SURFACE VEHICLE RECOMMENDED PRACTICE

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Truck and Bus Lane Departure Warning Systems Test Procedure and Minimum Performance Requirements

RATIONALE

This document has been revised as part of a Five-Year Review. Minor revisions are included to improve process clarity. One technical revision is made to the facility roadway conditions lane curvature (see 7.1.3). This document describes testing procedures for a straight road lane departure test course, but previously it did not define a straight road even though it frequently references SAE J2808, which does define a straight road. Therefore, a definition of a straight road has been added and the roadway surface lane curvature specification (see 7.1.3) is revised from greater than 152.4 m (500 feet) to greater than 500 m (1640 feet).

1. SCOPE

This SAE Recommended Practice establishes a uniform, powered vehicle test procedure and minimum performance requirement for lane departure warning systems used in highway trucks and buses greater than 4546 kg (10000 pounds) gross vehicle weight (GVW). Systems similar in function but different in scope and complexity, including lane keeping/lane assist and merge assist, are not included in this document. This document does not apply to trailers, dollies, etc. This document does not intend to exclude any particular system or sensor technology.

This document will test the functionality of the lane departure warning system (LDWS) (e.g., ability to detect lane presence and ability to detect an unintended lane departure), its ability to indicate LDWS engagement, its ability to indicate LDWS disengagement, and its ability to determine the point at which the LDWS notifies the human machine interface (HMI) or vehicle control system that a lane departure event is detected. Moreover, this document determines whether a system performs at a minimally acceptable level. The HMI is not addressed herein but is considered in SAE J2808.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/J3045_202502/

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2808 Lane Departure Warning Systems: Information for the Human Interface

SAE J3029 Forward Collision Warning and Automatic Emergency Braking Test Procedure and Minimum Performance Requirements - Truck and Bus

2.1.2 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 17361 Intelligent transport systems - Lane departure warning systems - Performance requirements and test procedures

2.1.3 Federal Highway Administration (FHWA) Publications

Available from Federal Highway Administration, 1200 New Jersey Ave, SE, Washington, DC 20590, Tel: 202-366-4000, https://www.fhwa.dot.gov/.

MUTCD Manual on Uniform Traffic Control Devices for Streets and Highways

2.1.4 National Highway Traffic Safety Administration (NHTSA) Publications

Available from National Highway Traffic Safety Administration, 1200 New Jersey Avenue, SE, Washington, DC 20590, Tel: 1-888-327-4236, https://www.nhtsa.gov/.

NHTSA (2013). Lane departure warning system confirmation test and lane keeping support performance documentation (Report no. NHTSA-2015-0119-0033). National Highway Traffic Safety Administration.

2.1.5 Other Publications

Houser, A., Pierowicz, J., and Fuglewicz, D. (2005). *Concept of operations and voluntary operational requirements for lane departure warning system (LDWS) on-board commercial motor vehicles* (Report no. FMCSA-MCRR-05-005). Federal Motor Carrier Safety Administration.

U.S. Department of Transportation Large Truck Crash Causation Study (LTCCS) Data Portal: https://data.transportation.gov/Trucking-and-Motorcoaches/Large-Truck-Crash-Causation-Study-LTCCS-/akau-xuhz.

World Meteorological Organization. Observing Systems Capability Analysis and Review Tool; Variable: Meteorological Optical Range (MOR): https://space.oscar.wmo.int/variables/view/meteorological_optical_range_mor_surface.

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 Code of Federal Regulations (CFR) Publications

Available from United States Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

49 CFR 571.101 Controls and Displays

2.2.2 European Union Publications

Available from European Commission, https://ec.europa.eu/info/index_en.

EU No. 351/2012 Implementing Regulation (EC) No 661/2009 of the European Parliament and of the Council as regards type-approval requirements for the installation of lane departure warning systems in motor vehicles

2.2.3 Other Publications

Camuffo, I., Fürstenberg, K., Westhoff, D., Zlocki, A., Lützow, J., Benmimoun, M., Lesemann, M., Iglesias, I., Isasi, L., Murgoitio, J., Jacobson, J., Eriksson, H., Hérard, J., Leanderson, S., Heinig, K., Karlsson, A.-S., Jansson, J., and Andersson, H. (2008). *Testing and evaluation methods for ICT-based safety systems*. eVALUE.

