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BLIND SPOT DETECTION SYSTEM CONFIRMATION TEST

(WORKING DRAFT)

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16. Abstract

This draft test procedure provides specifications used by the National Highway Traffic Safety Administration (NHTSA) to research Blind Spot Detection (BSD) system performance on light vehicles with gross vehicle weight ratings (GVWR) of up to 10,000 lbs (4,536 kg). The tests described in this document emulate two straight road, real-world scenarios where the subject vehicle (SV) blind zone is breached by a single principal other vehicle (POV).

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GLOSSARY

ASTM	formerly known as the American Society for Testing and Materials, and as ASTM International since 2001
BSD	blind spot detection
GVWR	gross vehicle weight rating
NHTSA	National Highway Traffic Safety Administration
POV	principal other vehicle
SAE	formerly known as the Society of Automotive Engineers, and as SAE International since 2006
SV	subject vehicle
U.S. DOT	United States Department of Transportation

1.0 PURPOSE AND APPLICATION

This draft test procedure provides specifications used by the National Highway Traffic Safety Administration (NHTSA) to research blind spot detection (BSD) system performance on light vehicles with gross vehicle weight ratings (GVWR) of up to 10,000 lbs (4,536 kg). The tests described in this document emulate two straight road, real-world scenarios where the subject vehicle (SV) blind zone is breached by a single principal other vehicle (POV).

Current BSD technology relies on sensors to detect the presence of other vehicles in the equipped vehicle's left and right blind zones. Although it is impossible to predict what technologies may be used by future BSD systems (e.g., vehicle-to-vehicle communication), it is believed that minor modifications to these procedures, when deemed appropriate, could be used to accommodate the evaluation of alternative or more advanced BSD systems.

2.0 GENERAL REQUIREMENTS

This document describes the methods used by NHTSA to research BSD operation on the test track. In the first scenario, the POV is driven at the same speed as the SV, at a constant headway. After a brief period of steady-state driving, the POV enters, then exits the SV blind zone from the side of the vehicle. In the second scenario, the POV is driven by the SV in an adjacent lane at a speed greater than the SV. During this pass-by, the POV enters, then exists the SV blind zone. In both scenarios, BSD performance is assessed by comparing the proximity of the POV to the SV at the time of the BSD alert to the SV blind zone defined in Section 3.2.

3.0 DEFINITIONS

3.1 Blind Spot Detection

A BSD system is a warning-based driver assistance system designed to help the driver recognize that another vehicle is approaching, or being operated within, the blind spot of their vehicle in an adjacent lane. Should the driver initiate a lane change toward this other vehicle, the BSD presents an alert before a collision is expected to occur. Depending on the implementation, BSD activation may or may not require the driver to operate their turn signal indicator during their lane change.

3.2 SV Blind Zone

For the tests described in this document, SV blind zones are defined by two rectangular regions that extend to the side and rear of the SV (see Figure 1). Each rectangle is 8.2 ft (2.5 m) wide and is represented by lines parallel to the longitudinal centerline of the vehicle; lines D and E for the left side of the vehicle and lines F and G for the right side of the vehicle. Lines E and F run parallel to the centerline of the SV and are located 1.6 ft (0.5 m) from the outermost edge of the SV's body excluding the side view mirror(s). The length of the rectangle (in the longitudinal direction) starts at line A, which is located at the rearmost part of the SV side mirror housing, in the

housing's fully-extended operating position, and runs perpendicular to the SV's longitudinal centerline, to line C, which is also perpendicular to the SV's longitudinal centerline. The distance between lines A and C depends on the differential speed (Δv) between the SV and the POV. Line B, which is used to calculate the position of line C using a curve fit of ISO Standard 17387-2008 performance specifications [1], is perpendicular to the SV's longitudinal centerline and located at the rearmost (trailing) edge of the SV.

