# Connected Commercial Vehicles—Retrofit Safety Device Kit Project

# Safety Applications Performance and Functional Test Plan and Procedure

**Publication No. FHWA-JPO-14-107** **March 28, 2014**

U.S. Department of Transportation
**Federal Highway Administration**

**Notice**

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document.

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

**Quality Assurance Statement**

The Federal Highway Administration provides high quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

# TECHNICAL REPORT DOCUMENTATION PAGE

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| **FHWA-JPO-14-107** | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| Connected Commercial Vehicles—Retrofit Safety Device Kit Project<br>Safety Applications Performance and Functional Test Plan and Procedure | March 28, 2014 |
| | **6. Performing Organization Code**<br>100005986 |
| **7. Author(s)**<br>Bryan Wells and Roger Berg | **8. Performing Organization Report No.**<br>100005986-402 |
| **9. Performing Organization Name And Address**<br>DENSO International America, Inc.—<br>North America Research and Development,<br>California Office<br>3252 Business Park Drive<br>Vista, CA 92081<br><br>Battelle<br>505 King Avenue<br>Columbus, OH 43201 | **10. Work Unit No. (TRAIS)** |
| | **11. Contract or Grant No.**<br>DTFH61-11-D-00014/T11001 |
| **12. Sponsoring Agency Name and Address**<br>Federal Highway Administration<br>1200 New Jersey Avenue, S.E.<br>Washington, DC 20590 | **13. Type of Report and Period Covered**<br>Task Final Report<br>9/1/2011-3/30/2014 |
| | **14. Sponsoring Agency Code** |

**15. Supplementary Notes**

**16. Abstract**

Connected vehicle wireless data communications can enable safety applications that may reduce injuries and fatalities. Cooperative vehicle-to-vehicle (V2V) safety applications will be effective only if a high fraction of vehicles are equipped. Deployment of V2V technology will be enhanced if it is available not only for manufacturing in new vehicles but also for retrofit to existing vehicles. The objective of the Connected Commercial Vehicles—Retrofit Safety Device (CCV-RSD) Kit Project was to develop complete hardware and software that can be used in various brands and models of heavy trucks. The RSD kits provide the functionality needed for cooperative V2V and vehicle-to-infrastructure (V2I) safety applications to support the Model Deployment and other USDOT connected vehicle projects. This project included testing and documentation needed for installation, operation, enhancement, and maintenance of the units. These retrofit kits were built so they could be installed in existing class 6, 7, or 8 trucks. The RSD kits achieved a V2V and V2I functionality similar to that of the Connected Commercial Vehicles—Integrated Truck vehicles, where onboard equipment was integrated with newly manufactured truck tractors.

This document describes the performance and functional test plan and procedures that were later used to verify that the safety applications in an RSD kit that had been installed in a tractor. The document specifies a series of tests for the Forward Collision Warning (FCW), Emergency Electronic Brake Lights (EEBL), Intersection Movement Assist (IMA), Blind Spot Warning/Lane Change Warning (BSW/LCW), and Curve Speed Warning (CSW) safety applications.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| Commercial vehicle, connected vehicle, commercial motor vehicle, CMV, dedicated short-range communication, DSRC, V2V | Distribution Unlimited |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 78 | |

## SI* (MODERN METRIC) CONVERSION FACTORS

**APPROXIMATE CONVERSIONS TO SI UNITS**

| SYMBOL | WHEN YOU KNOW | MULTIPLY BY | TO FIND | SYMBOL |
|---|---|---|---|---|
| | | **LENGTH** | | |
| **in** | inches | 25.4 | millimeters | mm |
| **ft** | feet | 0.305 | meters | m |
| **yd** | yards | 0.914 | meters | m |
| **mi** | miles | 1.61 | kilometers | km |
| | | **AREA** | | |
| **in$^2$** | square inches | 645.2 | square millimeters | mm$^2$ |
| **ft$^2$** | square feet | 0.093 | square meters | m$^2$ |
| **yd$^2$** | square yard | 0.836 | square meters | m$^2$ |
| **ac** | acres | 0.405 | hectares | ha |
| **mi$^2$** | square miles | 2.59 | square kilometers | km$^2$ |
| | | **VOLUME** | | |
| **fl oz** | fluid ounces | 29.57 | milliliters | mL |
| **gal** | gallons | 3.785 | liters | L |
| **ft$^3$** | cubic feet | 0.028 | cubic meters | m$^3$ |
| **yd$^3$** | cubic yards | 0.765 | cubic meters | m$^3$ |
| | | NOTE: volumes greater than 1000 L shall be shown in m$^3$ | | |
| | | **MASS** | | |
| **oz** | ounces | 28.35 | grams | g |
| **lb** | pounds | 0.454 | kilograms | kg |
| **T** | short tons (2000 lb) | 0.907 | megagrams (or "metric ton") | Mg (or "t") |
| | | **TEMPERATURE (exact degrees)** | | |
| **°F** | Fahrenheit | 5 (F-32)/9 or (F-32)/1.8 | Celsius | °C |
| | | **ILLUMINATION** | | |
| **fc** | foot-candles | 10.76 | lux | lx |
| **fl** | foot-Lamberts | 3.426 | candela/m$^2$ | cd/m$^2$ |
| | | **FORCE and PRESSURE or STRESS** | | |
| **lbf** | poundforce | 4.45 | newtons | N |
| **lbf/in$^2$** | poundforce per square inch | 6.89 | kilopascals | kPa |

**APPROXIMATE CONVERSIONS FROM SI UNITS**

| SYMBOL | WHEN YOU KNOW | MULTIPLY BY | TO FIND | SYMBOL |
|---|---|---|---|---|
| | | **LENGTH** | | |
| **mm** | millimeters | 0.039 | inches | in |
| **m** | meters | 3.28 | feet | ft |
| **m** | meters | 1.09 | yards | yd |
| **km** | kilometers | 0.621 | miles | mi |
| | | **AREA** | | |
| **mm$^2$** | square millimeters | 0.0016 | square inches | in$^2$ |
| **m$^2$** | square meters | 10.764 | square feet | ft$^2$ |
| **m$^2$** | square meters | 1.195 | square yards | yd$^2$ |
| **ha** | hectares | 2.47 | acres | ac |
| **km$^2$** | square kilometers | 0.386 | square miles | mi$^2$ |
| | | **VOLUME** | | |
| **mL** | milliliters | 0.034 | fluid ounces | fl oz |
| **L** | liters | 0.264 | gallons | gal |
| **m$^3$** | cubic meters | 35.314 | cubic feet | ft$^3$ |
| **m$^3$** | cubic meters | 1.307 | cubic yards | yd$^3$ |
| | | **MASS** | | |
| **g** | grams | 0.035 | ounces | oz |
| **kg** | kilograms | 2.202 | pounds | lb |
| **Mg (or "t")** | megagrams (or "metric ton") | 1.103 | short tons (2000 lb) | T |
| | | **TEMPERATURE (exact degrees)** | | |
| **°C** | Celsius | 1.8C+32 | Fahrenheit | °F |
| | | **ILLUMINATION** | | |
| **lx** | lux | 0.0929 | foot-candles | fc |
| **cd/m$^2$** | candela/m$^2$ | 0.2919 | foot-Lamberts | fl |
| | | **FORCE and PRESSURE or STRESS** | | |
| **N** | newtons | 0.225 | poundforce | lbf |
| **kPa** | kilopascals | 0.145 | poundforce per square inch | lbf/in$^2$ |

**TABLE OF CONTENTS**

**Page**

## LIST OF FIGURES



## LIST OF TABLES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| BSM | Basic Safety Message |
| BSW | Blind Spot Warning |
| CAN | Controller Area Network |
| CAMP | Crash Avoidance Metrics Partnership |
| CSW | Curve Speed Warning |
| DAS | Data Acquisition System |
| DSRC | Dedicated Short Range Communications |
| DVI | Driver-Vehicle Interface |
| EEBL | Emergency Electronic Brake Light |
| FCW | Forward Collision Warning |
| GPS | Global Positioning System |
| HDOP | Horizontal Dilution of Precision |
| HV | Host Vehicle |
| HVT | Host Vehicle Truck |
| IMA | Intersection Movement Assist |
| LCW | Lane Change Warning |
| NHTSA | National Highway Traffic Safety Administration |
| NTSC | National Television System Committee |
| OTA | Over the Air |
| PDOP | Percent Dilution of Precision |
| PER | Packet Error Rate |
| RSD | Retrofit Safety Device |
| RSE | Road Side Equipment |

| | |
|---|---|
| RV | Remote Vehicle |
| RVL | Remote Vehicle Light |
| SAE | SAE International |
| TC | Target Classification |
| TIM | Traveler Information Message |
| V2I | Vehicle-to-Infrastructure |
| V2V | Vehicle-to-Vehicle |
| VDA | Vehicle Dynamics Area |
| WAAS | Wide Area Augmentation System |

## EXECUTIVE SUMMARY

The Connected Commercial Vehicles—Retrofit Safety Device (CCV-RSD) Kit Project involved the development, validation, and field testing of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) safety applications for commercial vehicles. The V2V and V2I capability were built in a device that would be retrofit to an existing truck tractor, and the device was delivered as a kit for installation.

This document establishes a series of test procedures to verify that the safety applications are functioning properly when the RSD kit is installed on a truck tractor. There were objective performance tests of four applications: Emergency Electronic Brake Lights, Forward Crash Warning, Blind Spot Warning and Lane Change Warning, and Intersection Movement Assist. Several scenarios were established for each application, to test different aspects of its capability. Each scenario specifies the relative positions of the host truck and one or more remote vehicles, their speeds, whether the road is curved, and a criterion for success. In "true positive" scenarios, the application was to issue an alert to the driver under specified circumstances. In "false positive" scenarios, the host and remote vehicles drove near each other, but the correct behavior was to issue no alert.

A separate document presents the results of the tests.

# CHAPTER 1. INTRODUCTION

## PURPOSE

This document describes the performance and functional test plan and procedures that will be used to verify that the Connected Commercial Vehicles—Retrofit Safety Device (CCV-RSD) safety applications perform according to the requirements in the CCV-RSD Safety Applications and Development Plan document.[1] The results of this series of tests are in a separate report.[2]

## SCOPE

The tests described in this document are designed to validate the functionality of the CCV-RSD safety applications, and compliance with the applicable referenced requirements. These tests are not intended to verify RF performance or Society of Automotive Engineers (SAE) J2735 message structure. Separate interoperability testing will be performed to demonstrate that properly formatted messages are successfully exchanged between Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Safety Devices.

The tests described in this document will validate the functionality of the V2V and V2I CCV-RSD Safety Applications listed below using the Driver-to-Vehicle Interface (DVI).

V2V Safety Applications:

- Forward Collision Warning (FCW).
- Emergency Electronic Brake Lights (EEBL).
- Intersection Movement Assist (IMA).
- Blind Spot Warning/Lane Change Warning (BSW/LCW).

V2I Safety Application:

- Curve Speed Warning (CSW).

Sub-system performance is not evaluated as part of these procedures. If sub-systems were to fail during a test procedure but the system successfully warns or does not warn the driver as required by the procedures, the test is considered successful. Likewise, a failure of a sub-system that prevents a warning or warns inappropriately is considered an unsuccessful test. A failure of the system to warn when all subsystems are operating correctly is considered an unsuccessful test.

## PROCEDURE

Since the tests in this document verify the safety applications' performance at the system level, only system-level-performance details need to be recorded during the test. Additional sub-system-level performance details may be recorded to assist in diagnosing certain system or sub-system issues as long as this does not impact the results of the test.