Starnes, M. (2006). *Large-truck crash causation study: An initial overview*. National Center for Statistics and Analysis, National Highway Traffic Safety Administration, U.S. Department of Transportation, DOT HS 810 646.

3. DEFINITIONS

3.1 DEPARTURE

The situation in which the outside of one of the front wheels of a vehicle or of the leading part of an articulated vehicle is crossing a specified lane line (refer to SAE J2808, which follows from ISO 17361).

NOTE: The reference to three-wheel vehicles in SAE J2808 and ISO 17361 has been excluded due to the scope of this document.

3.2 EARLIEST WARNING LINE

The innermost limit of the warning threshold. See Table 1 and Figure 1 for the location of the earliest warning line location as a function of rate of departure (refer to SAE J2808, which follows from ISO 17361).

3.3 LANE

The area of roadway that a vehicle would be expected to travel along in the absence of any obstruction without the driver's desire to change the path of travel (refer to SAE J2808, which follows from ISO 17361).

3.4 LANE BOUNDARY

The borderline of the lane that is determined by a visible lane marking and in the absence of a visible lane marking by incidental visible road features or other means, such as global positioning system (GPS), electromagnetic nails, etc. In the case of a visible lane marking, the boundary shall be at the inside thereof (refer to SAE J2808, which follows from ISO 17361).

3.5 LANE CURVATURE

The radius of the lane as measured in the lane halfway between the left and right lane markers.

3.6 LANE DEPARTURE

The point of departure across the lane boundary (refer to SAE J2808, which follows from ISO 17361).

3.7 LANE DEPARTURE WARNING

A warning given to the driver in accordance with the lane departure warning condition in the absence of suppression requests (refer to SAE J2808, which follows from ISO 17361).

3.8 LANE DEPARTURE WARNING CONDITION

The phase where an unintended lane departure event is detected and the notice of detection is provided to the HMI, which provides warning information to the driver.

3.9 LANE DEPARTURE WARNING SYSTEM (LDWS)

A system that can automatically detect an impending or actual lane departure (e.g., intention indicated by active turn signals) and provide warnings.

3.10 LANE WIDTH

The distance between the inside of the inside lane marker on the left to the inside of the inside lane marker on the right (see Figure 1).

3.11 LATEST WARNING LINE

The outermost limit of the warning threshold (refer to SAE J2808, which follows from ISO 17361).

3.12 NO WARNING ZONE

Zone between the two earliest warning lines (refer to ISO 17361) (see Figure 1).

3.13 RATE OF DEPARTURE

The subject vehicle's approach velocity perpendicular to the lane boundary at the warning issue point (refer to SAE J2808, which is from ISO 17361).

3.14 ROAD

The surface that a vehicle would be expected to travel along in the absence of any obstruction (refer to SAE J2808).

3.15 ROAD BOUNDARY

The borderline of the road that is determined by incidental visible road features or other means, such as GPS (refer to SAE J2808).

3.16 ROAD DEPARTURE

The point of departure across the road boundary (refer to SAE J2808).

3.17 ROAD DEPARTURE WARNING

A warning given to the driver in accordance with the road departure warning condition in the absence of suppression requests (refer to SAE J2808, which follows from ISO 17361).

3.18 ROAD DEPARTURE WARNING SYSTEM

A system that provides road departure warnings (refer to SAE J2808).

3.19 STATUS/FUNCTION INDICATION

An indication that reflects a system may not (or is less likely to) deliver a road/lane departure warning (refer to SAE J2808, which follows from ISO 17361).

3.20 STRAIGHT ROAD

Road with a radius of curvature of 500 m or more (refer to SAE J2808).

3.21 SUBJECT VEHICLE

Vehicle being tested.

3.22 SUPPRESSION REQUEST

Driver request or system feature intended to prevent a lane departure warning if an intended lane departure is detected.

3.23 SYSTEM INCAPABLE

A state of the system in which it is unable to warn the driver of a lane departure due to temporary conditions (refer to SAE J2808, which follows from ISO 17361).

3.24 TIME-TO-LINE CROSSING (TTLC)

Calculated time-to-lane departure (refer to ISO 17361).