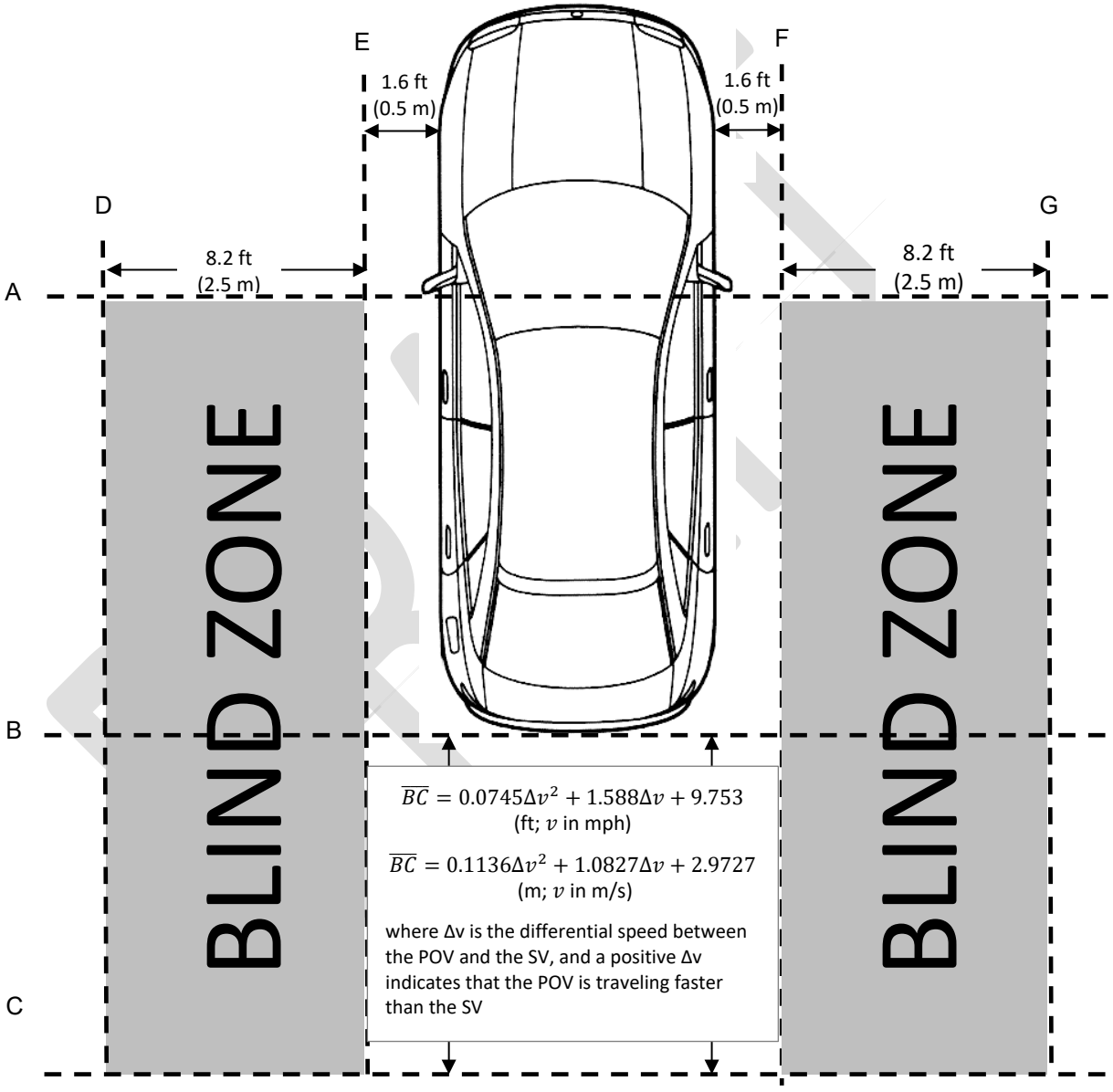

Figure 1. Minimum Blind Zone Coverage (not drawn to scale).

