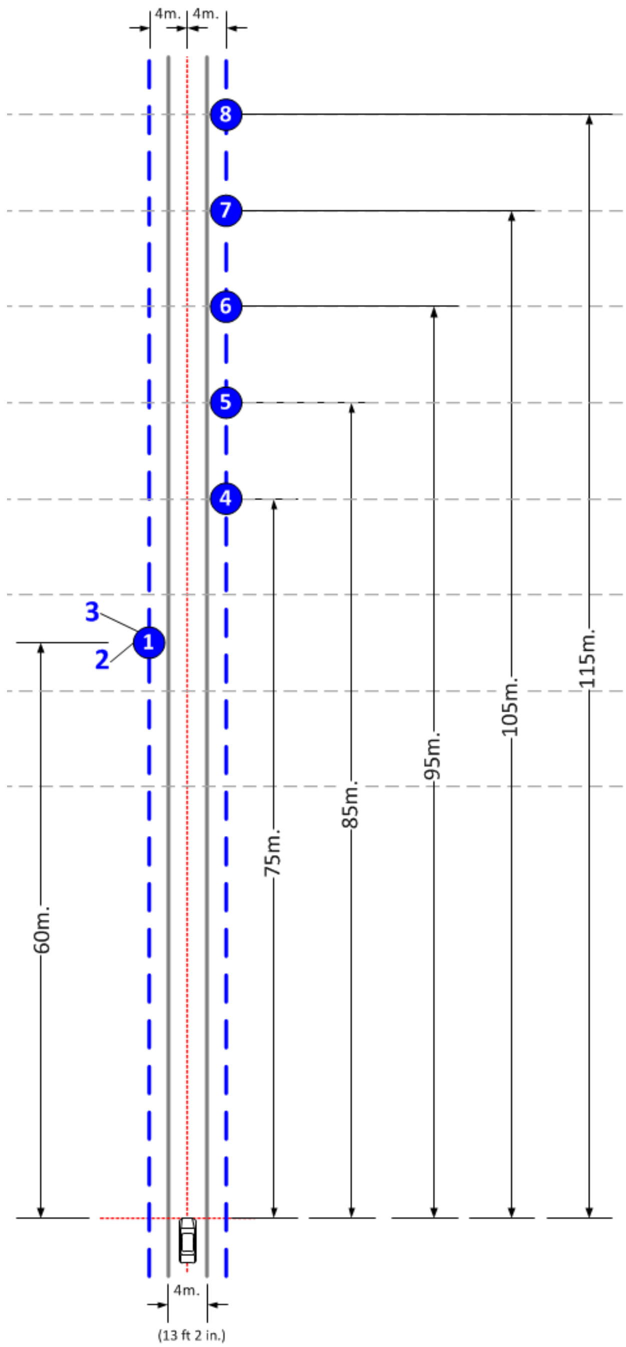

Figure 1. Draft Illuminance Measurement Locations and Added Glare Value Locations

Array 2 added measurement locations to the Array 1 set to permit lower beam headlamp illuminance to be measured over a broader area covering locations in the same lane and to the left of the vehicle. Array 2 measurement locations are shown in Figure 2.

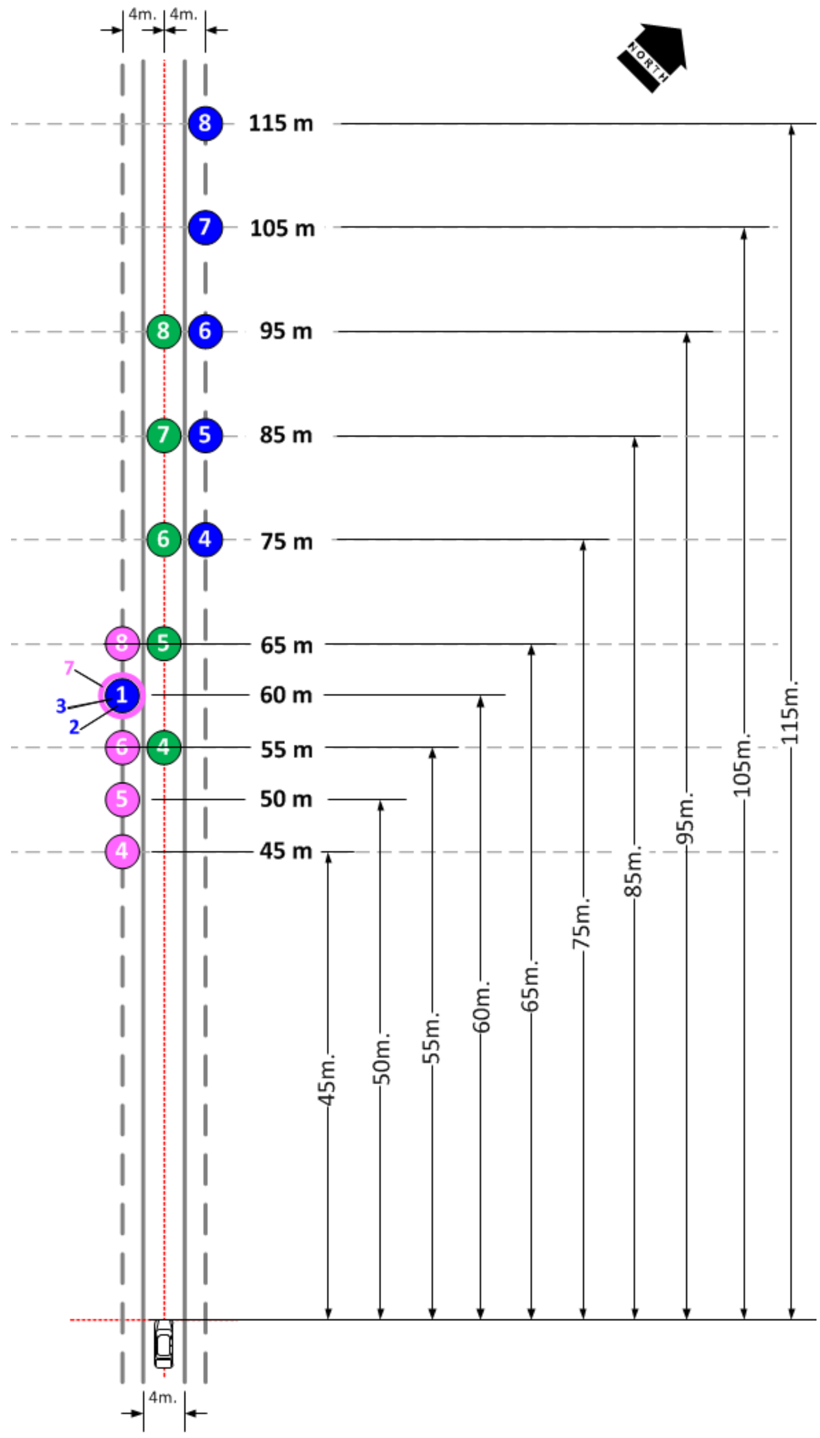

Figure 2. Expanded Set of Illuminance Measurement Locations

Receptor heads were mounted on tripods to position them at the required height vertically above the test pad surface. All measurement locations were marked on the test surface to permit repeatable placement of the receptor heads. A laser was also used to confirm accurate alignment of the receptor heads in each lane.