3.25 VISIBILITY

The distance at which the illuminance of a non-diffusive beam of white light with a color temperature of 2700 K is decreased to 5% of its original light source illuminance (refer to ISO 17361). For further information on Meteorological Optical Range (MOR), please refer to https://space.oscar.wmo.int/variables/view/meteorological_optical_range_mor_surface.

3.26 VISIBLE LANE MARKING

Delineators intentionally placed on the borderline of the lane that are directly visible by the driver while driving (i.e., not covered by snow, etc.) (refer to ISO 17361).

3.27 WARNING CONDITION

A condition in which lane departure across the warning threshold occurs (refer to SAE J2808, which follows from ISO 17361).

3.28 WARNING ISSUE POINT

Measured location and time at which a warning begins to be issued (refer to ISO 17361).

3.29 WARNING THRESHOLD

Location where the warning is issued on the road, which corresponds to a warning trigger point set in the system (refer to ISO 17361).

3.30 WARNING THRESHOLD PLACEMENT ZONE

Zone between the earliest and latest warning lines within which the warning threshold is placed (refer to ISO 17361) (see Figure 1).

Table 1 - Distance to earliest warning line as a function of vehicle rate of departure[1] based on a 2-second TTLC

Rate of Departure, m/s (ft/s)	Distance from Lane Boundary to Earliest Warning Line, m (feet)
0.2 (0.66)	0.1 (0.33)
0.4 (1.32)	0.2 (0.66)
0.6 (1.97)	0.3 (0.99)
0.8 (2.62)	0.4 (1.32)

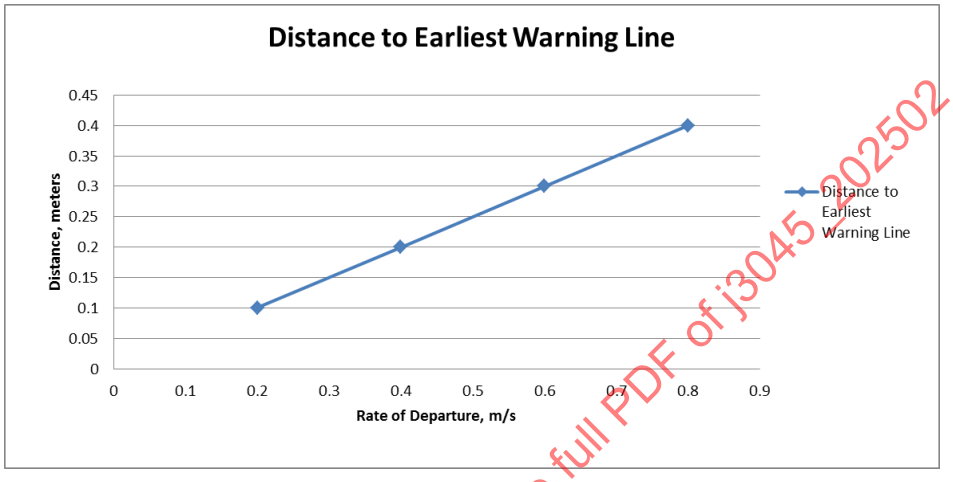

Figure 1 - Distance to earliest warning line as a function of vehicle rate of departure

4. TEST INSTRUMENTATION, DATA, AND ACCURACY LEVELS

4.1 LDWS Performance Measurement Instrumentation

The tester is free to choose the mix of instrumentation. Options include, but are not limited to:

4.1.1 Differential Real-Time Kinematic (RTK) GPS Method

A differential RTK GPS, including a base station providing an accuracy of up to 2 cm (0.787 inch), can be used. This method surveys the location of the lane markings before the start of the test. RTK GPS can provide the position of the wheels within 2 cm (0.787 inch) accuracy. This method requires extra instrumentation (RTK base and rover stations) and calibration effort (survey of the lane markers).

4.1.2 Video Overlayed with CAN Outputs Method

An external camera can be mounted and configured so that the wheel position with reference to lane marking can be determined and data (video and CAN) recorded simultaneously. When the video is synchronized with the CAN outputs, playing back the data file can show when the warning occurred. The tire width can be used as reference to estimate the position of the outer wheel edge when the warning happens.