4.0 PRETEST AND FACILITY REQUIREMENTS

4.1 Road Test Surface

Unless specified otherwise, the road test surface shall be dry (without visible moisture on the surface), straight, and flat, with a consistent slope between level and one percent. The road surface shall be constructed from asphalt or concrete and shall be free of irregularities, undulations, and/or cracks that could cause the SV to pitch excessively.

4.2 Line Markings

All lane lines described in this document shall meet Federal Highway Administration (FHWA) specifications as required by the Manual on Uniform Traffic Control Devices (MUTCD) and be considered in "very good condition" [2].

4.2.1 Lane Line Styles

The following lane line styles are acceptable for the tests described in this document:

A. Discontinuous dashed white

B. Discontinuous dashed yellow

C. Solid white

4.2.2 Line Marking Color and Reflectivity

Lane line marker color and reflectivity shall meet all applicable standards. These standards include those from the International Commission of Illumination (CIE) for color and the ASTM International for lane marker reflectance. Methods for determining lane marker characteristics are discussed in the Road Departure Crash Warning Systems (RDCWS) Field Operational Test (FOT) by the National Institute of Standards and Technology (NIST) [3].

4.2.3 Line Marker Width

The width of the edge line marker shall be 4 to 6 in. (10 to 15 cm). This is a normal width for longitudinal pavement markings under Section 3A.05 of the MUTCD [2].

4.3 Lane Width

Each of the three lanes required by this test procedure shall be delineated with two lane lines. Measured from inside edge to inside edge, these lines shall be spaced 12 to 14 ft (3.7 to 4.3 m) apart.

4.4 Ambient Conditions

4.4.1 Ambient Temperature

The ambient temperature shall be between 45 °F (7 °C) and 104 °F (40 °C).

4.4.2 Wind Speed

The maximum wind speed shall be no greater than 22 mph (35 km/h).

4.4.3 Inclement Weather

Tests shall not be performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, and/or ash.

4.4.4 Visibility

The tests shall be conducted during daylight hours with good atmospheric visibility defined as an absence of fog and the ability to see clearly for more than 3 miles (4.8 km). Tests shall not be conducted during very low sun angle conditions, where the sun is oriented 15 degrees or less from horizontal and potential camera "washout" or system inoperability could result.

All tests shall be conducted such that there are no overhead signs, bridges, or other significant structures over, or near, the testing site. Except for the POV, each trial shall be conducted with no vehicles, obstructions, or stationary objects within one lane width of either side the SV path.

4.5 Principal Other Vehicle Specifications

The POV shall be a high-production mid-sized passenger car from 175 to 197 in. (445 to 500 cm) long, and 70 to 76 in (178 to 193 cm) wide measured at the widest part of the vehicle, exclusive of signal lamps, marker lamps, outside rearview mirrors, flexible fender extensions, and mud flaps, determined with doors and windows closed and the wheels in the straight-ahead position. The color of the actual vehicle used as the POV is unrestricted.

4.6 Instrumentation Required

4.6.1 Sensors and Sensor Locations

A description overview of the sensors used for the tests described in this document is provided in Table 1.

4.6.1.1 SV and POV Position

The position of the SV and POV relative to their respective travel lanes, and the position of the SV relative to the POV, shall be measured within the applicable test validity period. The sensors used for these measurements are not constrained provided they meet the range, resolution, and accuracy specifications provided in Table 1.