A successful test is one in which the procedure is correctly completed, all validation criteria are fulfilled, and the driver is warned or not warned, as required by the CCV-RSD Safety Applications and Development Plan document. A Warning is defined as the Driver Vehicle Interface (DVI) notification module submitting a warning request to one or more warning modalities installed on the test vehicle. The maximum delay from the application submitting a warning request to the DVI device presenting the alert is given for each test as applicable. The tests included in this Test Plan will not include the latency of the DVI itself as evaluation criteria.

An unsuccessful test is one in which the driver was warned when a warning was not required (false positive unit response) by the test procedure, or the driver was not warned when a warning was required (failure due to no response) by the test procedure.

All test procedures described in this document shall be conducted at a closed test facility.

Each test will involve at least two people in the Host Vehicle (HV) in which the warning is tested, a test driver and a test conductor. The test driver operates the vehicle as specified by this test plan and the test conductor orchestrates the test maneuvers, observes and records test conditions, apparent test validity, and results. In the Remote Vehicle (RV) only the driver will be present. An RV is any vehicle participating in the test so that the conditions for the HV DVI to issue a warning are present. In this context a HV is defined as the test vehicle in which the correct issuing of the warning (or non-issue of warning in case of false positive tests) is tested.

In all tests the HV is a truck (HVT) and the RV is a light vehicle (RVL).

**ASSUMPTIONS**

It is assumed that the test conductors are not naïve. It is assumed that the test drivers are familiar with the test procedures. It is also assumed that the test conductors are familiar with the basic operation of the vehicle and the safety applications that are tested in the procedures. However, it is not assumed that the test conductors and test drivers are knowledgeable of the sub-systems or the design and construction of the CCV-RSD system. This does not preclude CCV-RSD team members to drive the vehicles as test drivers in the tests.

**TEST SCENARIOS OVERVIEW**

The tests specified in this document are grouped into test scenarios. A test scenario defines the test conditions, the test procedure, the expected results, and the number of test runs. A test run is one execution of the test scenario's test procedure.

The tests are divided into true positive tests and false positive tests. A true positive test is a test where the objective is to test whether the system issues a correct warning, defined as a necessary warning at the correct distance and/or time within the allowed error range, specified in each test scenario.

A false positive test is a test where the objective is to test whether the system can successfully avoid issuing a warning in a situation where no warning should be given. In contrast to the true positive tests, false positive tests have no successful/unsuccessful criteria associated with them.

The following table is an overview of test scenarios included in this document. Each scenario is presented with its name and a reference to the section that details its procedure.

**Table 1. Test scenario table.**

| Scenario Code | Name | Section | Test Type | Scenario Number |
|---|---|---|---|---|
| EEBL-T1 | HVT follows a braking RVL | 4.1 | True positive | 1 |
| EEBL-T2 | HVT follows RVL that follows a braking RVL | 4.2 | True positive | 2 |
| EEBL-T3 | HVT follows mild-braking RVL | 4.3 | True positive | 3 |
| EEBL-T4 | HVT passes RVL braking in adjacent lane | 4.4 | False positive | 4 |
| FCW-T1 | HVT approaches stopped RVL | 5.1 | True positive | 5 |
| FCW-T2 | HVT follows RVL that is approaching a stopped RVL | 5.2 | True positive | 6 |
| FCW-T3 | HVT tailgates RVL | 5.3 | False positive | 7 |
| FCW-T4 | HVT follows braking RVL | 5.4 | True positive | 8 |
| FCW-T5 | HVT changes lanes behind stopped RVL | 5.5 | True positive | 9 |
| FCW-T6 | HVT passes RVL that is stopped in a curve | 5.6 | False positive | 10 |
| FCW-T7 | HVT approaches RVL stopped in a curve | 5.7 | True positive | 11 |
| FCW-T8 | HVT passes moving RVL in adjacent lane in a Curve | 5.8 | False positive | 12 |
| BSWLCW-T1 | RVL passes HVT with trailer on Left | 6.1 | True positive | 13 |
| BSWLCW-T2 | RVL passes HVT with trailer on Right | 6.2 | True positive | 14 |
| BSWLCW-T3 | Two RVLs pass HVT with trailer on Left and Right | 6.3 | True positive | 15 |
| BSWLCW-T4 | HVT passes RVL on the Left and pauses | 6.4 | True positive | 16 |
| BSWLCW-T5 | RVL tailgates HVT | 6.5 | True positive | 17 |
| BSWLCW-T6 | RVL and HVT drive separated by one lane | 6.6 | False positive | 18 |
| BSWLCW-T7 | RVL passes HVT in a curve | 6.7 | False positive | 19 |
| IMA-T1 | Variable speed approaches with moving HVT and RVL | 7.1 | True positive | 20 |
| IMA-T2 | Stopped HVT, Moving RVL | 7.2 | True positive | 21 |
| CSW | Curve Speed Warning Test | 8.1 | True Positive | 22 |

Source: MBRDNA and DENSO

## INDIVIDUAL TEST SUCCESSFUL AND UNSUCCESSFUL DEFINITIONS

A test can be valid or invalid. Only a valid test may be defined as successful or unsuccessful. The results of an invalid test are not considered for successful/unsuccessful evaluation. As such, there are three test outcomes:

1. Invalid.
2. Valid and Successful.
3. Valid and Unsuccessful.

These outcomes are defined in the sections below.

### Test Validity

The test is valid only if all the following conditions are met:

- The initial vehicle speed shall not deviate from the stated test speed by greater than +/-2.5 mph.

- The packet error rate (PER) of the dedicated short range communications (DSRC) message exchange between the HVT and the RV shall not exceed 20 percent within a 300 meter separation distance between vehicles at any given time, unless the test is designed to increase PER (for example, EEBL with obstructing vehicles). The PER is calculated both continuously as well as over a sliding 1-second window using the message sequence number as an indication of missing packets. The corruption of received packets is not required to be included in the PER calculation.

- The GPS coverage shall satisfy the following conditions:
  - All GPS receivers used in the test for relative positioning solutions shall have :
    - Normal 3D fix with the number of common satellites visible from both vehicles to be at least four.
    - All GPS receivers employed in the test shall operate in WAAS mode (i.e., Wide Area Augmentation System).
    - Horizontal Dilution of Precision (HDOP) shall be less than 1.5.

- The test vehicles shall be driven within 1.5 meters of the centerline of the lane of travel, unless required otherwise by the scenarios.

Additional criteria are specified within the test procedures for each scenario.

**Definition of Successful Test and Unsuccessful Test**

The minimum requirements to determine successful or unsuccessful tests are:

- The test must be valid according to the Test Validity Section and possible additional validation criteria within the test procedures.
- A warning must be issued or not be issued as required by the individual test description.
- For a true positive test, the warning repeatability measurement must meet the specified criteria indicated in each test description.
- For false positive tests, no criteria for Successful or Unsuccessful will be specified.

Additional requirements for a successful and unsuccessful test are defined in the appropriate subsection that describes each test. Overall test success of a scenario is defined as successful passes of four out of five runs (80 percent test success rate). Overall test success of an application is defined as successful passes of all the scenarios for that application. Overall test success of the project is defined as successful passes of all the applications. Table 2 and table 3 are examples of Successful and Unsuccessful test runs.

**Table 2. Example of test result table – EEBL-Successful.**

| Test Name | Speed | Comment | Tests Conducted | Tests Successful | Successful / Unsuccessful |
|---|---|---|---|---|---|
| HVT at constant speed with decelerating RV in same lane | 50 | | 5 | 5 | Successful |
| HVT at constant speed with decelerating RV in left lane on curve | 50 | | 5 | 4 | Successful |
| HVT at constant speed with decelerating RV in same lane and obstructing vehicle in between | 50 | | 5 | 5 | Successful |
| HVT at constant speed with mild-decelerating RV in same lane | 50 | | 5 | 5 | Successful |
| HVT at constant speed with decelerating RV in 2nd right lane | 50 | | 5 | 5 | Successful |
| EEBL-Overall | | | | | Successful |

Source: MBRDNA and DENSO

**Table 3. Example of test result table – EEBL-Unsuccessful.**

| Test Name | Speed | Comment | Tests Conducted | Tests Successful | Successful / Unsuccessful |
|---|---|---|---|---|---|
| HVT at constant speed with decelerating RV in same lane | 50 | | 5 | 5 | Successful |
| HVT at constant speed with decelerating RV in left lane on curve | 50 | | 5 | 4 | Successful |
| HVT at constant speed with decelerating RV in same lane and obstructing vehicle in between | 50 | | 5 | 3 | Unsuccessful |
| HVT at constant speed with mild-decelerating RV in same lane | 50 | | 5 | 5 | Successful |
| HVT at constant speed with decelerating RV in 2nd right lane | 50 | | 5 | 5 | Successful |
| Overall | | | | | Unsuccessful |

Source: MBRDNA and DENSO

# CHAPTER 2. TEST PROCEDURE REQUIREMENTS

The following sections provide a description of the general requirements for conducting the tests described in this document. These sections are intended to describe the test requirements sufficiently in order to allow objective testing to be conducted at any sufficiently equipped vehicle test facility.

## GENERAL REQUIREMENTS

This section defines the requirements for data collection and the test facility for all applications. In addition, the specific test scenarios may define additional requirements based on the test.

### Vehicle Requirements

The HVT shall be equipped with the DENSO CCV-RSD onboard equipment (OBE) developed for this project as well as a Data Acquisition System (DAS) capable of recording the data elements outlined below. A van or container trailer 20 feet or more in length shall be coupled to the HVT for all tests. The trailer does not have to be instrumented.

The RVs will be light vehicles equipped with the DENSO Aftermarket Safety Device (ASD) OBE as well as DAS capable of recording the data elements outlined below.

In total one truck and two light vehicles equipped with DENSO OBE and DAS will be needed. One empty van trailer will also be needed.

### Vehicle-Vehicle Data Exchange

The Over-the-Air (OTA) data elements exchanged among the vehicles are described in the latest published standards document SAE J2735 Basic Safety Message (BSM) Part I.

### Data Collection Requirements

The following data elements must be collected for the HVT and RVs for all tests described in this document:

- Number of Global Position System (GPS) satellites visible and each satellite ID recorded using the GPS receiver's output.

- Positional Dilution of Positioning (PDOP) and Horizontal Dilution of Positioning (HDOP) recorded using the GPS receiver's output.

- Target Classification (TC) related data logged on the HVT system for each RV: vehicle ID, range, range rate, velocity, azimuth, location relative to HVT, longitudinal offset, longitudinal path distance between HVT and RV, lateral offset, and relative speed. For the IMA application, additional data logged includes the HVT's distance to intersecting point and the

RV's distance to intersecting point. In addition to the data listed, each application may define additional data that should be logged to evaluate the test validity and success.

- Warning status of the applications including vehicle ID and warning level.
- Vehicle latitude and longitude.
- System configuration settings if different from the system configuration in the test plan.
- Message sequence number defined in SAE J2735 BSM Part I.
- Vehicle speed with at least 0.5 mph resolution using the output from the test vehicle's Controller Area Network (CAN) bus.
- Vehicle brake status recorded using the brake status output from the CCV-RSD device.
- The engineering data sampling rate shall be 10 Hz or greater.
- Cone position, distance, and time-to-pass-cone setup for each test scenario if the setup deviates from the specification described in each scenario.
- HVT lane assignment and RV lane assignment.
- Video recording of views relevant the test. For example, forward view road view for EEBL/forward collision warning (FCW), side views for blind spot and lane change warning.
- Video shall be recorded in a standard NTSC format.