4.1.3 External Video with Microphone to Capture Warning Sound from the Cab

An external camera can be mounted and configured so that the wheel position with reference to lane marking can be determined. The audio input for video is recorded from inside the cab to capture the warning sound. The tire width can be used as reference to estimate the position of the outer wheel edge when the warning happens.

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[1] SAE J2808 uses “rate of departure” instead of “lateral velocity.”

4.2 LDWS Test Data to be Collected

4.2.1 Vehicle Dynamic Data

The data sufficient and necessary to ensure that the test vehicle properly executed the prescribed test trajectory (see 9.1).

4.2.1.1 Yaw rate measured to an accuracy of 0.02 deg/s.

4.2.1.2 Speed measured to an accuracy to 0.05 m/s (0.164 ft/s).

4.2.1.3 Rate of departure measured to an accuracy to 0.05 m/s (0.164 ft/s).

4.2.2 LDWS Warning State

This data is necessary and sufficient to validate the output of LDWS during the test trajectory.

4.2.3 Vehicle-Lane Marker/Lane Boundary Data

This data is necessary and sufficient to confirm in later analysis that a warning issued by the LDWS occurred within the warning threshold placement zone.

4.2.3.1 Distance from front tire outside edge to inside lane marker inside edge.

4.2.3.1.1 Left-side front tire, left-side lane marker for lane departure to the left: accuracy to 0.05 m (1.97 inches).

4.2.3.1.2 Right-side front tire, right-side lane marker for lane departure to the right: accuracy to 0.05 m (1.97 inches).