Table 1 – Recommended Measurements and Measurement Specifications

Type	Output	Range	Resolution	Accuracy
Various	Lateral and Longitudinal position of SV and POV	650 ft (200 m)	2 in. (5 cm)	At least 3.9 in (10 cm) absolute
Speed Sensors	SV and POV lateral and longitudinal velocity	0.1 – 62 mph (0.1 -100 km/h)	0.1 mph (0.2 km/h)	+/- 0.25% of full scale range
Rate Sensor	SV and POV yaw rate	+/- 100 deg/s	0.01 deg/s	+/- 0.25% of full scale range
Position Sensor	SV throttle and brake pedal positions	0 – 100 percent (normalized)	0.1 percent	0.1 percent
Data Flag* (BSD)	BSD alert status	0 – 10 VDC (nominally)	N/A	Output response ≤ 10 ms
Video Recorded Messages	Visual/audible vehicle BSD alerts presented to the driver	N/A	At least 720p	N/A
Vehicle Dimensional Measurements	Location of SV and POV GPS antennas; SV and POV centerlines; front-most SV bumper position; and rear-most POV and SOV bumper positions.	N/A	0.04 in. (1 mm)	0.04 in. (1 mm)
SV-to-POV Static Range	Distance to POV reference point (typically the longitudinal center of gravity (CG)) and rear-most POV bumper position.	N/A	2 in. (5 cm)	At least 3.9 in. (10 cm) absolute

*Use of a photocell within a light-blocking enclosure around the BSD alert is the preferred way of measuring system onset, operation, and termination, provided the BSD alert includes a visual component. If the use of a microphone is required, it should be placed close to the source of the sound. A unidirectional accelerometer may be used to capture tactile alerts in the steering wheel and/or driver's seat. All visual, audible, and haptic sensors should meet the range, resolution, and accuracy specifications stated above the BSD data flag.

4.6.1.2 Vehicle Speed

The lateral and longitudinal velocities of the SV and POV (where applicable) shall be measured within the test validity period. The sensors used for this measurement are not constrained provided they meet the range, resolution, and accuracy specifications in Table 1.

4.6.1.3 Yaw Rate

SV and POV yaw rate shall be measured. Alternatively, differentially corrected GPS may be used to provide data to calculate yaw rate in lieu of direct measurement, provided the resulting accuracy is comparable.

4.6.1.4 BSD Alert Data Flag

When activated, the BSD system shall present an auditory alert, a visual alert, haptic vibration (e.g., from the steering wheel or driver's seat), haptic vehicle cue (e.g., a brake pulse), or any combination thereof. This output shall be recorded, synchronized with the other recorded data channels, and used as the measure of when the system warns the driver.

5.0 TEST EXECUTION AND TEST REQUIREMENTS

5.1 Pre-Test Initialization and Calibration

5.1.1 Instrumentation Initialization

All instrumentation shall be secure and properly configured. With all instrumentation off, the SV and POV shall be driven to an outdoor location unobstructed by buildings, overpasses, or other structures capable of interfering with the ability of the GPS sensors to acquire satellite-based position information and real-time base station corrections (where applicable). At this location, the instrumentation shall be turned on, and static and dynamic GPS initializations be performed.

1. Static initialization

    A. Where applicable, the transmissions of the SV and POV shall be placed in park.

    B. The SV and POV shall remain at rest until transmissions from least 6 GPS satellites have been obtained and indicated by the vehicle's respective instrumentation.

2. Dynamic initialization

    A. The SV and POV shall be driven in a straight line, at a speed of at least 35 mph (56.3 km/h) for at least 350 ft (107 m).

B. The SV and POV shall be driven in three figure 8 patterns. The radii of the turns shall be approximately 20 ft (6 m).

C. Steps 5.1.1.2.A and 5.1.1.2.B shall be repeated until the respective instrumentation indicates that the required accuracies for position have been achieved.

5.1.2 Static Instrumentation Calibration

Calibration data shall be collected prior to the tests specified in S5.3.1 and S5.3.2 to assist in resolving uncertain test data.

1. The SV and POV shall be centered in the same travel lane with the same orientation (i.e., each must face the same direction).

2. The front-most location of the SV shall be positioned such that it just contacts a vertical plane that defines the rearmost location of the POV. This is the "zero position."

3. The zero position shall be documented prior to, and immediately after, conduct of a test series.

    A. If the zero-position reported by the data acquisition system differs by more than ±2 in (±5 cm) from that measured during collection of the pre-test static calibration data file, the pre-test longitudinal offset shall be adjusted to output zero and another pre-test static calibration data file shall be collected.