An alternative test procedure approach examined involved measuring illuminance at only the rearmost locations in each lane and then calculating the values for locations forward of those locations using the inverse square law of light. The inverse square law of light states that the intensity per unit area varies in inverse proportion to the square of the distance between the measurement point and the source. Examination of this alternative procedure did not require additional testing. Calculations used to assess this recommendation are presented in Section 3 of this report.

2.1.2 Measurement Adjustments and Illuminance Calculation

For each measurement location, the measured ambient illumination value was subtracted from the headlamp illumination value to determine the net illuminance provided by the test vehicle's headlighting system at that point. Performance levels were calculated based on measured values for the specified locations. The performance level was calculated using the following equation:

$$\text{Level} = [5 * \Sigma N_v] - [10 * N_g]$$

For determining the lower beam headlighting system's performance level, net illuminance measurements of 3.000 lux or greater are given an N_v value of 1. A net glare measurement of greater than or equal to 0.634 lux is given an N_g value of 1. The best possible performance level rating is 25 and the lower possible rating is 0.

2.2 Test Equipment

2.2.1 Cameras

Digital cameras were used to capture still photos of each test vehicle as well as headlighting beam patterns.

2.2.2 Weather Measurement Equipment

The test procedure stipulated an ambient temperature range and maximum wind speed. Equipment for measuring these aspects of ambient conditions included a portable weather station that provided temperature and humidity information. Ambient weather data was also obtained from the test facility's operations center.

2.2.3 Illuminance Measurement Equipment

A Konica Minolta T-10A illuminance meter was used to measure the amount of light emitted by a vehicle's lower beam headlamps. The T-10A is a multi-function digital illuminance meter with detachable receptor head. The T-10A 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 (at 35°C/95°F) relative humidity with no condensation [2]. The illuminance meter (pictured in Figure 3) had the capability to record both single-point (using analog output) and multi-point (using digital output) measurements. The meter could perform single-point measurements instantaneously or record continuous single-point measurements using its analog output. Multi-point measurement required that the meter be powered using an approved AC adapter and that two or more receptor heads be connected to the meter using adapters (T-A21) and commercially available 10Base-T network cable (category 5 straight cable)[2].

Figure 3. Konica Minolta T-10A Illuminance Meter

For this effort, multi-point measurement was performed in which the meter was fitted with a T-A20 main body adaptor and each receptor head was fitted with a T-A21 receptor head adaptor. Using the T-A21 adaptors, category 5 cables were connected between each receptor head in series and to the meter. Per the meter's instruction manual, the recommended AC adaptor was used to power the meter during multi-point measurement. The AC adaptor was connected to a power invertor and then to a Schumacher PSJ-3612 "Jump Starter and Portable Power Unit" that provided power. The power invertor was powered through the vehicle's cigarette lighter. Konica Minolta software consisting of a Microsoft Excel macro was run on a Windows-based laptop to record data. Figure 4 contains a photograph showing components used in the multi-point meter configuration. Illuminance measurements were captured over a duration of 10 seconds at a rate of 1 Hz.

Figure 4. Illuminance Meter and Components Used for Multi-Point Measurement

Model and serial number information for the meter and receptor head serial numbers for components used in the testing are provided in Table 1. The table also shows which specific receptor heads were used in each of the 18 measurement locations. Numerals in subscript for visibility location labels indicate the distance in meters from the test vehicle. Numerals in subscript for glare locations indicate both the distance from the test vehicle and the measurement location height.

Table 1. Model and Test Location Information for Illuminance Meter Components

Component Label	Serial Number	Location Label	Height
Konica-Minolta T-10A	20011265	N/A	N/A
Receptor Head 1 (RH1)	30011928	$g_{60-1.0}$	1.0 m
Receptor Head 2 (RH2)	30012155	$g_{60-1.1}$	1.1 m
Receptor Head 3 (RH3)	30012154	$g_{60-1.2}$	1.2 m
Receptor Head 4 (RH4)	30011738	v_{75}, c_{55}, l_{45}	200 mm
Receptor Head 5 (RH5)	30011924	v_{85}, c_{65}, l_{50}	200 mm
Receptor Head 6 (RH6)	30011927	v_{95}, c_{75}, l_{55}	200 mm
Receptor Head 7 (RH7)	30015294	v_{105}, c_{85}, l_{60}	200 mm
Receptor Head 8 (RH8)	30015768	v_{115}, c_{95}, l_{65}	200 mm

2.2.4 Test Vehicle Positioning Aids

Steps were taken to accurately position test vehicles in the center of the designated lane on the test surface. Two lasers were mounted on the test vehicle to aid vehicle alignment. One laser was mounted on the hood of the test vehicle at its centerline and pointed forward. A second laser was mounted at the rear of the vehicle at its centerline and pointed down at the ground. Pavement markings were used to highlight the lane center as well as to indicate the proper longitudinal location at which the headlamp light sources should be positioned to ensure the proper distance from the illuminance measuring equipment. The longitudinal lane centerline as well as a traffic delineator post (se Figure 5) positioned on that line provided a visual target when driving the test vehicle into position. The traffic delineator post had a vertical black (tape) stripe on which the laser beam could be seen and used as a guide when driving the vehicle forward into position. Once in position, the rear-mounted was laser was checked to ensure its beam intersected the lane centerline marking.

Figure 5. Traffic Delineator Post Used to Mark Desired Position of Center of Front Bumper

2.3 Test Surface

The draft test procedure specified that the test pad used should be flat, level asphalt with dimensions of at least 130 m long and 20 m wide.

For the effort documented in this report, testing was conducted on the Skid Pad facility of the Transportation Research Center [4]. This course has a concrete broomed surface and five smooth, delineated lanes. Three of the five 3,600-ft long lanes were used for this testing.

2.4 Photometric Measurement Locations and Test Setup

2.5 Test Vehicle Preparation

Each vehicle was prepared for testing by filling the fuel tank and ensuring test vehicle's tires were set to the vehicle manufacturer recommended cold inflation pressures. The vehicle's hood, trunk, and all doors were closed and the steering wheel was adjusted to the position where the longitudinal centerlines of all vehicle tires were parallel to the longitudinal centerline of the vehicle. Vehicle battery voltage level was confirmed to be within the nominal operating range (e.g., +11 to +16 V DC). The vehicle was loaded to simulate the weight of the driver only. The weight of the driver is represented by 45 kg (100 lbs) resting on the seat pan and 23 kg (50 lbs) resting on the vehicle floorboard placed in the driver's designated seating position.

All test vehicles' headlamps were aimed prior to testing.

2.6 Test Conditions

The draft test procedure requires that ambient illumination conditions measured at the six specified measurement locations with the test vehicle's headlamps off shall each be less than 0.200 lux.