**Radios**

Remote vehicle drivers and the test conductor will use radios for test conduction. The test conductor will use the same radio on the designated channel to communicate with the test facility control tower.

**Environmental and Roadway Conditions**

All the track test scenarios shall be conducted in the following conditions unless specified otherwise:

- Daytime.
- Good atmospheric visibility.
- Dry pavement.
- Smooth pavement.
- Well-marked lanes with the lane width of at least 3.6 meters.

The definition of the above environmental variables can be found in the CAMP-NHTSA FCW report.[3]

Unless otherwise stipulated in the test itself, the road geometry for each test should be straight and flat, where straight means the road having a horizontal curvature of less than 0.1 km-1 (curvature radius greater than 10000m) and flat means a grade of less than 0.1 percent.[3] The curved tests will be performed on the flattest surface available at the test facility.

## ESTABLISHING BREADCRUMBS

In every test where the RV is stationary and also sending out location data over DSRC, a proper trail of "breadcrumbs" must be established for the system to work correctly. To establish the trail of breadcrumbs, the RV shall drive for 300 meters in the same lane in which it will come to a stop. To preserve the breadcrumbs, the vehicle and DSRC system must remain on after coming to a stop. If the testing takes longer than an hour to complete or the system is turned off, a new trail of breadcrumbs must be established.

## HOST VEHICLE BRAKING

Unless required by the test, the driver of the HVT shall not press the brake pedal when a warning is expected because most of the applications are designed to suppress the warnings once the vehicle brake status is on. Of course the driver should apply the brakes to avoid a collision should a dangerous situation arise.

## TEST FACILITY REQUIREMENTS

All tests shall be conducted in a closed facility (no public access or open roadways). To support the tests, the minimum requirements are:

- A straight road with at least three lanes and a length of 1200 meters.
- A curved road with at least three lanes with an inside curve radius that allows the conduction of the curve tests at the test speed. This curve should reflect curves normally found on freeways. A curve radius of larger than 250 meters is preferred.
- An intersection of two 2-lane roads that represent a normal stop controlled intersection.
- The approaches should be at least 150 meters in length. If such an intersection is not available at the test facility, it can be substituted by an intersection that is laid out by using cones on a flat area such as a parking lot or a Vehicle Dynamics Area (VDA) found on vehicle proving grounds.
- The width of the intersection box should be at least 7.2 meters, representing a lane width of 3.6 meters.

## CHAPTER 3. EVALUATION OF RESULTS

Collision alert test procedures are driving maneuvers involving two or more vehicles. These maneuvers are designed such that the countermeasure-equipped host vehicle (HVT) encounters situations that should trigger a collision alert for a countermeasure system that meets the minimum functional requirements. The significant data from each test run is a comparison of the position, velocity, and/or timing at which the collision alert onset actually occurred (if they occurred) and the position, velocity, and/or timing at which the alerts were required to occur.

Data analysis must evaluate and document the performance of the countermeasure for the required alerts. Due to the variations in range, velocity, and acceleration of the vehicles when performing maneuvers, the alert onset for each individual test run may vary. The nominal alert criteria should not be used as the pass/fail criteria for a test run. Rather, the alert criteria should be recomputed for each test run using the actual (achieved) range, velocity, and acceleration variables.

For example, a test procedure may specify a 60 mph speed for the HVT. The actual test run may report the HVT traveling at 58 mph rather than the nominal 60 mph. The 2 mph difference in speed may result in different alert criteria minimum and maximum for the test run. Instead of using the 60 mph nominal alert criteria values, the alert criteria values should be recomputed for the 58 mph speed to determine the pass/fail of the test run.

The computation of the test run alert criteria should be performed by the same mechanism that generated the original nominal alert criteria given in the test procedure. With the new alert criteria, pass/fail of the test run may be determined.

The maximum and minimum alert criteria are ± X percent of the nominal alert criteria. For example, if the alert criteria is the range at which the alert occurred, if X percent of the nominal alert range is less than 0.5 meters, the maximum and minimum alert ranges are the nominal alert range ± 0.5 meters.

(Note: Each test will have a different computed ± X percent based on possible alert criteria calculations that factors in tests conditions, system delays, and possible test runs failures.)

Alert onset for an individual run should not occur outside of the allowable alert range. If alert onset occurs between the minimum and maximum ranges specified by the computed values for the test run, the countermeasure passes the test run. The countermeasure must pass four out of five test runs for the test to be successful.

## CHAPTER 4. ELECTRONIC EMERGENCY BRAKE LIGHT TEST PROCEDURES

The operational goal of EEBL as defined in the Concept of Operations is to warn the driver of a hard braking event by a vehicle ahead in traffic, even when the driver's view is obstructed by other vehicles or bad weather conditions.

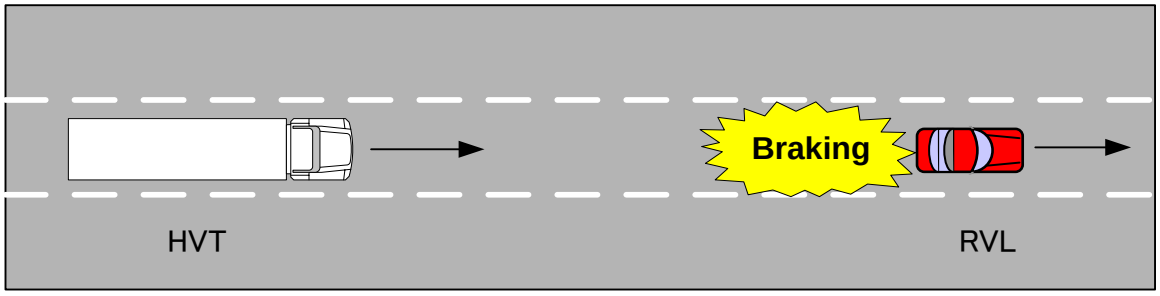
To pass this test, the system must warn the driver when one or more leading vehicles apply the brakes and decelerate at a level exceeding 0.4 g as called for in the CCV-RSD Safety Applications and Development Plan document. The following scenarios are selected to cover the typical EEBL cases with RVs in the same lane/left lane/right lane, traveling in the same direction ahead of the HVT. The 35 mph speed is selected as a moderate and appropriate speed for heavy trucks in closed course testing.

### EEBL-T1: HVT FOLLOWS BRAKING RVL

#### Purpose

This test will verify that the EEBL safety application issues a warning when the brakes of a vehicle in its forward path and direction of travel have been applied abruptly and the instantaneous braking of the RVL exceeds the braking threshold as defined by the application.

An illustration of this test procedure is shown in figure 1.




Source: MBRDNA and DENSO

**Figure 1. Illustration. HVT following braking RVL.**

#### Test Setup

- HVT.
- RVL.
- Test Surface: Skid pad.
- Lane of travel: any lane that has an escape lane on both sides of the lane of travel.

**Target Conditions**

- Both vehicle speeds of 35 mph.
- The headway between the HVT and RVL should be 8 seconds or greater.
- The RVL's deceleration shall start at 0.4 g or greater and ramp up to at least 0.5 g.

**Driving Instructions**

- The HVT and RVL exit the return loop of the skid pad and accelerate to 35 mph.
- While maintaining this approximate speed the drivers set a 3 second or greater headway between the vehicles.
- Once the test conductor confirms that the test speed and headway have been attained, the conductor instructs the driver of the RVL to begin braking.
- Once the HVT DVI issues or should have issued a warning, the test conductor instructs both drivers to cease braking and set up for another test run.

**Successful Criteria**

The HVT DVI issues a warning to the driver within the latency specified in the Minimum Performance Requirements (300 ms of EEBL Maximum Processing Latency + 300 ms Common Maximum warning Latency) for at least four out of five test runs.

**Unsuccessful Criteria**

The test is unsuccessful if the warning is not issued or is issued outside the time range specified in the Successful Criteria for two or more out of five test runs.

**Evaluation Criteria**

| Number of Valid Test Runs | HVT Speed (mph) | RV Speed (mph) | Number of Successful Test Runs |
|---|---|---|---|
| 5 | 35 | 35 | $\geq 4$ |

**Test Results**

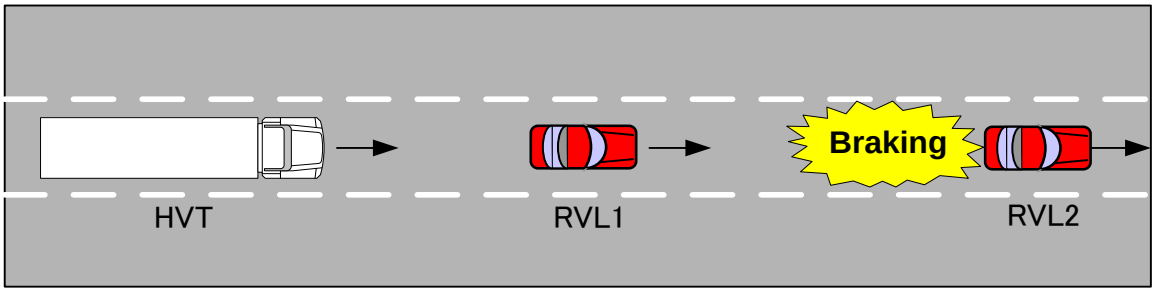
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the EEBL-T1 Success and Evaluation Criteria for at least four out of five test runs | | |

## EEBL-T2: HVT FOLLOWS RVL THAT FOLLOWS BRAKING RVL

### Purpose

This test will verify that the EEBL safety application issues a warning when the brakes of a vehicle in its forward path and direction of travel have been applied in an abrupt manner and there is a non-braking vehicle positioned between the HVT and the braking vehicle. This test can be used to verify EEBL performance in the presence of obstructing vehicles and/or adverse weather conditions.

An illustration of this test procedure is shown in figure 2.




Source: MBRDNA and DENSO

**Figure 2. Illustration. HVT following RVL1 following RVL2.**

### Test Setup

- HVT.
- RVL1 & RVL2.
- Test Surface: skid pad.
- Lane of travel: any lane with an escape lane to the left and right of the lane of travel.

### Target Conditions

- All three vehicle speeds of 35 mph.
- The headway between the HVT and RVL1 should be 3 seconds or greater.
- The longitudinal path distance between HVT and RVL2 shall be less than 300m.
- The headway between RVL1 and RVL2 should be 2 seconds or greater.
- The RVL2's deceleration shall start at 0.4 g or greater and ramp up to at least 0.5 g.

### Driving Instructions

- The HVT and RVL exit the return loop of the skid pad and accelerate to 35 mph.
- While maintaining this approximate speed, the HVT and RVL1 drivers set their respective headway between the leading vehicles.
- All three vehicles drive in the same lane.

- Once the test conductor confirms that the speeds and headways have been attained, the conductor instructs the driver of the RVL2 to begin braking.
- Once the HVT DVI issues or should have issued a warning, the test conductor instructs the drivers to cease braking and set up for another test run.

**Successful Criteria**

The HVT DVI issues a warning to the driver within the maximum latency as specified in the Minimum Performance Requirements (300 ms of EEBL Maximum Processing Latency + 300 ms Common Maximum warning Latency) for at least four out of five test runs.

**Unsuccessful Criteria**

The test is unsuccessful if the warning is missed or issued outside the time range specified in the successful criteria for two or more out of five test runs.