    B. **If the zero-position reported by the data acquisition system differs by more than ±2 in (±5 cm) from that measured during collection of the post-test static calibration data file, the tests performed between collection of that post-test static calibration data file and the last valid pre-test static calibration data file shall be repeated.**

4. Static data files shall be collected prior to, and immediately after, conduct of the test series described in S5.3.1 and S5.3.2. The pre-test static files shall be reviewed prior to test conduct to confirm that all data channels are operational and properly configured.

5.2 BSD Pre-Test System Initialization

Some SVs may require a brief period of initialization (e.g., verification of sensor alignment and detection readiness) before their respective BSD system performance can be properly assessed. If a manufacturer-specific initialization procedure is required, NHTSA will obtain the appropriate procedure from the respective vehicle manufacturer, and provide it to the contractor. The contractor shall perform any NHTSA-provided initialization schedule prior to performing the tests described in this test document.

5.3 Test Scenarios

5.3.1 Straight Lane Converge and Diverge Test

Throughout the duration of each Straight Lane Converge and Diverge test, the SV and POV shall be driven at a speed of 45 mph (72 km/h), and the front-most part of the POV shall be 3.3 ft (1 m) ahead of the rear-most part of the SV. Each of the three lanes used in this scenario shall be straight and parallel to each other. The use of cruise control (conventional or adaptive) is permitted as long as the test tolerances specified in S5.3.1.1 are satisfied.

This test begins with the POV two lanes away from the SV. Once the vehicles have been driven in this formation for 2.5 seconds, the POV shall perform a single lane change into the lane adjacent to the SV using a lateral velocity of 3 ft/s (1 m/s). Once the lane change is completed, the POV shall continue in a straight lane for at least 2.5 seconds, and then perform a lane change back into its original lane using a lateral velocity of 3 ft/s (1 m/s). The test shall conclude once the POV has remained in the original travel lane for at least 1 second.

The Straight Lane Converge and Diverge Test, shown in Figure 2, includes POV approaches towards the SV from the left and right. The SV and POV turn signals shall not be activated during any test trial.

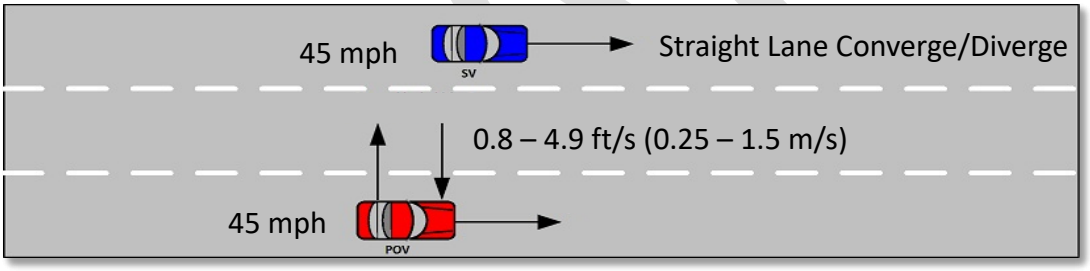

Figure 2. Straight Lane Converge and Diverge test. POV converge and diverege from the right is shown.

5.3.1.1 Test Validity Criteria

Each Straight Lane Converge and Diverge Test trial must satisfy the following validity criteria from a time 2.5 seconds prior to initiating the first POV lane change, to a time 1.0 second after completion of the final POV lane change. If any data channel, for either or both vehicles, exceeds an allowable tolerance within the validity period of a given test trial, that trial shall be deemed invalid.