Ambient temperature, humidity, and wind speed information was obtained both from the test facility's official conditions measurement data and from portable weather stations mounted in or on the test vehicles. The test procedure calls for ambient temperature to be within the operating range of the measuring equipment but also within 45°F (7°C) and 104°F (40°C) and wind speed less than 22 mph (35 kph). Tests should not be performed during periods of inclement weather including, but not limited to, rain, snow, hail, fog, smoke, and/or ash.

2.7 Test Procedure

2.7.1 Pre-Test Photographic Documentation

Still, color photographs were taken of each vehicle tested including the following views:

- Vehicle exterior, front
- Vehicle exterior, rear
- Vehicle exterior, four three-quarter pictures

Photos were also obtained of the vehicles' headlighting system projection patterns before and after aiming.

2.7.2 Headlamp Aiming

The test procedure specifies the following pre-test steps for ensuring that the headlamps are properly aimed:

1. Place the test vehicle on a flat, level surface.

2. Place the headlamp-aiming screen 7.6 m in front of the vehicle, adjust the screen height to match the headlamp mounting height, and photograph the illuminated screen.

3. Aim the headlamps according to the owner's manual.

4. Photograph the illuminated headlamp-aiming screen to document the vehicle's headlighting system projection pattern.

2.7.3 Test Procedure Steps

Per the draft test procedure, the following steps were carried out to measure the lower beam headlamp illuminance:

1. Confirm suitable ambient conditions for testing.
2. Start the vehicle's engine and use the vehicle's headlamp control to activate the lower beam headlamps to allow both the engine and headlamps to reach normal operating temperature.
3. Position the test vehicle accurately on the test surface and properly aligned to the photometric instrumentation setup.
4. Place 45 kg (100 lbs) resting on the seat pan and 23 kg (50 lbs) resting on the vehicle floorboard placed in the driver's designated seating position.
5. Turn the vehicle's lower beam headlamps off and measure and record/document the ambient illumination conditions at each illuminance receptor head.
6. Turn the vehicle's lower beam headlamps on and measure the illuminance at each receptor head.

Illuminance measurement data were recorded over a 10-second period at a rate of 1 Hz. An average of the 10 recorded values was calculated for use in lower beam performance level scoring.

Ambient illumination measurements were also obtained at the specified measurement points. Ambient illuminance values were subtracted from corresponding average headlamp illuminance value for each measurement point to obtain a value for illuminance attributable only to the test vehicle's headlamps.

2.7.4 Net Illuminance Calculation

For each measurement location, the ambient illumination value was subtracted from the headlamp illumination value to determine the net illuminance provided by the test vehicle's headlighting system. Each net illuminance value must be 3.000 lux or greater to be included in the calculation. Net illuminance measurements of 3.000 lux or greater are given an N_v value of 1. If the net glare measurement is above 0.634 lux, it will be included in the calculation. A net glare measurement of greater than or equal to 0.634 lux is given an N_g value of 1. The five N_v values are summed for use in calculating performance level, as described in the next section.

An example of net illuminance calculations is given below. Measurement location descriptors indicate the type of measurement ('v' for visibility and 'g' for glare) and the distance in meters from the test vehicle.

Example 1:

Measurement Location	Lower Beam Headlamp Illuminance (Lux)	Ambient Illumination (Lux)	Net Illuminance (Lux)	N_v	N_g
v_{75}	8.051	0.063	7.988	+1	
v_{85}	6.445	0.063	6.382	+1	
v_{95}	4.355	0.063	4.292	+1	
v_{105}	2.870	0.063	2.807	0	
v_{115}	1.897	0.063	1.834	0	
g_{60}	0.533	0.063	0.470		0
			ΣN_v	3	

2.7.5 Determine the Performance Level

The draft test procedure indicated the following Level Formula for use in calculating the performance level:

$$\text{Level} = [5 * \Sigma N_v] - [10 * N_g]$$

The best possible performance level is 25 and the lowest possible level is 0.

The performance level calculations for Example 1 above would be:

$$\text{Level} = [5 * \Sigma N_v] - [10 * N_g]$$
$$= [5 * 3] - [10 * 0]$$
$$\text{Level} = 15$$

2.7.6 Additional Details of Test Procedure Implementation for This Effort

Using the illuminance meter's multi-point measurement capability, measurements from 8 receptor heads were recorded simultaneously. Data were recorded over a 10-second period at a rate of 1 Hz. Ambient illumination measurements were also obtained in multi-point configuration.

During initial testing in this effort, it was observed that moving the receptor heads from lane to lane took longer than repositioning an individual test vehicle. As a result, for improved data collection efficiency in this effort, lower beam and ambient illuminance measurements for all three test vehicles were made for one lane before repositioning the receptor heads in the next lane.

Each vehicle's headlamps were turned off when they were not being measured so as not to interfere with testing of another vehicle. All test vehicles engines were running throughout a test set except the Infiniti for which the headlamps could not be turned off unless the vehicle's engine was shut off.

3.0 MEASUREMENT RESULTS

This section presents the results of testing conducted in support of the evaluation of the draft lower beam headlighting system visibility confirmation test procedure.

3.1 Test Vehicles

Three vehicles were examined in this testing. The vehicle mode information and headlighting system information are listed in the following table. The height of each vehicle's lower beam headlamps was determined using the optical axis marking on the headlamp lens (a circle on the lens in front of the light source).

Table 2. Vehicles Examined

Vehicle Model Info	Body Type	Mileage	Light Source Type	Auto Leveling ?	Lower Beam Headlamp Height (to nearest cm)
2015 Cadillac ATS (AWD 3.6L Premium)	Sedan	1,245	HID	No	68
2014 Infiniti Q50	Sedan	3,621	LED	Yes	67
2016 Volvo XC90 T6	SUV	3,184	LED	No	94

3.1.1 2015 Cadillac ATS

Still, color photographs of the measured 2015 Cadillac ATS (AWD 3.6L Premium) are presented Figures 6 to 8. Figure 9 contains a photograph of the lower beam headlamp illumination pattern.

Figure 6. 2015 Cadillac ATS - Front

Figure 7. 2015 Cadillac ATS - Rear

Figure 8. 2015 Cadillac ATS - Four Three-Quarter Photos

Figure 9. 2015 Cadillac ATS - Lower Beam Headlamp Projection Pattern (VOR, Aimed)

3.1.2 2014 Infiniti Q50

Still, color photographs of the measured 2014 Infiniti Q50 are presented in Figures 10 to 12. Figure 13 contains a photograph of the lower beam headlamp illumination pattern.