**Evaluation Criteria**

| Number of Valid Test Runs | HVT Speed (mph) | RV Speed (mph) | Number of Successful Test Runs |
|---|---|---|---|
| 5 | 35 | 35 | $\geq 4$ |

**Test Results**

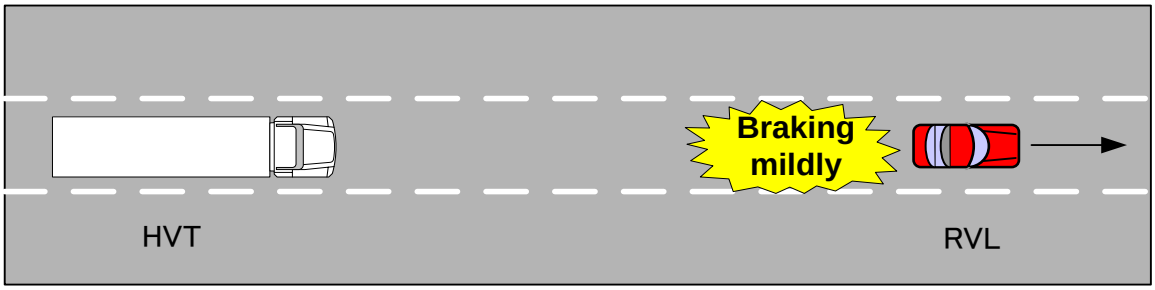
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the EEBL-T2 Success and Evaluation Criteria for at least four out of five test runs | | |

**EEBL-T3: HVT FOLLOWS MILD-BRAKING RVL**

**Purpose**

This test will verify that the EEBL safety application does NOT issue a warning when the brakes of a vehicle inside of the HVT's forward-path (including immediate adjacent lanes) traveling in the same direction have been applied below the threshold set for the activation of the EEBL event.

An illustration of this test procedure is shown in figure 3.




Source: MBRDNA and DENSO

**Figure 3. Illustration. HVT following mildly braking RVL.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: Skid pad.
- Lane of travel: any lane that has an escape lane on both sides of the lane of travel.

**Target Conditions**

- Both vehicle speeds of 35 mph.
- The headway between the HVT and RVL should be 3 seconds or greater.
- The RVL's deceleration shall be less than 0.4 g.

**Driving Instructions**

- The HVT and RVL exit the return loop of the skid pad and accelerate to 35 mph.
- While maintaining this approximate speed the drivers set a 3 second or greater headway between the vehicles.
- Once the test conductor confirms that the test speed and headway have been attained, the conductor instructs the driver of the RVL begin braking.
- Once the HVT DVI issues or should have issued a warning the test conductor instructs the drivers to cease braking and set up for another test run.

**Successful Criteria**

The test is successful if no EEBL Warning is observed (deceleration was less than 0.4 g).

**Unsuccessful Criteria**

The test is unsuccessful if an EEBL warning is observed from this test and deceleration was less than 0.4 g.

**Evaluation Criteria**

| Number of Valid Test Runs | HVT Speed (mph) | RV Speed (mph) | Number of Successful Test Runs |
|---|---|---|---|
| 2 | 35 | 35 | 2 |

**Test Results**

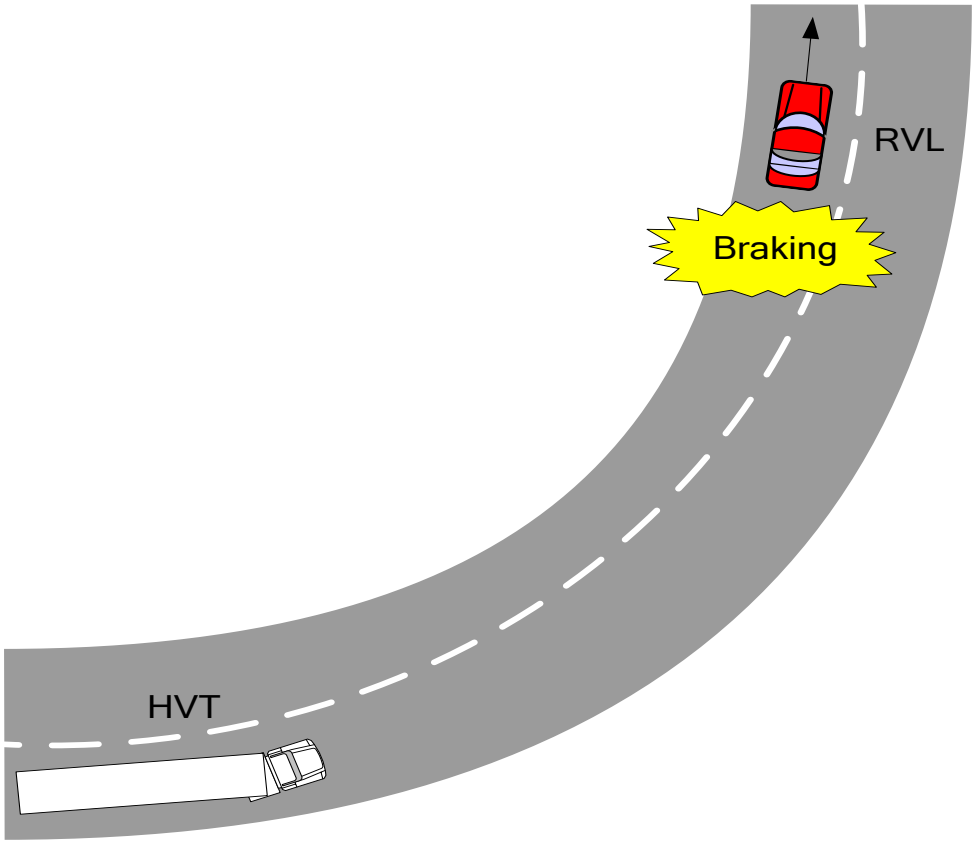
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the EEBL-T3 Success and Evaluation Criteria for all test runs | | |

**EEBL-T4: HVT PASSES RVL BRAKING IN ADJACENT LANE IN A CURVE**

**Purpose**

This test will verify that the EEBL safety application issues an Inform on a curved road when a vehicle traveling in front of and the same direction in the adjacent left lane applies its brakes in an abrupt manner. The EEBL is expected to issue an Inform for vehicles in the same lane and in adjacent lanes.

An illustration of this test procedure is shown in figure 4.




Source: MBRDNA and DENSO

**Figure 4. Illustration. HVT passing braking RVL in adjacent lane on curve.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: coned curve on the VDA or the high speed test track.
- Lane of travel: The RVL one lane to the left of the HVT.

**Target Conditions**

- Both vehicle speeds of 35 mph.
- The headway between the HVT and RVL should be 3 seconds or greater.
- The RVL's deceleration shall start at 0.4 g or greater and ramp up to at least 0.5 g.

**Driving Instructions**

- The HVT and RVL exit the return loop of the VDA and accelerate to 35 mph.
- The HVT drives in the right lane and the RVL in the left lane.
- While maintaining this approximate speed the drivers set a 3 second or greater headway between the vehicles.
- Once the test conductor confirms that the speeds and headway have been attained and the vehicles are in the curve the conductor instructs the driver of the RVL to begin braking.
- Once the HVT DVI issues or should have issued a warning the test conductor instructs the drivers to cease braking and set up for another test run.

**Successful Criteria**

HVT DVI issues an Inform to the driver within the maximum latency as specified in the Minimum Performance Requirements (300 ms of EEBL Maximum Processing Latency + 300 ms Common Maximum warning Latency) for at least four out of five test runs.

**Unsuccessful Criteria**

The test is unsuccessful if the Inform is missed or issued outside the time range specified in the successful criteria, or if a Warning is received for two or more out of five test runs.

**Evaluation Criteria**

| Number of Valid Test Runs | HVT Speed (mph) | RV Speed (mph) | Number of Successful Test Runs |
|---|---|---|---|
| 5 | 35 | 35 | $\geq 4$ |

**Test Results**

| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the EEBL-T4 Success and Evaluation Criteria for at least four out of five test runs | | |

## CHAPTER 5. FORWARD COLLISION WARNING TEST PROCEDURES

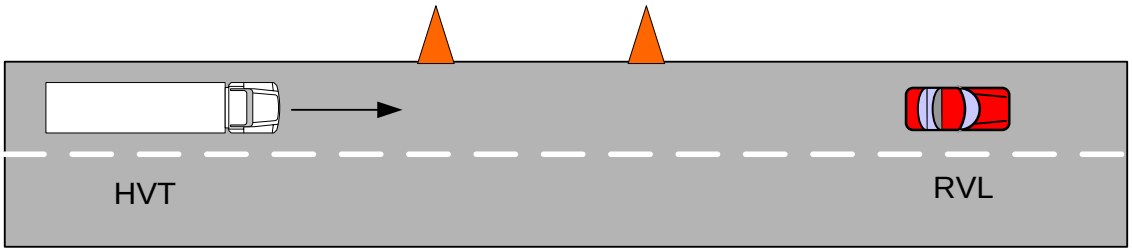
Forward Collision Warning (FCW) is a V2V communication based safety feature that issues a warning to the driver of the HVT in case of an impending rear-end collision with a vehicle ahead in traffic in the same lane and direction of travel. FCW will help drivers in avoiding or mitigating rear-end vehicle collisions in the forward path of travel.

### FCW-T1: HVT APPROACHES STOPPED RVL

#### Purpose

This test will verify that the FCW safety application issues a warning when there is a stopped vehicle in the same lane of travel. The test determines whether the application's collision alert occurs at the expected range. This test will verify the ability of the system to accurately identify stationary in-path targets on a flat, straight road.

An illustration of this test procedure is shown in figure 5.




Source: MBRDNA and DENSO

**Figure 5. Illustration. HVT approaching stopped RVL.**

#### Test Setup

- HVT.
- RVL.
- Test Surface: Skid pad.
- Lane of travel: any lane that has an escape lane on both sides of the lane of travel.
- The first cone is placed at the earliest valid HVT WARN point.
- A second cone is placed at 90 percent of the allowable alert range.
- RVL needs to establish a breadcrumb trail before stopping.

#### Target Conditions

- RVL speed of 35 mph prior to stopping.
- HVT speed of 35 mph.

**Driving Instructions**

- The RVL will exit the return loop and drive in the lane of travel sufficiently far loop to allow the HVT to reach the test speed in steady state and then stop.
- The HVT exits the return loop of the skid pad and accelerates to the test speed in the same lane as the RVL.
- The HVT will change out of the lane at the second cone.
- After the lane change the HVT will set up for another test run.

**Successful Criteria**

HVT DVI issues a warning to the driver within the ranges specified in table 4 for at least four out of five test runs.

**Unsuccessful Criteria**

A run is unsuccessful if any of the conditions below occur:

- The alert was given before the first cone was reached by the HVT.
- The alert was given after the second cone was passed by the HVT.
- No alert was given.

If at least two runs out of five runs fail, the test is Unsuccessful.