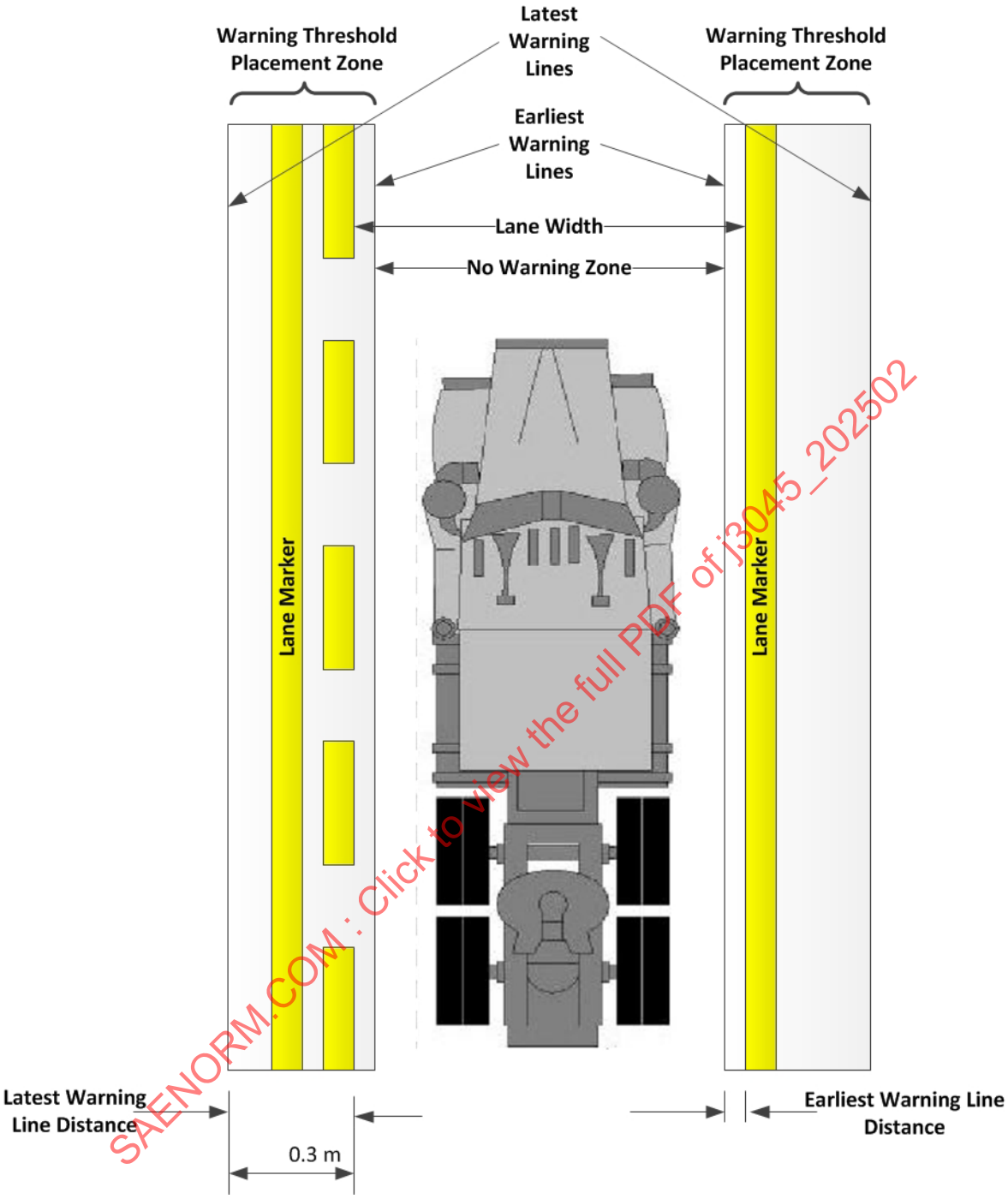

Figure 2 - Graphical representation of warning threshold placement zone; lane markings drawn above based on the MUTCD
Adapted from Houser et al. (2005)

5. VEHICLE INFORMATION

5.1 Vehicle Information to be Recorded on the Data Sheet

Vehicle GVW data plate door frame.

5.2 Vehicle Weight

Two conditions:

5.2.1 Lightly loaded vehicle weight (LLVW) plus up to 227 kg (500 pounds) for driver and instrumentation.

5.2.2 Loaded to its gross vehicle weight rating (GVWR).

5.3 Tire Pressures

Vehicle manufacturer’s recommended pressure.

6. ENVIRONMENTAL TEST CONDITIONS

6.1 Ambient Temperature

0 < T < 40 °C (32 < T < 104 °F).

6.2 Atmospheric Precipitation

None.

6.3 Minimum Atmospheric Visibility

3.2 km (2 miles).

6.4 Ambient Lighting

Overcast or brighter.

6.5 Maximum Wind Speed

Gentle breeze (22.2 km/h [13.8 mph]).

6.6 Sun Angle

Greater than 15 degrees above the horizon.

7. FACILITIES

7.1 Roadway Surface

7.1.1 Road Condition

Dry.

7.1.2 Road Striping Condition

7.1.2.1 Striping Type

White solid fog line, yellow solid, or skip center line per the MUTCD. Variations allowed for different lane markings used in countries other than the U.S.

7.1.2.2 Striping Widths

10.2 cm (4 inches) minimum, 15.2 cm (6 inches) maximum.

7.1.3 Lane Curvature

Radius of curvature greater than 500 m (1640 feet).[2]

7.1.4 Road Grade

Less than 1%.

7.1.5 Road Cross-Slope

Less than 2%.

7.1.6 Lane Width

3.66 m (12 feet).

7.2 Test Track Geometry

7.2.1 Straight road lane departure test course is shown in Figure 3. Cones and gates are used to align the test vehicle with the lane boundary at the initiation of the test. Approach distance of 96 m (315 feet) gives system time to "lock on" to lane boundaries, and a 200-m (656-foot) cessation distance allows vehicle to slow at the conclusion of the test.

7.2.2 Recommended pylon spacing to facilitate valid lateral velocities within the bounds of the test is shown in Figure 4. Steering toward the left pylon produces a greater rate of departure than steering toward the right pylon.

[2] Approximately 20% of large truck lane departure crashes for drivers responsible in single-vehicle crashes and 13% for drivers responsible in multi-vehicle crashes occurred on roadways with no paved shoulder. A horizontal curve was present for 65% of drivers responsible in a single-vehicle lane departure crash and for 26% of drivers in multi-vehicle crashes. From Investigating Factors Contributing to Large Truck Lane Departure Crashes Using the Federal Motor Carrier Safety Administration's Large Truck Crash Causation Study (LTCCS) Database. Center for Transportation Research and Education, Iowa State University, January 2009.