Figure 10. 2014 Infiniti Q50 - Front

Figure 11. 2014 Infiniti Q50 - Rear

Figure 12. 2014 Infiniti Q50 - Four Three-Quarter Photos

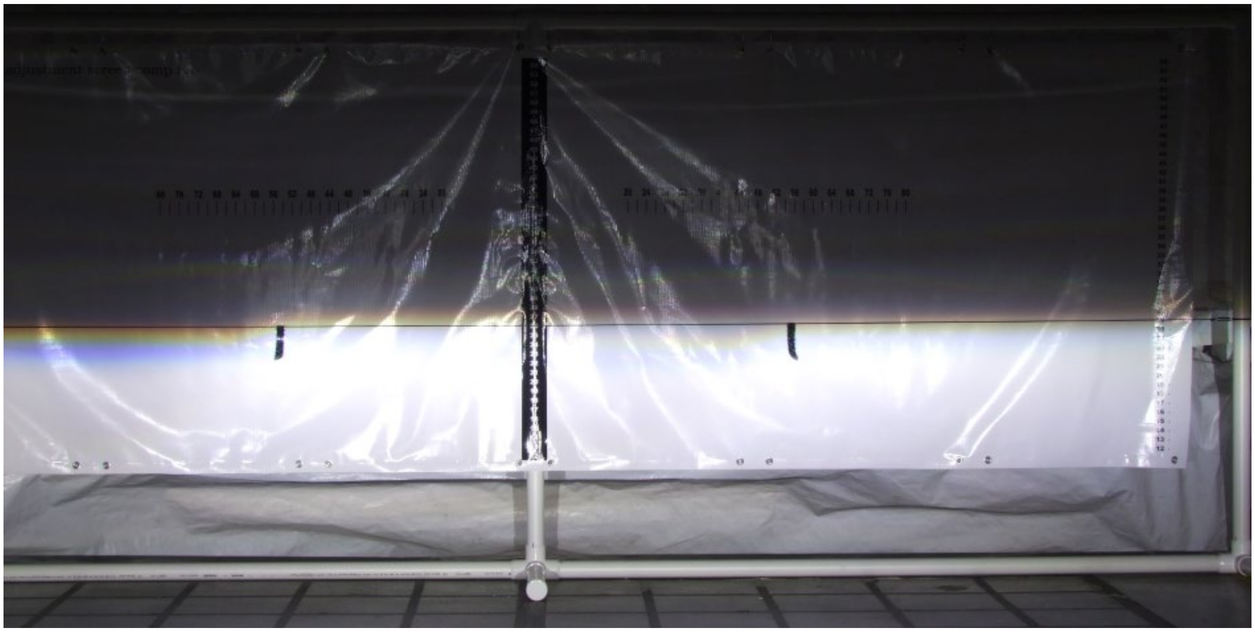

Figure 13. 2014 Infiniti Q50 - Lower Beam Headlamp Projection Pattern (VOR, Aimed)

3.1.3 2016 Volvo XC90 T6

Still, color photographs of the measured 2016 Volvo XC90 T6 are presented in Figures 14 to 16. Figure 17 contains a photograph of the lower beam headlamp illumination pattern.

Figure 14. 2016 Volvo XC90 T6 - Front

Figure 15. 2016 Volvo XC90 T6 - Rear

Figure 16. 2016 Volvo XC90 T6 - Four Three-Quarter Photos

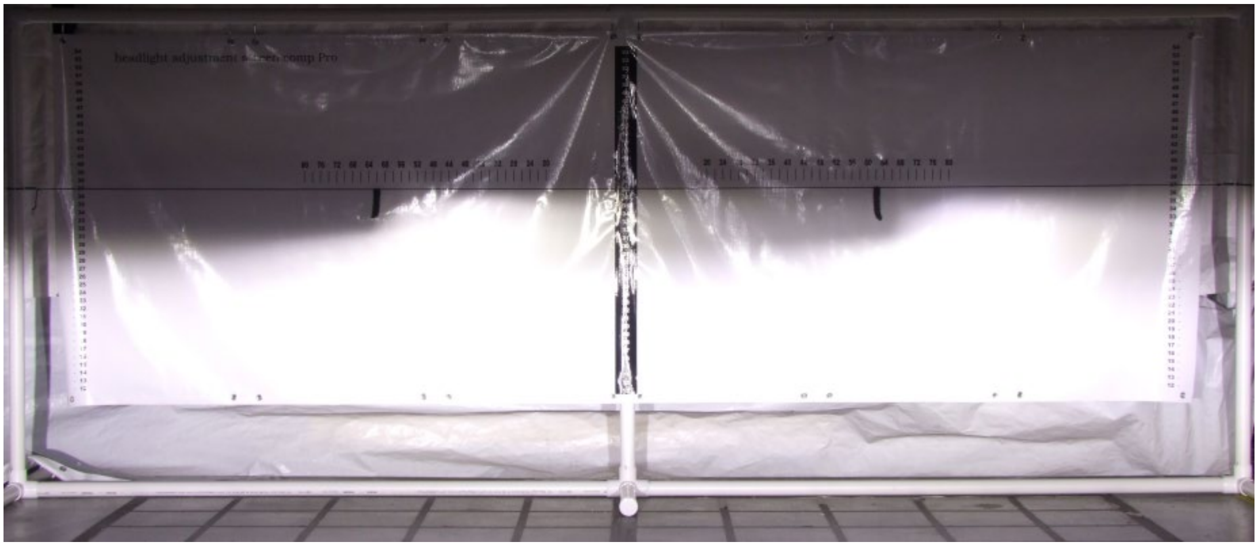

Figure 17. 2016 Volvo XC90 T6 - Lower Beam Headlamp Projection Pattern (VOL, Aimed)

3.2 Illuminance Values and Performance Level Results by Vehicle for Array 1 Measurement Locations

This section presents illuminance data for 5 visibility measurement locations and 3 glare measurement locations. Three complete sets of illuminance measurement data were recorded to permit an assessment of test repeatability. A quantitative assessment was performed using a statistical analysis of variance. The coefficient of variation (CV) is a measure of variability expressed as a percentage of the mean. CV is a unitless measure of spread calculated by dividing the standard deviation by the mean value and then multiplying by 100. CV is calculated according to the formula below.

$$CV = \sigma / X \times 100\%$$

where

σ = standard deviation of values

X = mean of values

Historically, NHTSA has categorized the CV scores according to Table 3 [4].

Table 3. Assessment of CV Values

CV	Assessment
0-5%	Excellent
>5 – 8%	Good
>8 – 10%	Marginal (Acceptable)
>10%	Poor (Unacceptable)

There are several considerations that must be taken into account when CV values are interpreted. Consideration must also be given to the magnitude of the response. If the mean response is small, then even a small number for the standard deviation can result in a large CV.

Since ambient light levels were subtracted from the average lower beam headlamp illuminance values to get net illuminance, set to set differences in net illuminance values for each vehicle are not due to ambient light level differences.

Tables 4 to 6 contain measurement results for the Cadillac ATS, Infiniti Q50, and Volvo XC90, respectively. Measurement locations indicated with a “v” focus on visibility while measurement locations designated by a “g” address glare. Numerals in subscript for visibility locations indicate the distance in meters from the test vehicle. Numerals in subscript for glare locations indicate both the distance from the test vehicle and the measurement location height.

Differences in measured values across test sets were small, with the highest standard deviation being 0.07 lux. Coefficient of variation values were in the “good” range for all except one glare point value for the Cadillac test vehicle.