**Table 4. Alert Range for FCW-T1.**

| | **Collision Alert Test** |
|---|---|
| Maximum Range | 93.7 m |
| Nominal Range | 85.2 m |
| Minimum Range | 76.7 m |

Source: MBRDNA and DENSO

**Evaluation Criteria**

| **Number of Valid Test Runs** | **HVT Speed (mph)** | **RVL Speed (mph)** | **Number of Successful Test Runs** |
|---|---|---|---|
| 5 | 35 | 0 | $\geq 4$ |

**Test Results**

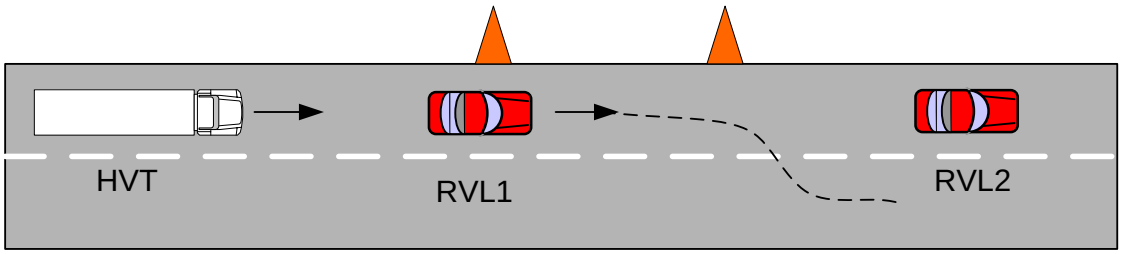
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the FCW-T1 Success and Evaluation Criteria for at least four out of five test runs | | |

**FCW-T2: HVT FOLLOWS RVL THAT IS APPROACHING STOPPED RVL**

**Purpose**

This test will verify that the FCW safety application issues a warning when there is a stopped vehicle in the same lane of travel and there is an obstructing RVL between them. This test will verify that the FCW alert occurs at the expected time even when switching primary targets.

An illustration of this test procedure is shown in figure 6.




Source: MBRDNA and DENSO

**Figure 6. Illustration. HVT following RVL1 that is approaching stopped RVL2.**

**Test Setup**

- HVT.
- RVL1 and RVL2.
- Test Surface: Skid pad.
- Lane of travel: any lane that has an escape lane on both sides of the lane of travel.
- The first cone is placed at the earliest valid HVT warn point.
- A second cone is placed at 90 percent of the allowable alert range.
- RVL2 needs to establish a breadcrumb trail before parking.

**Target Conditions**

- RVL2 speed of 35 mph prior to stopping.
- HVT and RVL1 speed of 35 mph.

**Driving Instructions**

- The RVL2 exits the return loop and drives sufficiently far to allow the HVT and RVL1 to achieve the test speed in steady state and then stops.
- HVT and RVL1 exit the return loop of the skid pad and accelerate to 35 mph in the same lane as RVL2.
- The RVL1 will change out of the lane after the first cone and before the second cone.
- The HVT will change out of the lane at the second cone.
- After the lane change the HVT and RVL1 will set up for another test run.

**Successful Criteria**

HVT DVI issues a warning to the driver within the ranges specified in table 5 for at least four runs out of five runs.

**Unsuccessful Criteria**

A run fails if any of the conditions below occur:

- The alert was given before the first cone was reached by the HVT.
- The alert was given after the second cone was passed by the HVT.
- No alert was given.

The test fails if at least two runs out of five runs fail.

**Table 5. Alert Range for FCW-T2.**

| | **Collision Alert Test** |
|---|---|
| Maximum Range | 93.7 m |
| Nominal Range | 85.2 m |
| Minimum Range | 76.7 m |

Source: MBRDNA and DENSO

**Evaluation Criteria**

| Number of Valid Test Runs | HVT Speed (mph) | RVL1 Speed (mph) | RVL2 Speed (mph) | Number of Successful Test Runs |
|---|---|---|---|---|
| 5 | 35 | 35 | 0 | ≥ 4 |

**Test Results**

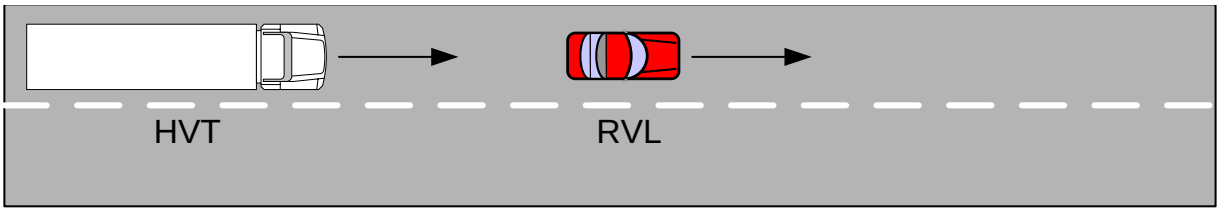
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the FCW-T2 Success and Evaluation Criteria for at least four out of five test runs | | |

**FCW-T3: HVT TAILGATES RVL**

**Purpose**

This test will verify that the FCW safety application will NOT issue a warning when closely following another vehicle in steady state driving.

An illustration of this test procedure is shown in figure 7.




Source: MBRDNA and DENSO

**Figure 7. Illustration. HVT tailgating RVL.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: Skid pad.
- Lane of travel: any lane that has an escape lane on both sides of the lane of travel.

**Target Conditions**

- HVT and RVL speed of 35 mph.
- Headway between HVT and RVL of 1.0 second.

**Driving Instructions**

- HVT and RVL exit the return loop of the skid pad and accelerate to 35 mph.
- The RVL sets it's cruise control and radios the test conductor.
- The HVT will reduce the headway to 1.0 second.
- The vehicles will drive in formation for 2.0 seconds.
- The vehicles will split apart and then get in position for another test run.

**Successful Criteria**

The test is Successful if no FCW Warnings are observed during the 2.0 seconds that the vehicles drive in formation.

**Unsuccessful Criteria**

The test is Unsuccessful if any FCW Warnings are observed during the 2.0 seconds that the vehicles drive in formation.

**Evaluation Criteria**

| Number of Valid Test Runs | HVT Speed (mph) | RVL Speed (mph) | Number of Successful Test Runs |
|---|---|---|---|
| 2 | 35 | 35 | 2 |

**Test Results**

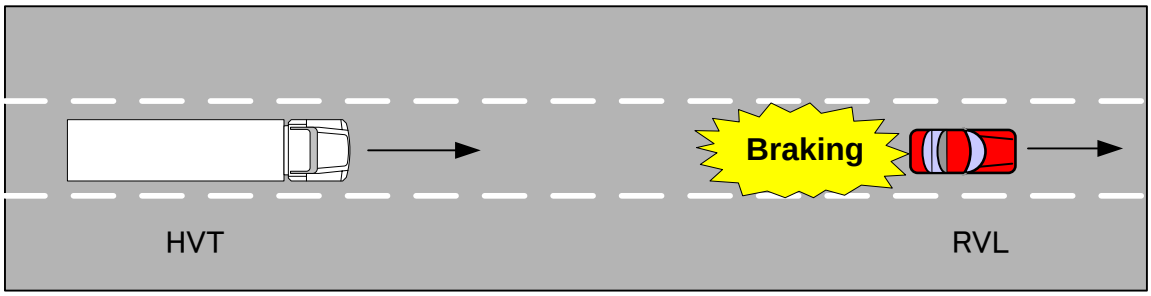
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the FCW-T3 Success and Evaluation Criteria for at least four out of five test runs | | |

## FCW-T4: HVT FOLLOWS BRAKING RVL

### Purpose

This test will verify that the FCW alert occurs at an expected range after the RVL brakes heavily. This test will verify the ability of the system to issue a timely warning in response to a lead vehicle braking heavily.

An illustration of this test procedure is shown in figure 8.




Source: MBRDNA and DENSO

**Figure 8. Illustration. HVT following braking RVL.**

### Test Setup

- HVT.
- RVL.
- Test Surface: Skid pad.
- Lane of travel: any lane that has an escape lane on both sides of the lane of travel.

### Target Conditions

- HVT and RVL speed of 35 mph.
- Headway between HVT and RVL of 4.0 seconds.
- The RVL's deceleration shall start at 0.2 g and quickly ramp up to at least 0.4 g.

### Driving Instructions

- HVT and RVL exit the return loop of the skid pad and accelerate to 35 mph.
- The RVL sets it's cruise control and radios the test conductor.
- The HVT will reduce the headway to 4.0 seconds.
- The vehicles will drive in formation for 2.0 seconds.
- The RVL will radio the test conductor and then begin braking.

- The HVT will change lanes after receiving the warning or after the warning should have been given.
- The vehicles will then move into position for another test run.

**Successful Criteria**

HVT DVI issues a warning to the driver within the ranges specified in table 6 for at least four out of five runs.

**Unsuccessful Criteria**

A run fails if any of the conditions below occur:

- The warning was given outside the ranges calculated in table 6 using run-specific variables.
- No alert was given.

The test fails if at least two runs out of five runs fail.

**Table 6. Alert Range for FCW-T4.**

| | **Collision Alert Test** |
|---|---|
| Maximum Range | 57.5 m |
| Nominal Range | 52.3 m |
| Minimum Range | 47.1 m |

Source: MBRDNA and DENSO

**Evaluation Criteria**

| **Number of Valid Test Runs** | **HVT Speed (mph)** | **RVL Speed (mph)** | **Headway** | **Number of Successful Test Runs** |
|---|---|---|---|---|
| 5 | 35 | 35 | 4 sec | ≥ 4 |

**Test Results**

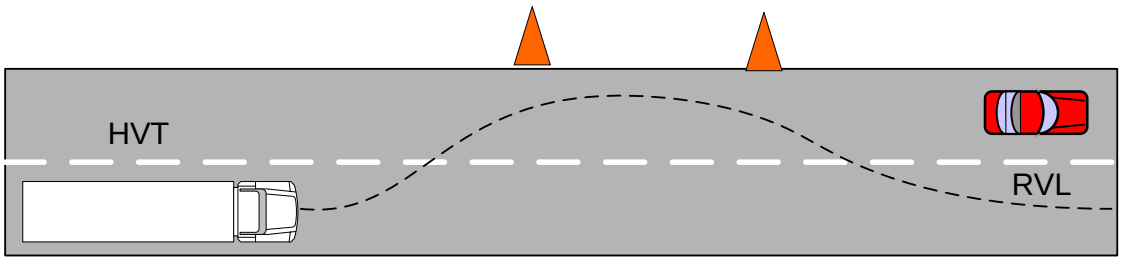
| **Test Step** | **Test Action** | **Actual Result** | **Test Status Pass/Fail** |
|---|---|---|---|
| 1 | Test meets the FCW-T4 Success and Evaluation Criteria for at least four out of five test runs | | |

## FCW-T5: HVT CHANGES LANES BEHIND STOPPED RVL

### Purpose

This test will verify that the FCW alert occurs at a range that is consistent with the expected range. This test also verifies the ability of the FCW safety application to issue a timely warning during a lane change on a straight roadway.

An illustration of this test procedure is shown in figure 9.




Source: MBRDNA and DENSO

**Figure 9. Illustration. HVT changing lanes behind stopped RVL.**

### Test Setup

- HVT.
- RVL.
- Test Surface: Skid pad.
- Lane of travel: any lane that has an escape lane on both sides of the lane of travel.
- The first cone will be placed at 110 percent the maximum warning distance given in table 7.
- The second cone will be placed at 90 percent of the minimum warning distance given in table 7.
- The RVL must establish a breadcrumb trail before parking.

### Target Conditions

- HVT speed of 35 mph.

### Driving Instructions

- The RVL exits the return loop and drives in the left lane sufficiently far to allow the HVT to achieve the test speed in steady state and then parks.
- The HVT exits the return loop and accelerates to the test speed in the right lane.
- The HVT will change lanes behind the RVL before reaching the first cone.

- The HVT will change lanes to the original lane after the second cone.
- The HVT will then move into position for another test run.

**Successful Criteria**

HVT DVI issues a warning to the driver within the ranges specified in table 7 for at least four out of five runs.

**Unsuccessful Criteria**

A run fails if any of the conditions below occur:

- The warning was given outside the ranges calculated in table 7 using run-specific variables.
- The warning is missed such that the HVT passes the second cone and no alert is triggered.