- SV and POV: 45 mph ± 1 mph (72 km/h ± 1.6 km/h) for entire trial
- Front-most part of the POV to rear-most part of the SV: 1 ± 0.5 m (3.3 ± 1.6 ft) ahead of SV rear for entire trial
- SV yaw rate: ± 1.0 deg/sec when not performing a lane change maneuver

- Lateral distance between SV and POV before POV begins the converge lane change: >4m (13.1 ft)

- Lateral distance between SV and POV when the POV is in the lane adjacent to the SV: 1.5 ± 0.5 m (4.9 ± 1.6 ft)

- Lateral distance between SV and POV after the POV completes the diverge lane change: >4m (13.1 ft)

- POV lateral velocity of during its lane changes: 0.25 to 1.5 m/s (0.8 to 4.9 ft/s)

5.3.1.2 End-of-Test Instructions

1. After the validity period is complete,

    A. The SV driver shall manually apply force to the brake pedal, bring the vehicle to a stop, and place the transmission in park.

    B. The POV shall be braked to a stop.

2. The Straight Lane Converge and Diverge test trial is complete.

5.3.1.3 Number of Test Trials

Seven valid trials per POV approach direction shall be performed for the Straight Lane Converge and Diverge Test scenario, for a total of 14 tests overall. If the test conductor performs more than 7 trials per approach direction within this scenario, the first 7 trials satisfying all test tolerances per approach direction shall be used to assess the SV performance.

5.3.1.4 Evaluation Criteria

During converge lane changes, the BSD alert must activate, within 300 ms, when any part of the POV enters the SV blind zone defined by the intersections of lines A,C,D, and E for left side tests and of lines A,C,F, and G for right side tests, and shall remain on while any part of the POV resides within the SV blind zone. During the diverge lane changes, the BSD alert may remain active when the lateral distance between the SV and POV is >3 m (9.8 ft), but ≤5 m (16.4 ft). The BSD shall not be active once the lateral distance between the SV and POV >5 m (16.4 ft).

5.3.2 Straight Lane Pass-by Test

In the Straight Lane Pass-by Test scenario, shown in Figure 3, the POV approaches and then passes by the SV while being driven in an adjacent lane. For each trial, the SV and POV are driven at one of the four constant speed combinations described in Table 3. The lateral distance between the SV and POV shall be 1.5 m (4.9 ft) throughout the duration of each test trial. The

Straight Lane Pass-by Test scenario includes POV approaches towards the SV from adjacent lanes to the left and right of the SV. The SV and POV turn signals shall not be activated during any test trial.

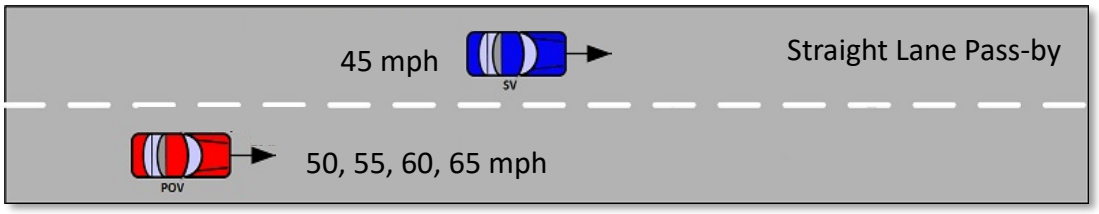

Figure 3. Straight Lane Pass-by test. Right-side POV Pass-by is shown.

5.3.2.1 Test Validity Criteria

Each Straight Lane Pass-by Test trial must satisfy the validity criteria defined in Table 3 from a nominal time of 5 seconds before to 2 seconds after the rearmost part of the POV passes beyond a plane defined by the front most part of the SV perpendicular to the SV centerline. If any data channel, for either or both vehicles, exceeds an allowable tolerance within the validity period of a given test trial, that trial shall be deemed invalid.