Table 4. 2015 Cadillac ATS (VOR) –Net Illuminance Measurements and Descriptive Statistics for Array 1 Measurement Locations and Two Additional Glare Point Heights

	Illuminance (Lux)					
Measurement Location	**Set 1**	**Set 2**	**Set 3**	**Average Across Sets**	**SD**	**Coefficient of Variation**
v_{75}	3.38	3.47	3.53	3.46	0.0616	1.78
v_{85}	2.60	2.67	2.68	2.65	0.0356	1.34
v_{95}	2.06	2.13	2.15	2.11	0.0386	1.83
v_{105}	1.65	1.71	1.71	1.69	0.0283	1.67
v_{115}	1.37	1.42	1.42	1.40	0.0236	1.68
$g_{60\text{-}1.0}$	0.37	0.40	0.45	0.41	0.0330	8.11
$g_{60\text{-}1.1}$	0.31	0.33	0.37	0.34	0.0249	7.41
$g_{60\text{-}1.2}$	0.28	0.28	0.32	0.29	0.0189	6.43

Table 5. 2014 Infiniti Q50 (VOR) - Net Illuminance Measurements and Descriptive Statistics for Array 1 Measurement Locations and Two Additional Glare Point Heights

	Illuminance (Lux)					
Measurement Location	**Set 1**	**Set 2**	**Set 3**	**Average Across Sets**	**SD**	**Coefficient of Variation**
v_{75}	7.68	7.54	7.68	7.63	0.0660	0.865
v_{85}	6.05	5.93	6.08	6.02	0.0648	1.08
v_{95}	4.81	4.71	4.88	4.80	0.0698	1.45
v_{105}	3.82	3.78	3.94	3.85	0.0680	1.77
v_{115}	3.13	3.07	3.24	3.15	0.0704	2.24
$g_{60\text{-}1.0}$	0.42	0.37	0.40	0.40	0.0205	5.18
$g_{60\text{-}1.1}$	0.38	0.33	0.36	0.36	0.0205	5.76
$g_{60\text{-}1.2}$	0.35	0.32	0.34	0.34	0.0125	3.70

Table 6. 2016 Volvo XC90 T6 (VOL) - Net Illuminance Measurements and Descriptive Statistics for Array 1 Measurement Locations and Two Additional Glare Point Heights

	Illuminance (Lux)					
Measurement Location	**Set 1**	**Set 2**	**Set 3**	**Average Across Sets**	**SD**	**Coefficient of Variation**
v_{75}	5.37	5.34	5.30	5.34	0.0287	0.537
v_{85}	4.31	4.31	4.33	4.32	0.0094	0.218
v_{95}	3.46	3.44	3.46	3.45	0.0094	0.273
v_{105}	2.76	2.75	2.80	2.77	0.0216	0.780
v_{115}	2.19	2.18	2.24	2.20	0.0262	1.191
$g_{60\text{-}1.0}$	0.23	0.22	0.20	0.22	0.0125	5.76
$g_{60\text{-}1.1}$	0.22	0.21	0.20	0.21	0.00816	3.89
$g_{60\text{-}1.2}$	0.21	0.21	0.19	0.20	0.00943	4.64

Using the above data, performance levels were calculated. Tables 7 to 9 summarize the calculated levels for each test vehicle by data set. As stated previously, the draft test procedure indicated the following formula for calculating the performance level:

$$\text{Level} = [5 * \Sigma N_v] - [10 * N_g]$$

In this scoring scheme, the best possible performance level is 25 and the lowest possible level is 0.

Table 7. Cadillac Performance Level Calculations by Test Set for Measured Illuminance Values

Set 1			
Location	Net Illum. (lux)	N_v	N_g
v_{75}	3.38	1	
v_{85}	2.60	0	
v_{95}	2.06	0	
v_{105}	1.65	0	
v_{115}	1.37	0	
$g_{60\text{-}1.0}$	0.37		0
	$\sum N_v$	1	
	Level Result:	5	

Set 2			
Location	Net Illum. (lux)	N_v	N_g
v_{75}	3.47	1	
v_{85}	2.67	0	
v_{95}	2.13	0	
v_{105}	1.71	0	
v_{115}	1.42	0	
$g_{60\text{-}1.0}$	0.40		0
	$\sum N_v$	1	
	Level Result:	5	

Set 3			
Location	Net Illum. (lux)	N_v	N_g
v_{75}	3.53	1	
v_{85}	2.68	0	
v_{95}	2.15	0	
v_{105}	1.71	0	
v_{115}	1.42	0	
$g_{60\text{-}1.0}$	0.45		0
	$\sum N_v$	1	
	Level Result:	5	

Table 8. Infiniti Performance Level Calculations by Test Set for Measured Illuminance Values

Set 1			
Location	Net Illum. (lux)	N_v	N_g
v_{75}	7.68	1	
v_{85}	6.05	1	
v_{95}	4.81	1	
v_{105}	3.82	1	
v_{115}	3.13	1	
$g_{60\text{-}1.0}$	0.42		0
	$\sum N_v$	5	
	Level Result:	25	

Set 2			
Location	Net Illum. (lux)	N_v	N_g
v_{75}	7.54	1	
v_{85}	5.93	1	
v_{95}	4.71	1	
v_{105}	3.78	1	
v_{115}	3.07	1	
$g_{60\text{-}1.0}$	0.37		0
	$\sum N_v$	5	
	Level Result:	25	

Set 3			
Location	Net Illum. (lux)	N_v	N_g
v_{75}	7.68	1	
v_{85}	6.08	1	
v_{95}	4.88	1	
v_{105}	3.94	1	
v_{115}	3.24	1	
$g_{60\text{-}1.0}$	0.40		0
	$\sum N_v$	5	
	Level Result:	25	

Table 9. Volvo Performance Level Calculations by Test Set for Measured Illuminance Values

Set 1			
Location	Net Illum. (lux)	N_v	N_g
v_{75}	5.37	1	
v_{85}	4.31	1	
v_{95}	3.46	1	
v_{105}	2.76	0	
v_{115}	2.19	0	
$g_{60\text{-}1.0}$	0.23		0
	$\sum N_v$	3	
	Level Result:	15	

Set 2			
Location	Net Illum. (lux)	N_v	N_g
v_{75}	5.34	1	
v_{85}	4.31	1	
v_{95}	3.44	1	
v_{105}	2.75	0	
v_{115}	2.18	0	
$g_{60\text{-}1.0}$	0.22		0
	$\sum N_v$	3	
	Level Result:	15	

Set 3			
Location	Net Illum. (lux)	N_v	N_g
v_{75}	5.30	1	
v_{85}	4.33	1	
v_{95}	3.46	1	
v_{105}	2.80	0	
v_{115}	2.24	0	
$g_{60\text{-}1.0}$	0.20		0
	$\sum N_v$	3	
	Level Result:	15	

Performance level values were consistent across test sets for each vehicle. Table 10 presents a summary of performance levels for each vehicle and data set.