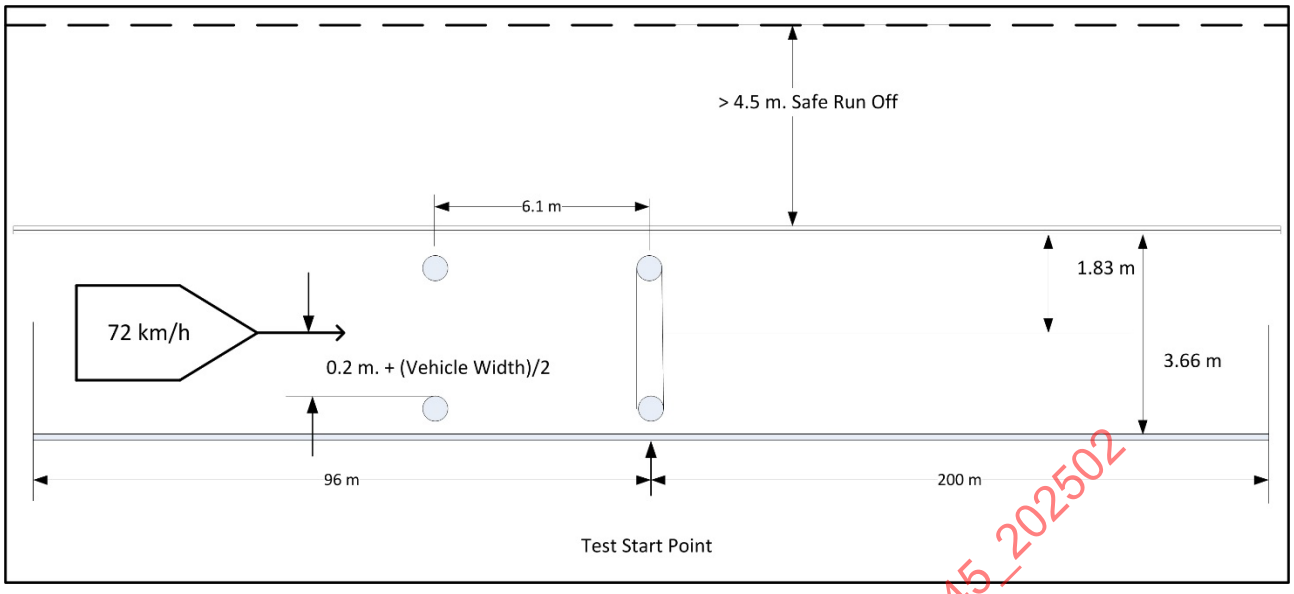

Figure 3 - Straight road lane departure test course; left lane departure is illustrated above, right lane departure warning test requires symmetry about the reference lane marker
Adapted from U.S. NHTSA NCAP LDW Test Procedure:
https://downloads.regulations.gov/NHTSA-2015-0119-0033/attachment_1.pdf