The test fails if at least two runs out of five runs fail.

**Table 7. Alert Range for FCW-T5.**

| | **Collision Alert Test** |
|---|---|
| Maximum Range | 93.7 m |
| Nominal Range | 85.2 m |
| Minimum Range | 76.7 m |

Source: MBRDNA and DENSO

**Evaluation Criteria**

| **Number of Valid Test Runs** | **HVT Speed (mph)** | **RVL Speed (mph)** | **Number of Successful Test Runs** |
|---|---|---|---|
| 5 | 35 | 0 | $\geq 4$ |

**Test Results**

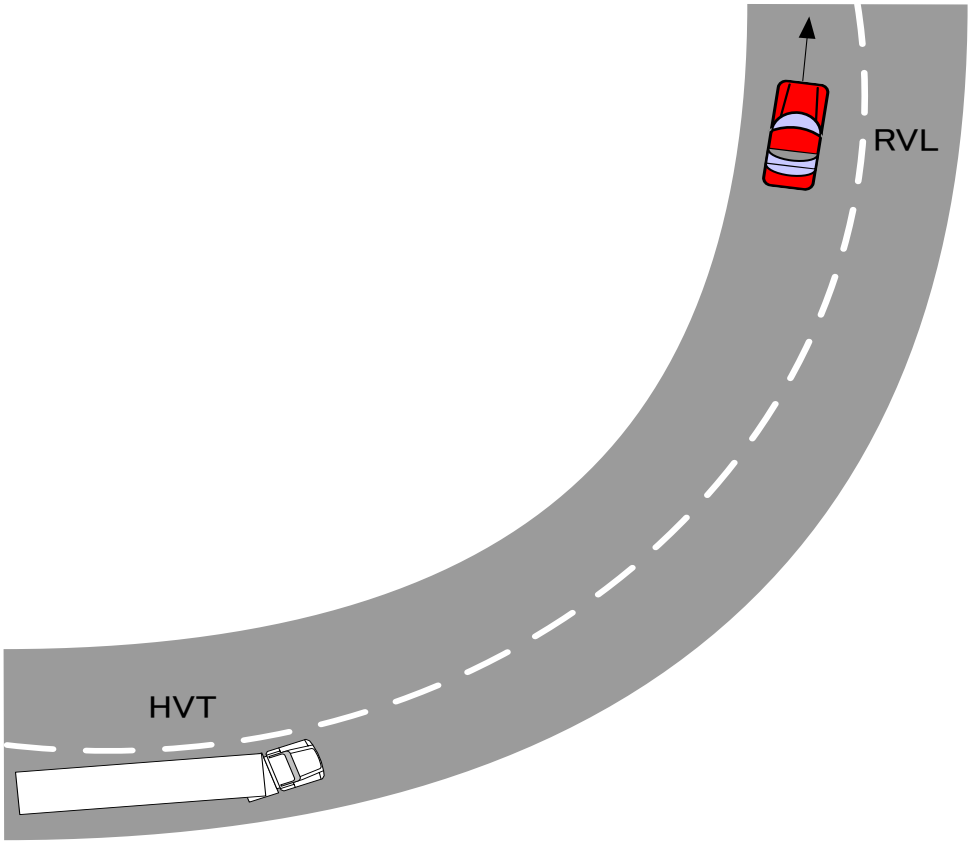
| **Test Step** | **Test Action** | **Actual Result** | **Test Status Pass/Fail** |
|---|---|---|---|
| 1 | Test meets the FCW-T5 Success and Evaluation Criteria for at least four out of five test runs | | |

**FCW-T6: HVT PASSES RVL STOPPED IN A CURVE**

**Purpose**

This test will verify that the system can determine that a RVL is not in the lane of travel of the HVT in a curve. No collision alert should be given when there are no FCW threats in the HVT path.

An illustration of this test procedure is shown in figure 10.




Source: MBRDNA and DENSO

**Figure 10. Illustration. HVT passing a stopped RVL in a curve.**

**Test Set Up**

- HVT.
- RVL.
- Test Surface: VDA.
- Lane of travel: coned or painted curves on the VDA that has an escape on both sides of the lane of travel.

- All vehicles will be well into the curve of 233 meter radius.
- The RVL must establish a breadcrumb trail before parking.

**Target Conditions**

- HVT speed of 35 mph.

**Driving Instructions**

- The RVL exits the return loop and drives in the left lane sufficiently far to allow the HVT to achieve the test speed in steady state and then parks.
- The HVT exits the return loop and accelerates to the test speed in the right lane.
- The HVT passes the parked RVL at the test speed.
- The HVT will then move into position for another test run.

**Successful Criteria**

The test is Successful if no FCW Warnings are observed.

**Unsuccessful Criteria**

The test is Unsuccessful if any FCW Warnings are observed.

**Evaluation Criteria**

| Number of Valid Test Runs | HVT Speed (mph) | RVL Speed (mph) | Number of Successful Test Runs |
|---|---|---|---|
| 2 | 35 | 0 | 2 |

**Test Results**

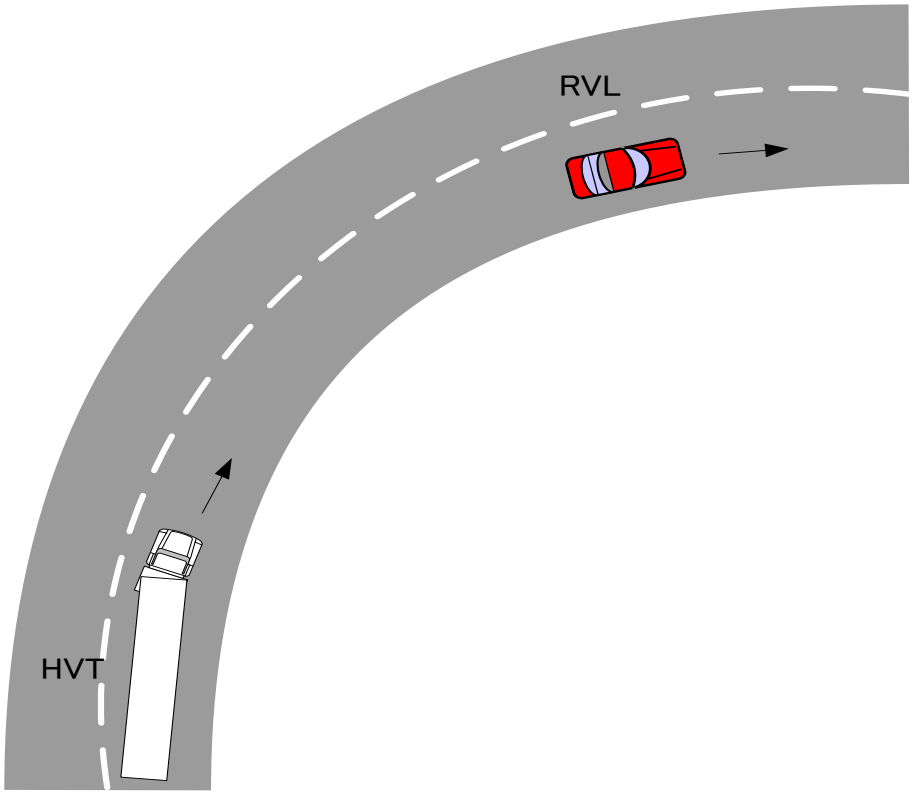
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the FCW-T6 Success and Evaluation Criteria for at least four out of five test runs | | |

## FCW-T7: HVT APPROACHES RVL STOPPED IN A CURVE

### Purpose

This test will verify that the FCW alert occurs at the expected range while approaching a stopped vehicle in a curve. This test will verify the ability of the system to accurately identify stationary in-path targets in a curve and generate a warning at the expected range.

An illustration of this test procedure is shown in figure 11.




Source: MBRDNA and DENSO

**Figure 11. Illustration. HVT approaching RVL stopped in a curve.**

### Test Setup

- HVT.
- RVL.
- Test Surface: VDA.
- All vehicles will be well into the curve of 233 meter radius.
- Lane of travel: coned or painted curve on the VDA that has an escape on both sides of the lane of travel.
- The RVL must establish a breadcrumb trail before parking.

**Target Conditions**

- HVT speed of 35 mph.

**Driving Instructions**

- The RVL exits the return loop and drives in the right lane sufficiently far to allow the HVT to achieve the test speed in steady state and then parks in the curve.
- The HVT exits the return loop and accelerates to the test speed in the right lane.
- The HVT changes lanes after the minimum range for the warning has passed.
- The HVT will then move into position for another test run.

**Successful Criteria**

HVT DVI issues a warning to the driver within the ranges specified in table 8 for at least four runs out of five runs.

**Unsuccessful Criteria**

A run fails if any of the conditions below occur:

- The Warning occurs outside the range calculated in table 8 using run-specific variables.
- The warning is missed such that the HVT passes the minimum range given in table 8 (using run-specific variables) and no alert is triggered.

The test fails if at least two out of five runs fail.

**Table 8. Alert Range for FCW-T7.**

| | **Collision Alert Test** |
|---|---|
| Maximum Range | 93.7 m |
| Nominal Range | 85.2 m |
| Minimum Range | 76.7 m |

Source: MBRDNA and DENSO

**Evaluation Criteria**

| **Number of Valid Test Runs** | **HVT Speed (mph)** | **RVL Speed (mph)** | **Number of Successful Test Runs** |
|---|---|---|---|
| 5 | 35 | 0 | ≥ 4 |

**Test Results**

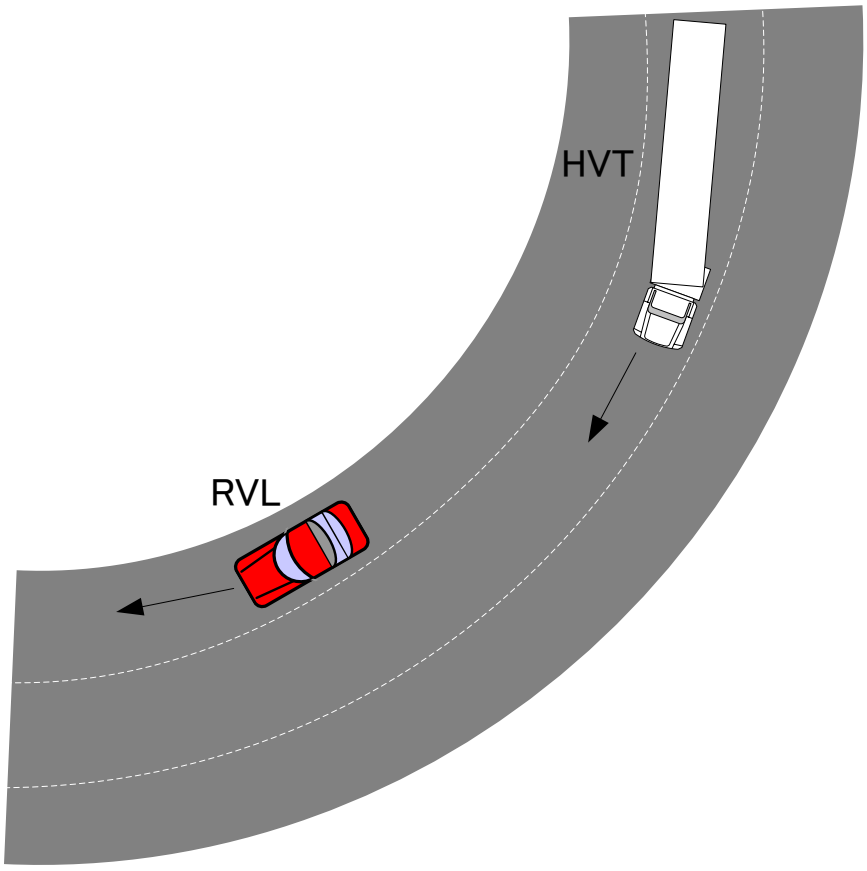
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the FCW-T7 Success and Evaluation Criteria for at least four out of five test runs | | |

**FCW-T8: HVT PASSES MOVING RV IN ADJACENT LANE IN A CURVE**

**Purpose**

This test verifies that the system can determine that an RVL is not in the lane of travel of the HVT even though the articulated vehicles take up more of the lane width in a curve than in a straight section of road.