Table 10. Summary of NHTSA Lower Beam Headlighting System Visibility Performance Level by Vehicle for Measured Illuminance Values

	Repetition / Data Set		
	1	**2**	**3**
2015 Cadillac ATS	5	5	5
2014 Infiniti Q50	25	25	25
2016 Volvo XC90	15	15	15

3.3 Illuminance Values and Performance Levels by Vehicle for Expanded Array 2 Measurement Locations

This section presents illuminance data for an expanded set of measurement locations that includes the NHTSA measurement locations, as well as the SAE recommended locations forward and to the left of the test vehicle. Measurements for two additional glare measurement heights, as noted in Section 2.4 of this report are also included. Measurement locations indicated with a "v" focus on visibility while measurement locations designated by a "g" address glare. Numerals in subscript indicate the distance in meters from the test vehicle.

Three complete sets of illuminance measurement data were recorded. For each set, receptor heads were positioned in a lane and remained there while each test vehicle was moved into position for measurement to record measurement for that lane. Receptor heads were then moved to the next lane and remained in position while the three test vehicles were moved into place and measured in succession. This provided information on system performance consistency and test repeatability.

Values shown in Tables 11 to 13 for the Array 1 measurement locations (right lane and glare points) are the same as those presented in Tables 4 to 6.

Table 11. 2015 Cadillac ATS (VOR) Net Illuminance Measurements and Descriptive Statistics for Array 2 Measurement Locations

		Illuminance (Lux)					
	Measurement Location	**Set 1**	**Set 2**	**Set 3**	**Average Across Sets**	**SD**	**Coefficient of Variation**
NHTSA / Right	v_{75}	3.38	3.47	3.53	3.46	0.0616	1.78
	v_{85}	2.60	2.67	2.68	2.65	0.0356	1.34
	v_{95}	2.06	2.13	2.15	2.11	0.0386	1.83
	v_{105}	1.65	1.71	1.71	1.69	0.0283	1.67
	v_{115}	1.37	1.42	1.42	1.40	0.0236	1.68
Center	c_{55}	9.45	9.73	10.07	9.75	0.254	2.60
	c_{65}	6.49	6.67	6.99	6.72	0.207	3.08
	c_{75}	4.61	4.75	5.02	4.79	0.170	3.55
	c_{85}	3.40	3.51	3.72	3.54	0.133	3.75
	c_{95}	2.61	2.69	2.89	2.73	0.118	4.31
Left	l_{45}	5.34	5.74	6.16	5.75	0.335	5.83
	l_{50}	4.12	4.38	4.90	4.47	0.324	7.26
	l_{55}	3.46	3.59	4.18	3.74	0.313	8.37
	l_{60}	3.20	3.34	3.91	3.48	0.307	8.82
	l_{65}	3.04	3.11	3.60	3.25	0.249	7.67
	$g_{60\text{-}1.0}$	0.37	0.40	0.45	0.41	0.0330	8.11
	$g_{60\text{-}1.1}$	0.31	0.33	0.37	0.34	0.0249	7.41
	$g_{60\text{-}1.2}$	0.28	0.28	0.32	0.29	0.0189	6.43

Table 12. 2014 Infiniti Q50 (VOR) Net Illuminance Measurements and Descriptive Statistics for Array 2 Measurement Locations

		Illuminance (Lux)					
	Measurement Location	**Set 1**	**Set 2**	**Set 3**	**Average Across Sets**	**SD**	**Coefficient of Variation**
NHTSA / Right	v_{75}	7.68	7.54	7.68	7.63	0.0660	0.865
	v_{85}	6.05	5.93	6.08	6.02	0.0648	1.08
	v_{95}	4.81	4.71	4.88	4.80	0.0698	1.45
	v_{105}	3.82	3.78	3.94	3.85	0.0680	1.77
	v_{115}	3.13	3.07	3.24	3.15	0.0704	2.24
Center	c_{55}	13.00	14.19	14.72	13.97	0.719	5.15
	c_{65}	8.56	10.01	10.24	9.60	0.744	7.74
	c_{75}	5.61	7.43	7.54	6.86	0.885	12.9
	c_{85}	3.81	5.55	5.64	5.00	0.842	16.9
	c_{95}	2.69	4.26	4.35	3.77	0.762	20.2
Left	l_{45}	10.30	8.81	9.14	9.42	0.639	6.79
	l_{50}	7.52	6.24	6.34	6.70	0.581	8.68
	l_{55}	5.35	4.39	4.52	4.75	0.425	8.95
	l_{60}	4.17	3.50	3.59	3.75	0.297	7.91
	l_{65}	3.35	2.82	2.88	3.02	0.237	7.86
	$g_{60-1.0}$	0.42	0.37	0.40	0.40	0.0205	5.18
	$g_{60-1.1}$	0.38	0.33	0.36	0.36	0.0205	5.76
	$g_{60-1.2}$	0.35	0.32	0.34	0.34	0.0125	3.70

Table 13. 2016 Volvo XC90 (VOL) Net Illuminance Measurements and Descriptive Statistics for Array 2 Measurement Locations

	Measurement Location	Illuminance (Lux)					Coefficient of Variation
		Set 1	Set 2	Set 3	Average Across Sets	SD	
NHTSA / Right	v_{75}	5.37	5.34	5.30	5.34	0.0287	0.537
	v_{85}	4.31	4.31	4.33	4.32	0.0094	0.218
	v_{95}	3.46	3.44	3.46	3.45	0.0094	0.273
	v_{105}	2.76	2.75	2.80	2.77	0.0216	0.780
	v_{115}	2.19	2.18	2.24	2.20	0.0262	1.191
Center	c_{55}	6.53	6.84	6.67	6.68	0.127	1.90
	c_{65}	4.08	4.38	4.26	4.24	0.123	2.91
	c_{75}	2.61	2.88	2.78	2.76	0.116	4.04
	c_{85}	1.59	1.85	1.74	1.73	0.1066	6.17
	c_{95}	0.99	1.23	1.16	1.13	0.101	8.94
Left	l_{45}	3.05	3.14	2.98	3.06	0.0655	2.14
	l_{50}	1.92	1.96	1.84	1.91	0.0499	2.62
	l_{55}	1.22	1.25	1.15	1.21	0.0419	3.47
	l_{60}	0.83	0.84	0.76	0.81	0.0356	4.39
	l_{65}	0.50	0.59	0.51	0.53	0.0403	7.55
	$g_{60\text{-}1.0}$	0.23	0.22	0.20	0.22	0.0125	5.76
	$g_{60\text{-}1.1}$	0.22	0.21	0.20	0.21	0.00816	3.89
	$g_{60\text{-}1.2}$	0.21	0.21	0.19	0.20	0.00943	4.64

Coefficient of variation values were as high as 9 for both the Cadillac and the Volvo, while the ratio reached as high as 20 (c_{95}) for the Infiniti. Coefficient of variation across all three test vehicles was higher for the center and left lanes than it was for the right lane (Array 1 visibility location) measurements.