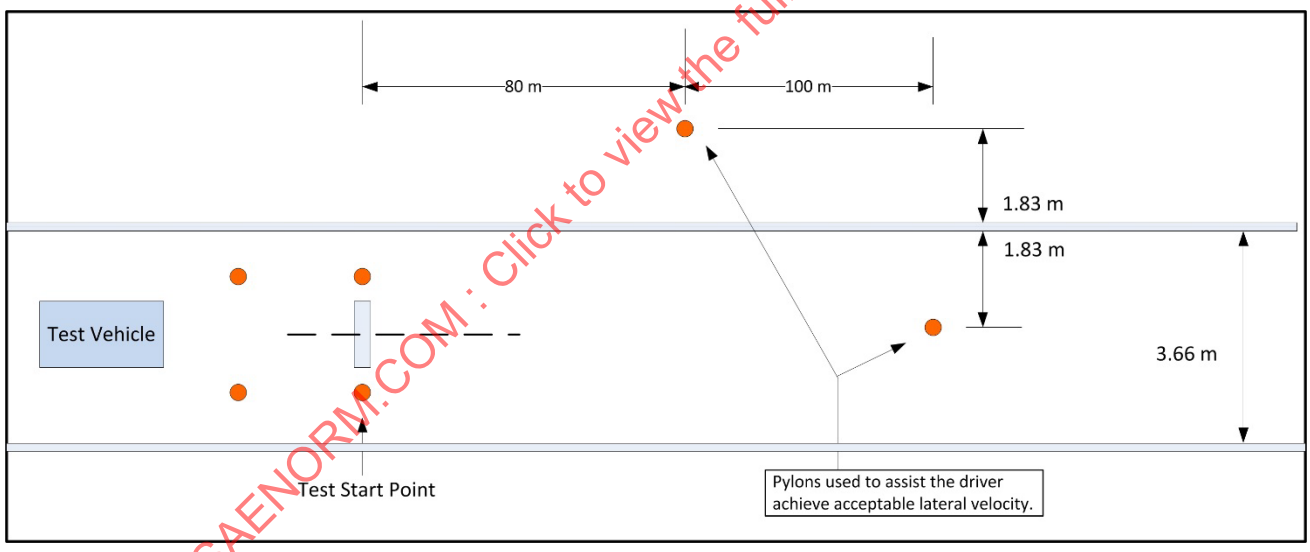

Figure 4 - Recommended pylon spacing to facilitate valid lateral velocities; left lane departure is illustrated above, right lane departure warning test requires symmetry about the reference lane marker
Adapted from U.S. NHTSA NCAP LDW Test Procedure:
https://downloads.regulations.gov/NHTSA-2015-0119-0033/attachment_1.pdf

8. CALIBRATION OF CONTROL SYSTEM AND SENSOR

The LDW system shall be installed and in operating condition according to manufacturer's specification.

9. TEST SEQUENCE

9.1 Performance Test Procedure

9.1.1 Step 1

Maintain speed at 72 km/h (44.7 mph) on a clearly marked surface with appropriate lane markings. Test speed shall be monitored, and a test will be considered valid if the test speed remains within 72 km/h ± 4 km/h (44.7 mph ± 2.5 mph). The speed must remain within this window from the start of the test until any part of the vehicle has crossed the latest warning line.

9.1.2 Step 2

Drift outside the left-side lane marker at a rate of departure between 0.1 m/s (0.33 ft/s) and 0.6 m/s (1.97 ft/s) according to the conditions shown in Table 2 for speed, turn signal status, and lane marking types. Return back to the center of the lane before doing the next departure. The cab yaw rate during the period between the time when the vehicle passes through the start point to the point of lane departure warning issuance should not exceed 1.0 deg/s.

9.1.3 Repeat step 2 for a minimum of four times for each condition according to Table 2.

9.1.4 Repeat step 2 for a right-side lane departure according to Table 3.

Table 2 - Test conditions for left lane departure test[3]

Test	Vehicle Loading	Target Speed	Left Turn Signal	Right Turn Signal	Hazards	Lane Marker Type	Lane Marker Color	Warning Status
LDW Left	Lightly loaded	72 km/h	Off	Off	Off	Solid	White	Warn
	Lightly loaded	72 km/h	Off	Off	Off	Dashed	White	Warn
	Lightly loaded	72 km/h	Off	Off	Off	Solid	Yellow	Warn
	Lightly loaded	72 km/h	Off	Off	Off	Dashed	Yellow	Warn
	GVWR	72 km/h	Off	Off	Off	Solid	Yellow	Warn
	GVWR	72 km/h	Off	Off	Off	Dashed	Yellow	Warn

Table 3 - Test conditions for right lane departure test[4]

Test	Vehicle Loading	Target Speed	Left Turn Signal	Right Turn Signal	Hazards	Lane Marker Type	Lane Marker Color	Warning Status
LDW Right	Lightly loaded	72 km/h	Off	Off	Off	Solid	White	Warn
	Lightly loaded	72 km/h	Off	Off	Off	Dashed	White	Warn
	GVWR	72 km/h	Off	Off	Off	Solid	White	Warn
	GVWR	72 km/h	Off	Off	Off	Dashed	White	Warn

[3] Up to 5 minutes allowed between loading conditions to allow the LDWS to recalibrate between load conditions.
[4] Up to 5 minutes allowed between loading conditions to allow the LDWS to recalibrate between load conditions.