An illustration of this test procedure is shown in figure 12.




Source: MBRDNA and DENSO

**Figure 12. Illustration. HVT passing moving RVL in adjacent lane in a curve.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: VDA.
- Lane of travel: coned or painted curve on the VDA that has an escape on both sides of the lane of travel.
- All vehicles will be well into the curve of 233 meter radius.
- The RVL must establish a breadcrumb trail before parking.

**Target Conditions**

- HVT speed of 35 mph.
- RVL speed of 30 mph.
- HVT passes RVL in the curve.

**Driving Instructions**

- The HVT and RVL exit the return loop with the RVL 3 seconds in front.
- The RVL enters the right lane.
- The HVT enters the left lane.
- The vehicles accelerate to their respective test speeds.
- The HVT passes RVL in the curve.
- The vehicles will then move into position for another test run.

**Successful Criteria**

The test is Successful if no FCW Warnings are observed.

**Unsuccessful Criteria**

The test is Unsuccessful if any FCW Warnings are observed.

**Evaluation Criteria**

| Number of Valid Test Runs | HVT Speed (mph) | RV Speed (mph) | Number of Successful Test Runs |
|---|---|---|---|
| 2 | 35 | 30 | 2 |

**Test Results**

| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the FCW-T8 Success and Evaluation Criteria for at least four out of five test runs | | |

## CHAPTER 6. BLIND SPOT AND LANE CHANGE WARNING TEST PROCEDURES

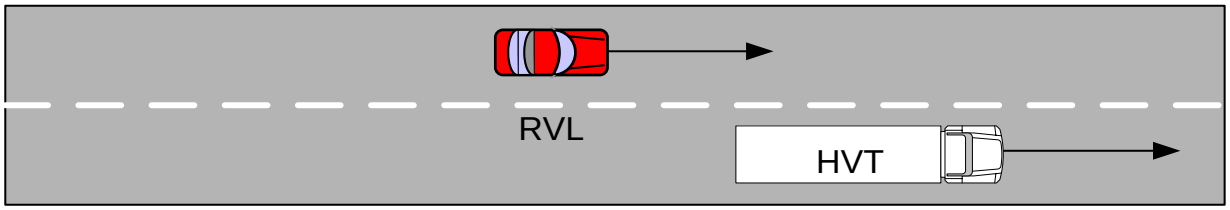
The Blind Spot Warning + Lane Change Warning (BSWLCW) application informs the driver when an RV occupies the HVT blind spot. For safety none of the vehicles will change lanes during these tests.

### BSWLCW-T1: RVL PASSES HVT WITH TRAILER ON LEFT

#### Purpose

This test is will verify the functionality of the BSWLCW safety application with the vehicles in adjacent lanes on a straight two or more lane road.

An illustration of this test procedure is shown in figure 13.




Source: MBRDNA and DENSO

**Figure 13. Illustration. RVL passing HVT on the left.**

#### Test Setup

- HVT.
- RVL.
- Test Surface: skid pad.
- Lane of travel: any two adjacent lanes.

#### Target Conditions

- HVT and speed of 30 mph.
- RVL speed of 35 mph.

#### Driving Instructions

- The HVT and RVL exit the return loop with the HVT 3 seconds in front.
- The RVL enters the left lane.
- The HVT enters the right lane.
- The vehicles accelerate to their respective test speeds.

- The RVL completes the pass of the HVT.
- The vehicles then move into position for another test run.

**Successful Criteria**

The HVT DVI Informs the driver that an RV is in the left blind zone when the RVL enters the blind zone, and this Inform disappears after the RVL has moved ahead of the HVT in at least four runs out of five runs.

**Unsuccessful Criteria**

The HVT DVI does not Inform the driver that an RV is in the left blind zone when the RVL is inside the HVT blind zone, or the Inform persists after the RVL has moved ahead of the HVT in at least two runs out of five runs.

**Evaluation Criteria**

| Number of Valid Test Runs | Number of Instances HVT Shows Left: | | Number of Successful Test Runs |
|---|---|---|---|
| | Inform | Warning | |
| 5 | ≥ 4 | 0 | ≥ 4 |

**Test Results**

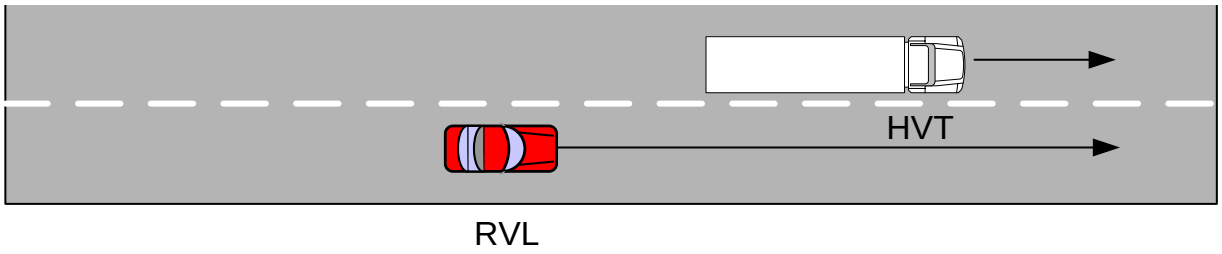
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the BSWLCW-T1 Success and Evaluation Criteria for at least four out of five test runs | | |

**BSWLCW-T2: RVL PASSES HVT WITH TRAILER ON RIGHT**

**Purpose**

This test will verify the functionality of the BSWLCW safety application with the vehicles in adjacent lanes on a straight two or more lane road.

An illustration of this test procedure is shown in figure 14.




Source: MBRDNA and DENSO

**Figure 14. Illustration. RVL passing HVT on the right.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: skid pad.
- Lane of travel: any two adjacent lanes.

**Target Conditions**

- HVT at speed of 30 mph.
- RVL speed of 35 mph.

**Driving Instructions**

- The HVT and RVL exit the return loop with the HVT 3 seconds in front.
- The RVL enters the right lane.
- The HVT enters the left lane.
- The vehicles accelerate to their respective test speeds.
- The RVL completes the pass of the HVT.
- The vehicles then move into position for another test run.

**Successful Criteria**

The HVT DVI Informs the driver that an RV is in the right blind zone when the RVL enters the blind zone, and this Inform disappears after the RVL has moved ahead of the HVT in at least four runs out of five runs.

**Unsuccessful Criteria**

The HVT DVI does not Inform the driver that an RV is in the right blind zone when the RVL is inside the HVT blind zone, or the Inform persists after the RVL has moved ahead of the HVT in at least two runs out of five runs.

**Evaluation Criteria**

| Number of Valid Test Runs | Number of Instances HVT Shows Right: | | Number of Successful Test Runs |
|---|---|---|---|
| | Inform | Warning | |
| 5 | ≥ 4 | 0 | ≥ 4 |

**Test Results**

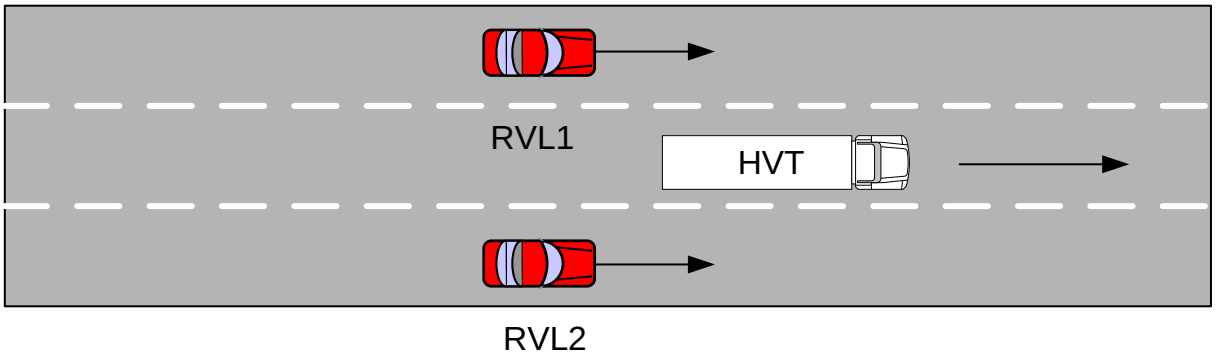
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the BSWLCW-T2 Success and Evaluation Criteria for at least four out of five test runs | | |

**BSWLCW-T3: TWO RVLS PASS HVT WITH TRAILER ON LEFT AND RIGHT**

**Purpose**

This test will verify the functionality of the BSWLCW safety application with three vehicles on a straight three or more lane road with two RVL's present.

An illustration of this test procedure is shown in figure 15.




Source: MBRDNA and DENSO

**Figure 15. Illustration. Two RVLs pass HVT on left and right.**

**Test Setup**

- HVT.
- RVL1 and RVL2.
- Test Surface: skid pad.
- Lane of travel: any three adjacent lanes.

**Target Conditions**

- HVT at speed of 30 mph.
- RVLs at speed of 35 mph.

**Driving Instructions**

- The HVT and both RVLs exit the return loop with the HVT 3 seconds in front.
- RVL1 enters the left lane.
- The HVT enters the center lane.
- RVL2 enters the right lane.
- The vehicles accelerate to their respective test speeds.
- The RVLs completes the pass of the HVT.
- The vehicles then move into position for another test run.

**Successful Criteria**

The HVT DVI activates a left and right Inform while RVL1 and RVL2 are occupying the left- and right-blind zones, and the HVT left and right Inform disappears after RVL1 and RVL2 have moved ahead of the HVT in at least four runs out of five runs.

**Unsuccessful Criteria**

The HVT DVI does not activate a left and right Inform while RVL1 and RVL2 are occupying the left- and right-blind zones, or the HVT left and right Inform persists after RVL1 and RVL2 have moved ahead of the HVT in at least two runs out of five runs.

**Evaluation Criteria**

| Number of Valid Test Runs | Number of Instances HVT Shows: | | | Number of Successful Tests |
|---|---|---|---|---|
| | Left Inform | Right Inform | Warning | |
| 5 | $\geq 4$ | $\geq 4$ | 0 | $\geq 4$ |

**Test Results**

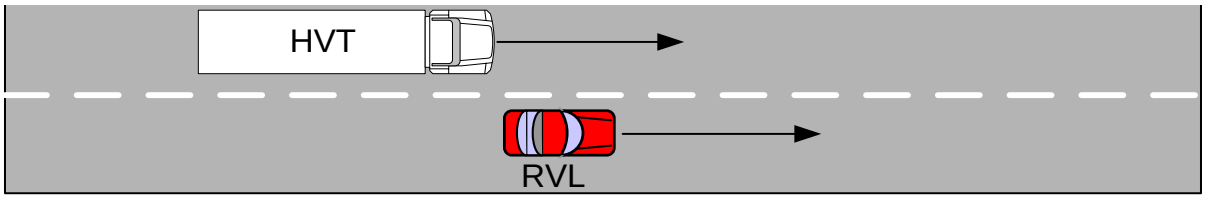
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the BSWLCW-T3 Success and Evaluation Criteria for at least four out of five test runs | | |

**BSWLCW-T4: HVT PASSES RVL ON THE LEFT AND PAUSES**

**Purpose**

This test will verify the functionality of the BSWLCW safety application with two vehicles on a straight two or more lane road. This test will verify that the extended CCV-RSD right side blind zone is working correctly.