The set 3 performance level for the Volvo expanded location set is different than the levels for sets 1 and 2. This is because one of the measured values was very close to the 3.0 lux cutoff for visibility scoring. Specifically, value l_{45} for Volvo data set 3 was 2.98 lux, while the values for sets 1 and 2 were slightly above 3.0 lux (3.05 and 3.14 lux, respectively).

Visibility performance level was calculated for Array 2 measurement location data. Separately, the results from all the receptor heads were summed equally to obtain a maximum 15-point visibility score rather than a 25-point score. This visibility score was then combined with the glare calculation after the glare points had been adjusted for a 15-point system (i.e., glare gives either 0 or -6 points based on the conversion (15/25)*(-10)).

Table 14 summarizes the calculated performance levels for each test vehicle by data set for the expanded set of measurement locations. Values obtained using the NHTSA method of calculating performance level are also shown for comparison.

Table 14. Lower Beam Headlighting System Visibility Performance Level by Vehicle Considering Expanded Array of Measurement Locations

Set:	1		2		3	
Max. Possible Performance Level:	25	15	25	15	25	15
Cadillac ATS	5	10	5	10	5	10
Infiniti Q50	25	14	25	14	25	14
Volvo XC90	15	6	15	6	15	5

3.4 Calculated Lower Beam Headlighting System Visibility Values

An alternative test procedure approach examined involved measuring illuminance at only the rearmost locations in each lane and then calculating the values for locations forward of those locations using the inverse square law of light. The inverse square law of light states that the intensity per unit area varies in inverse proportion to the square of the distance between the measurement point and the source. Tables 15 to 17 present calculated illuminance values by set and average values across the three sets for each location. For comparison purposes, average measured values for each location are listed along with a column noting the difference between the calculated and measured values.

Table 15. 2015 Cadillac ATS – Illuminance Values Calculated From Measured Values From Rearmost Locations

			Illuminance (Lux)					
	Measurement Location	Measured or Calculated	Set 1	Set 2	Set 3	Average for Calculated Values	Average for Measured Values	Difference
NHTSA / Right	v_{75}	Calculated	3.22	3.34	3.34	3.30	3.46	0.16
	v_{85}	Calculated	2.51	2.60	2.60	2.57	2.65	0.08
	v_{95}	Calculated	2.01	2.08	2.08	2.06	2.11	0.05
	v_{105}	Calculated	1.64	1.70	1.70	1.68	1.69	0.01
	v_{115}	Measured	1.37	1.42	1.42	N/A	1.40	N/A
Center	c_{55}	Calculated	7.79	8.03	8.62	8.14	9.75	1.61
	c_{65}	Calculated	5.58	5.75	6.17	5.83	6.72	0.89
	c_{75}	Calculated	4.19	4.32	4.64	4.38	4.79	0.41
	c_{85}	Calculated	3.26	3.36	3.61	3.41	3.54	0.13
	c_{95}	Measured	2.61	2.69	2.89	N/A	2.73	N/A
Left	l_{45}	Calculated	6.34	6.49	7.51	6.78	5.75	-1.03
	l_{50}	Calculated	5.14	5.26	6.08	5.49	4.47	-1.03
	l_{55}	Calculated	4.25	4.34	5.03	4.54	3.74	-0.80
	l_{60}	Calculated	3.57	3.65	4.23	3.81	3.48	-0.33
	l_{65}	Measured	3.04	3.11	3.60	N/A	3.25	N/A

Table 16. 2014 Infiniti Q50 - Illuminance Values Calculated From Measured Values From Rearmost Locations

			Illuminance (Lux)					
	Measurement Location	**Measured or Calculated**	**Set 1**	**Set 2**	**Set 3**	**Average for Calculated Values**	**Average for Measured Values**	**Difference**
NHTSA / Right	v_{75}	Calculated	7.36	7.22	7.62	7.40	7.63	0.24
	v_{85}	Calculated	5.73	5.62	5.93	5.76	6.02	0.26
	v_{95}	Calculated	4.59	4.50	4.75	4.61	4.80	0.19
	v_{105}	Calculated	3.75	3.68	3.89	3.77	3.85	0.07
	v_{115}	Measured	3.13	3.07	3.24	N/A	3.15	N/A
Center	c_{55}	Calculated	8.03	12.71	12.98	11.24	13.97	2.73
	c_{65}	Calculated	5.75	9.10	9.29	8.05	9.60	1.56
	c_{75}	Calculated	4.32	6.83	6.98	6.04	6.86	0.82
	c_{85}	Calculated	3.36	5.32	5.43	4.71	5.00	0.29
	c_{95}	Measured	2.69	4.26	4.35	N/A	3.77	N/A
Left	l_{45}	Calculated	6.99	5.88	6.01	6.29	9.42	3.12
	l_{50}	Calculated	5.66	4.77	4.87	5.10	6.70	1.60
	l_{55}	Calculated	4.68	3.94	4.02	4.21	4.75	0.54
	l_{60}	Calculated	3.93	3.31	3.38	3.54	3.75	0.21
	l_{65}	Measured	3.35	2.82	2.88	N/A	3.02	N/A

Table 17. 2016 Volvo XC90 - Illuminance Values Calculated From Measured Values From Rearmost Locations

			Illuminance (Lux)					
	Measurement Location	Measured or Calculated	Set 1	Set 2	Set 3	Average for Calculated Values	Average for Measured Values	Difference
NHTSA / Right	v_{75}	Calculated	5.15	5.13	5.27	5.18	5.34	0.16
	v_{85}	Calculated	4.01	3.99	4.10	4.03	4.32	0.28
	v_{95}	Calculated	3.21	3.19	3.28	3.23	3.45	0.22
	v_{105}	Calculated	2.63	2.62	2.69	2.64	2.77	0.13
	v_{115}	Measured	2.19	2.18	2.24	N/A	2.20	N/A
Center	c_{55}	Calculated	***2.95***	3.67	3.46	3.36	6.68	3.32
	c_{65}	Calculated	***2.11***	***2.63***	***2.48***	***2.41***	4.24	1.83
	c_{75}	Calculated	1.59	1.97	1.86	1.81	2.76	0.95
	c_{85}	Calculated	1.24	1.54	1.45	1.41	1.73	0.32
	c_{95}	Measured	0.99	1.23	1.16	N/A	1.13	N/A
Left	l_{45}	Calculated	***1.04***	***1.23***	***1.06***	***1.11***	3.06	1.94
	l_{50}	Calculated	0.85	1.00	0.86	0.90	1.91	1.01
	l_{55}	Calculated	0.70	0.82	0.71	0.74	1.21	0.46
	l_{60}	Calculated	0.59	0.69	0.60	0.63	0.81	0.18
	l_{65}	Measured	0.50	0.59	0.51	N/A	0.53	N/A

Results in Tables 15 to 17 show that the magnitudes of differences for the Array 1 visibility measurement locations were 0.25 lux or less, while the magnitudes of differences for the center and left lanes were larger, up to as much as 3.32 lux. Tables 15 and 16 show that for the Cadillac and Infiniti, while the magnitude of some differences between measured and calculated illuminance values obtained seem somewhat large, none of the calculated values were less than 3.0 lux. As a result, the calculated illuminance values for these two vehicles produce the same performance levels as were obtained based on the measured values.