9.1.5 Minimum Performance Requirements

Detection and warning of an unintended lane departure event:

9.1.5.1 Single Test Condition

The minimum performance pass rate for any series of valid test runs for a single test condition is 80%. For example, for the LDW Left, Lightly Loaded, Solid White line, the system has to successfully operate at an 80% rate or higher.

9.1.5.2 Grouped Test Condition

The minimum performance pass rate for any grouped test condition is 80%. For example, for any valid tests involving a solid lane-marker line, the system passing rate must be 80% or greater. Grouped test conditions are:

9.1.5.2.1 Vehicle Loading

Lightly loaded or GVWR. (The system must exhibit an 80% aggregate for all tests that use the lightly loaded condition and for all tests that use the GVWR condition.)

9.1.5.2.2 Lane Marker Type

Solid or dashed. (The system must exhibit an 80% aggregate pass rate for all tests using solid lines and all tests using dashed lines.)

9.1.5.2.3 Lane Marker Type

White or yellow. (The system must exhibit an 80% aggregate pass rate for all tests using white lines and all tests using yellow lines.)

9.1.5.3 Aggregate Test Condition

The minimum pass rate for the entirety of the test conditions in Tables 2 and 3 is 85%.

9.1.5.3.1 For the 30 test runs associated with Table 2, the system must function properly in 26 of 30 valid tests.

9.1.5.3.2 For the 20 test runs associated with Table 3, the system must function properly in 17 of 20 valid tests.

9.2 Driver Intent Suppression Request Test

LDWS infer intentional lane departures via the turn signals; an active turn signal indicates driver intent to change lanes.

9.2.1 Test Procedure

Execute one instance of a test found in either Table 2 or Table 3, with the change that the appropriate turn signal be active. Record response of the system; a warning should not be presented if the turn signal matches the direction of the lane departure.

9.2.2 Minimum Performance Requirement

For every time that 9.2.1 is executed, the LDWS must not warn a driver of a lane departure during instance of the driver intent suppression request test.

9.3 Inoperability/System Incapable Warning Tests

9.3.1 Response to a Component Failure

9.3.1.1 The system is made inoperable by a component failure. An example of such a component failure is an open or short-circuited connection or an inserted software fault. Such a simulated failure is specifically a function of the technology used but is required to be of sufficient severity that functionality of the LDWS is discontinued. This failure can be an LDWS electrical or LDWS component failure; for example, disconnecting a communication line, loss of camera signal, loss of GPS receiver, etc.

9.3.1.2 In this failure state, the vehicle under test conducts the specified test procedure.

9.3.1.3 The specific driver warning signal is recorded.

9.3.1.4 Record the condition of the status/function failure warning signal.

9.3.1.5 Depending upon the particular fault inserted and the intended reaction of the system, the functionality of the system might be restored after an ignition cycle. The particular fault could be of sufficient severity that an ignition cycle will not restore functionality, and the fault logged internal to the system will need to be intentionally cleared.

9.3.1.6 Repair the electrical or component failure and turn on the engine ignition switch.

9.3.1.7 Record status of the failure warning signal.

9.3.1.8 Minimum Performance Requirements

9.3.1.8.1 In the faulted state, the system must produce a driver status/function failure warning signal within 1 minute of the ignition cycle or the invocation of the component failure.

9.3.2 Response to an External Loss of Input

9.3.2.1 Depending upon the particular technology used, the vehicle is operated in an environment such that the external indication of lane position is not present. Examples would be a roadway without lane markers or borders visible to a visual-based detection system or a GPS-based system operated in a GPS shadow. The system is operational but does not receive the expected input from the environment.

9.3.2.2 The vehicle conducts the equivalent of the test procedure without lane boundaries. The intent is to make sure that the vehicle is at sufficient speed and otherwise functional so that the lane detection system is otherwise operational.

9.3.2.3 The specific driver warning signal is recorded.

9.3.2.4 Minimum Performance Requirement

9.3.2.4.1 The system must produce a system status/function warning signal a minimum of one of four times.[5]

9.4 Deactivation Test

9.4.1 For subject vehicles equipped with the means to manually deactivate the LDWS, turn the ignition (start) switch to the run (on) position and deactivate the LDWS.

9.4.1.1 Record the system status signal(s).

[5] The one of four requirement is reflective of the potential inability to provide a repeatable loss of external input due to transient environmental conditions at the test facility.