Table 3 – Straight Lane Pass-by Test Speed and Headway Validity Criteria

SV Speed	45 ± 1 mph (72 ± 1. 6 km/h)	45 ± 1 mph (72 ± 1. 6 km/h)	45 ± 1 mph (72 ± 1. 6 km/h)	45 ± 1 mph (72 ± 1. 6 km/h)
POV Speed	50 ± 1 mph (80.5 ± 1. 6 km/h)	55 ± 1 mph (88.5 ± 1. 6 km/h)	60 ± 1 mph (96.6 ± 1. 6 km/h)	65 ± 1 mph (104.6 ± 1. 6 km/h)
SV-to-POV Differential Speed	5 ± 1 mph (8.0 ± 1. 6 km/h)	10 ± 1 mph (16.1 ± 1. 6 km/h)	15 ± 1 mph (24.1 ± 1. 6 km/h)	20 ± 1 mph (32.2 ± 1. 6 km/h)
Starting Longitudincal Distance between SV and POV (nominally a 5 second gap)	36.7 ft (11.2 m)	73.3 ft (22.4 m)	110.0 ft (33.5 m)	146.7 ft (44.7 m)
SV Yaw Rate	± 1.0 deg/sec	± 1.0 deg/sec	± 1.0 deg/sec	± 1.0 deg/sec
Lateral distance between SV and POV	4.9 ± 1.6 ft (1.5 ± 0.5 m); 5 ± 1 ft (1.5 ± 0 3 m)	4.9 ± 1.6 ft (1.5 ± 0.5 m); 5 ± 1 ft (1.5 ± 0 3 m)	4.9 ± 1.6 ft (1.5 ± 0.5 m); 5 ± 1 ft (1.5 ± 0 3 m)	4.9 ± 1.6 ft (1.5 ± 0.5 m); 5 ± 1 ft (1.5 ± 0 3 m)

5.3.2.2 End-of-Test Instructions

1. After the validity period is complete,

    A. The SV driver shall manually apply force to the brake pedal, bring the vehicle to a stop, and place the transmission in park.

    B. The POV shall be braked to a stop.

2. The Straight Lane Pass-by test trial is complete.

5.3.2.3 Number of Test Trials

Seven valid trials per POV approach orientation (i.e., left or right side of the SV), per pass-by speed, shall be performed for the Straight Lane Pass-by Test scenario, for a total of 56 tests overall. If the test conductor performs more than 7 trials per each approach direction pass-by speed combination within this scenario, the first 7 trials satisfying all test tolerances per test condition shall be used to assess the SV performance.

5.3.2.4 Evaluation Criteria

The BSD alert must activate, within 300 ms, when the front-most part of the POV enters the blind zone defined by the intersections of lines A,C,D, and E for left side tests and of lines A,C,F, and G for right side tests, and shall remain on while any part of the POV resides within the SV blind zone. The BSD shall not be active once the longitudinal distance between the front-most part of the SV and the rear-most part of the POV exceeds the BSD termination distances specified in Table 4.

Table 4 – Straight Lane Pass-by BSD Evaluation Criteria

SV Speed	POV Speed	BSD Onset Headway[1]	BSD Termination Headway[2]
45 ± 1 mph (72 ± 1. 6 km/h)	50 ± 1 mph (80.5 ± 1. 6 km/h)	Within 300 ms after $\overline{BC}$ = 19.6 ft (6.0 m)	>7.3 ft (2.2 m)
	55 ± 1 mph (88.5 ± 1. 6 km/h)	Within 300 ms after $\overline{BC}$ = 33.1 ft (10.1 m)	>14.7 ft (4.5 m)
	60 ± 1 mph (96.6 ± 1. 6 km/h)	Within 300 ms after $\overline{BC}$ = 50.3 ft (15.3 m)	>22.0 ft (6.7 m)
	65 ± 1 mph (104.6 ± 1. 6 km/h)	Within 300 ms after $\overline{BC}$ = 71.3 ft (21.7 m)	>29.3 ft (8.9 m)

[1] The BSD onset headway nominally occurs 2.5 seconds before the front-most part of the POV passes by the rear-most part of the SV.

[2] The BSD termination headway nominally occurs 1 second after the rear-most part of the POV passes by the front-most part of the SV.

6.0 REFERENCES

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2. Federal Highway Administration. (2012, May). *Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition*. Washington, DC: Author. https://mutcd.fhwa.dot.gov/pdfs/2009r1r2/pdf_index.htm.

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