However, this was not the case for the Volvo XC90. Some illuminance values (in bold italics in Table 17) for the Volvo XC90 were greater than 3.0 lux when measured but when calculated were found to be less than 3.0 lux, which resulted in a lower performance level for that vehicle when considering calculated illuminance values. Table 17 shows that two measurement location values, c_{65} and l_{45}, for the Volvo have average values that are less than 3.0 lux when calculated but were greater than 3.0 lux when measured. In addition, the c_{55} value for Volvo set 1 is also less than 3.0 lux where it had a value greater than 3.0 lux when measured. These three differences in values result in lower performance levels for this vehicle, as shown in Table 18 below. The Volvo's performance levels drop from 6 to 3 for set 1, from 6 to 4 for set 2, and from 5 to 4 for set 3.

Table 18. Comparison of Lower Beam Headlighting System Visibility Performance Levels for the Volvo XC90 Measured Versus Calculated Lower Beam Illuminance Values

Set:	1		2		3	
Measurement Scheme:	**NHTSA**	**Expanded**	**NHTSA**	**Expanded**	**NHTSA**	**Expanded**
Volvo XC90 – **Measured** Values	15	6	15	6	15	5
Volvo XC90 – **Calculated** Values	15	3	15	4	15	4

3.5 Height of Glare Measurement Location

Table 19 summarizes measured illuminance values for the three glare point heights examined. For the three vehicles examined, the results show that illuminance differed very little across the three glare point heights. Measured values for all three vehicles were below the 0.63 lux requirement in FMVSS No. 108. The lowest measured glare point values were observed for the Volvo XC90 SUV.

Table 19. Lower Beam Headlighting System Glare Point Values by Glare Measurement Point Height

		Average Illuminance (lux)		
Height (m)	**Measurement Location**	**Cadillac (Sedan)**	**Infiniti (Sedan)**	**Volvo (SUV)**
1	g_{60}	0.4067	0.3967	0.2167
1.1	$g_{60-1.1}$	0.3367	0.3567	0.2100
1.2	$g_{60-1.2}$	0.2933	0.3367	0.2033

4.0 SUMMARY

This report summarizes an effort to evaluate a draft test procedure for confirming the visibility performance of the lower beam headlighting system on a motor vehicle with a GVWR of less than 10,000 pounds. Lower beam headlighting system performance was determined at night on an outdoor test course by activating the lower beam headlamps on a full-scale production vehicle and measuring the amount of light that is cast onto the forward roadway over an array of specified locations. Based on measured values for the specified locations, headlighting system performance levels were calculated.

Three vehicles were subjected to three repetitions (sets) of the test procedure. Illuminance measurements were made using a basic meter, the Konica Minolta T-10A. Measured values were used to calculate a lower beam performance level using this formula:

$$\text{Level} = [5 * \Sigma N_v] - [10 * N_g]$$

Measured values for Array 1 visibility measurement locations located to the right of the test vehicle and glare measurement location to the left of the vehicle were found to be consistent across the three measurement sets. The coefficient of variation was greater for the glare measurement locations than for the visibility measurement locations. Calculated performance levels were consistent across the three measurement sets as shown in Table 20. The maximum possible performance level value was 25.

Table 20. Lower Beam Headlighting System Visibility Performance Level by Vehicle For Array 1 Measurement Locations

Set:	**1**	**2**	**3**
Measurement Scheme:	**NHTSA**	**NHTSA**	**NHTSA**
Cadillac ATS	5	5	5
Infiniti Q50	25	25	25
Volvo XC90	15	15	15

An alternative array of measurement locations, “Array 2,” covering a broader area including points forward and to the left of the vehicle was also examined. The maximum possible performance level value for this scheme was 15. Results for Array 2 measurement locations showed higher coefficient of variation values across all three test vehicles for the center and left lanes than were seen for the right lane.

Lower beam performance levels calculated using the additional two lanes of measurement points were consistent across the three sets for two of three test vehicles, as shown in Table 21. The set 3 performance level for the Volvo expanded location array was different than the performance levels for sets 1 and 2 because one of the measured values was very close to the 3.0 lux cutoff for visibility scoring.

Table 21. Lower Beam Headlighting System Visibility Performance Level by Vehicle For Array 2 Measurement Locations

Set:	1	2	3
Measurement Scheme:	**Expanded**	**Expanded**	**Expanded**
Cadillac ATS	10	10	10
Infiniti Q50	14	14	14
Volvo XC90	6	6	5

A test procedure approach was also examined that involved measuring only the rearmost points and then calculating the remaining points based on the measured values. While the magnitudes of differences for the Array 1 measurement locations were 0.25 lux or less across sets, the magnitudes of differences for the center and left lanes were larger, up to as much as 3.32 lux. Results show for the Cadillac and Infiniti that, while the magnitude of some differences between measured and calculated illuminance values obtained seem somewhat large, none of the calculated values were less than 3.0 lux. As a result, the calculated illuminance values for these two vehicles produce the same performance levels as were obtained based on the measured values.

However, this was not the case for the Volvo XC90. Some illuminance values for the Volvo XC90 were greater than 3.0 lux when measured, but when calculated were found to be less than 3.0 lux. This resulted in a lower performance level for that vehicle when considering calculated illuminance values. Table 22 below highlights the differences between performance levels based on measured versus calculated values for the Volvo XC90. Given the detailed steps taken to ensure the accuracy of the positioning of test vehicle and illuminance measurement components, it is possible that differences in measured illuminance values may be related to variations in the intensity of light through this region of the beam pattern.

Table 22. Comparison of Lower Beam Headlighting System Visibility Performance Levels Based on Measured Versus Calculated Lower Beam Illuminance Values

Set:	1		2		3	
Measurement Scheme:	**Expanded**	**Calculated**	**Expanded**	**Calculated**	**Expanded**	**Calculated**
Cadillac ATS	10	10	10	10	10	10
Infiniti Q50	14	14	14	14	14	14
Volvo XC90	***6***	***3***	***6***	***4***	***5***	***4***

Overall, the draft test procedure presented no difficulties to execute and was effective in characterizing lower beam performance levels. This test effort provided valuable information on system performance consistency and test repeatability. The inclusion of center and left lane measurement points to augment the Array 1 right lane measurement points was informative, but also showed more variance in measured values which may result in different performance level values across multiple test repetitions. The use of alignment aids such as those used in this test effort are recommended to achieve accurate and repeatable test vehicle positioning.

5.0 REFERENCES

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4. Rhule, D., Rhule, H., & Donnelly, B et al. (2005). The process of evaluation and documentation of crash test dummies for Part 572 of the Code of Federal Regulations. 19th International Technical Conference on the Enhanced Safety of Vehicles, Washington, DC, June 6-9, 2005. (Paper No. 05-0284). Available at http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.621.5617&rep=rep1&type=pdf

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