An illustration of this test procedure is shown in figure 16.




Source: MBRDNA and DENSO

**Figure 16. Illustration. HVT passing RVL on the left and pausing.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: skid pad.
- Lane of travel: any two adjacent lanes.

**Target Conditions**

- HVT and RVL at speed of 35 mph.

**Driving Instructions**

- The HVT and RVL exit the return loop with the RVL 3 seconds in front.
- The RVL enters the right lane.

- The HVT enters the left lane.
- The vehicles accelerate to the test speed.
- The RVL activates cruise control and radios the test conductor.
- The HVT moves up until it's front bumper is slightly ahead of the RVL rear bumper.
- The vehicles then move into position for another test run.

**Successful Criteria**

The HVT DVI displays an Inform for the right front blind zone for at least four out of five runs.

**Unsuccessful Criteria**

The HVT DVI does not display an Inform when the RVL is in the right front blind zone for at least two out of five runs.

**Evaluation Criteria**

| Number of Valid Test Runs | Number of Instances HVT Shows Inform: | | Number of Successful Test Runs |
|---|---|---|---|
| | Left | Right | |
| 5 | 0 | $\geq 4$ | $\geq 4$ |

**Test Results**

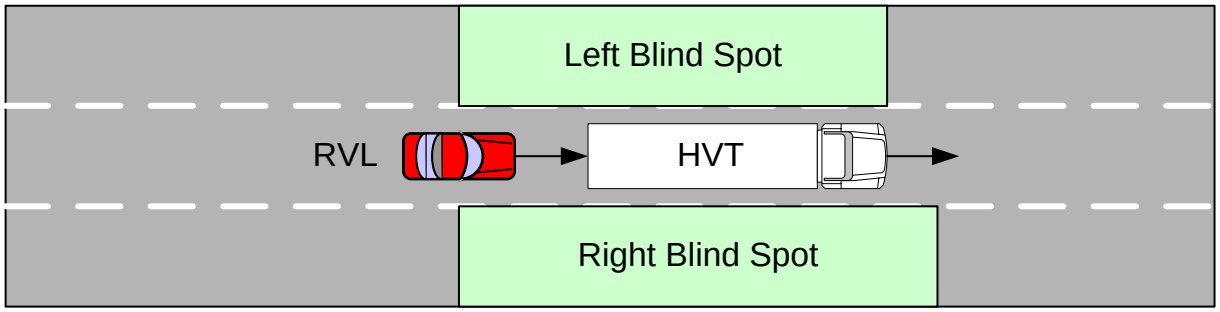
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the BSWLCW-T4 Success and Evaluation Criteria for at least four out of five test runs | | |

**BSWLCW-T5: RVL TAILGATES HVT**

**Purpose**

This test will verify the system can differentiate that a vehicle tailgating the HVT is not in an adjacent lane. No alert or warning should be displayed when a RV is following directly behind the HVT.

An illustration of this test procedure is shown in figure 17.




Source: MBRDNA and DENSO

**Figure 17. Illustration. RVL tailgating HVT.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: skid pad.
- Lane of travel: any three adjacent lanes.

**Target Conditions**

- HVT and RVL at speed of 30 mph.
- Single car length headway.

**Driving Instructions**

- The HVT and RVL exit the return loop with the HVT 1 second in front.
- The HVT and RVL enters the center lane.
- The vehicles accelerate to the test speed.
- The HVT activates its cruise control.
- The RVL closes the gap to 1 car length.
- The vehicles maintain this gap for 3 seconds.
- The vehicles then move into position for another test run.

**Successful Criteria**

The test is Successful if no BSWLCW Informs are observed.

**Unsuccessful Criteria**

The test is Unsuccessful if any BSWLCW Informs are observed.

**Evaluation Criteria**

| Number of Valid Test Runs | Number of Instances HVT Shows Inform or Warning | Number of Successful Test Runs |
|---|---|---|
| 2 | 0 | 2 |

**Test Results**

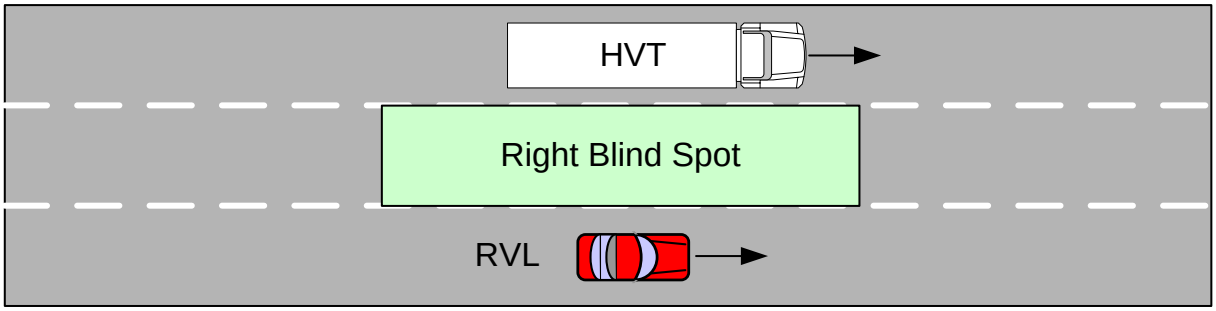
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the BSWLCW-T5 Success and Evaluation Criteria for at least four out of five test runs | | |

**BSWLCW-T6: HVT AND RVL DRIVE SEPARATED BY ONE LANE**

**Purpose**

This test will verify the system can accurately determine the RVL is not in the adjacent lane. No information or warning should be displayed when a RV is two or more lanes separated from the HVT.

An illustration of this test procedure is shown in figure 18.




Source: MBRDNA and DENSO

**Figure 18. Illustration. HVT and RVL separated by one lane.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: skid pad.
- Lane of travel: any three adjacent lanes.

**Target Conditions**

- HVT and RVL at speed of 35 mph.
- HVT and RVL drive in center of each lane.

**Driving Instructions**

- The HVT and RVL exit the return loop with minimal separation.
- The RVL enters the right lane.
- The HVT enters the left lane.
- The center lane is empty.
- The vehicles accelerate to the test speeds.
- The HVT adjusts its speed so the front bumpers of the vehicles are aligned.
- The vehicles maintain this position for 5 seconds.
- The vehicles then move into position for another test run.

**Successful Criteria**

The test is Successful if no BSWLCW Informs are observed.

**Unsuccessful Criteria**

The test is Unsuccessful if any BSWLCW Informs are observed.

**Evaluation Criteria**

| Number of Valid Test Runs | Number of Instances HVT Shows Inform or Warning | Number of Successful Test Runs |
|---|---|---|
| 2 | 0 | 2 |

**Test Results**

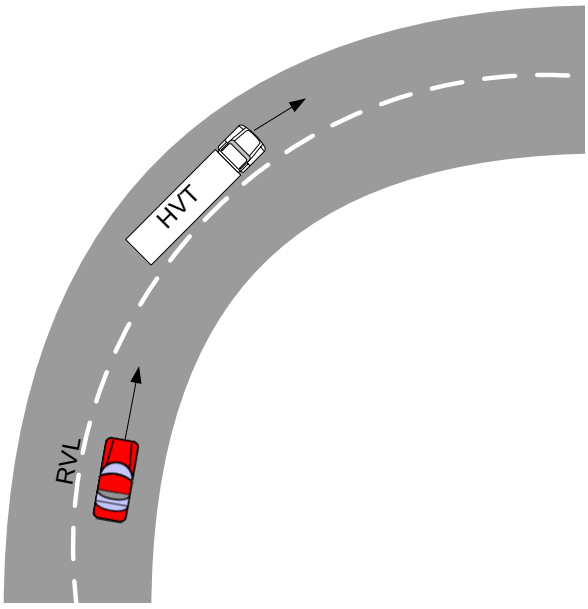
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the BSWLCW-T6 Success and Evaluation Criteria for at least four out of five test runs | | |

**BSWLCW-T7: RVL PASSES HVT IN A CURVE**

**Purpose**

This test will verify the functionality of the BSWLCW safety application with two vehicles on a curved two or more lane road.

An illustration of this test procedure is shown in figure 19.




Source: MBRDNA and DENSO

**Figure 19. Illustration. RVL passing HVT in a curve.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: VDA.
- Lane of travel: coned or painted curve on the VDA that has an escape on both sides of the lane of travel.
- All vehicles will be well into the curve of 233 meter radius during pass.

**Target Conditions**

- HVT speed of 30 mph.
- RVL speed of 35 mph.
- RVL passes HVT in the curve.

**Driving Instructions**

- The HVT and RVL exit the return loop with the HVT 1 second in front.
- The RVL enters the right lane.
- The HVT enters the left lane.
- The vehicles accelerate to their respective test speeds.
- The RVL passes HVT in the curve.
- The vehicles will then move into position for another test run.

**Successful Criteria**

The HVT DVI displays an Inform for the right blind zone when the RVL enters the blind zone and the Inform ends when the RVL has completed the pass in at least four out of five test runs.

**Unsuccessful Criteria**

The HVT DVI does not display an Inform for the right blind zone when the RVL is in the HVT blind zone, or the Inform persists after the RVL has completed the pass in at least two out of five test runs.

**Evaluation Criteria**

| Number of Valid Test Runs | Number of Instances HVT Shows: | | Number of Successful Test Runs |
|---|---|---|---|
| | Alert | Warning | |
| 5 | $\geq 4$ | 0 | $\geq 4$ |

**Test Results**

| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the BSWLCW-T7 Success and Evaluation Criteria for at least four out of five test runs | | |

# CHAPTER 7. INTERSECTION MOVEMENT ASSIST TEST PROCEDURES

The Intersection Movement Assist (IMA) is a V2V communication safety application that aims to prevent crashes at uncontrolled and stop sign controlled intersections for straight through traffic with intersecting paths. IMA does this by issuing a warning to the driver of the HVT in case a conflict is detected. The IMA presents two levels of alert. An Inform is presented to the driver if other vehicles are approaching and a potential conflict has been detected. A Warn is presented to the driver if a potential conflict has been detected and a crash is likely to occur if corrective action is not taken. Only warnings will be tested.

The tests fall into two general scenarios–the HVT stopped while the RV is moving, and both HVT and RV are moving. These tests will be conducted at a real intersection if available or a coned or painted intersection on the VDA. The test intersection will have clear sightlines between the RV and the HVT.

The distances for Inform and Warn are calculated in reference to the conflict point. The conflict point is the location in the intersection where the projected trajectories of the HVT and the RVL intersect.

## GENERAL DRIVING INSTRUCTIONS

The drivers conducting the tests will select the rates of acceleration, braking, and the starting and stopping points that allow the test to be conducted safely. Cruise control will be used to accurately maintain the HVT test speed. The drivers shall not touch the brake before the Warn is presented. If the driver touches the brake before the Warn is issued, the test is invalid.

## IMA-T1: VARIABLE SPEED APPROACHES WITH MOVING HVT AND RVL

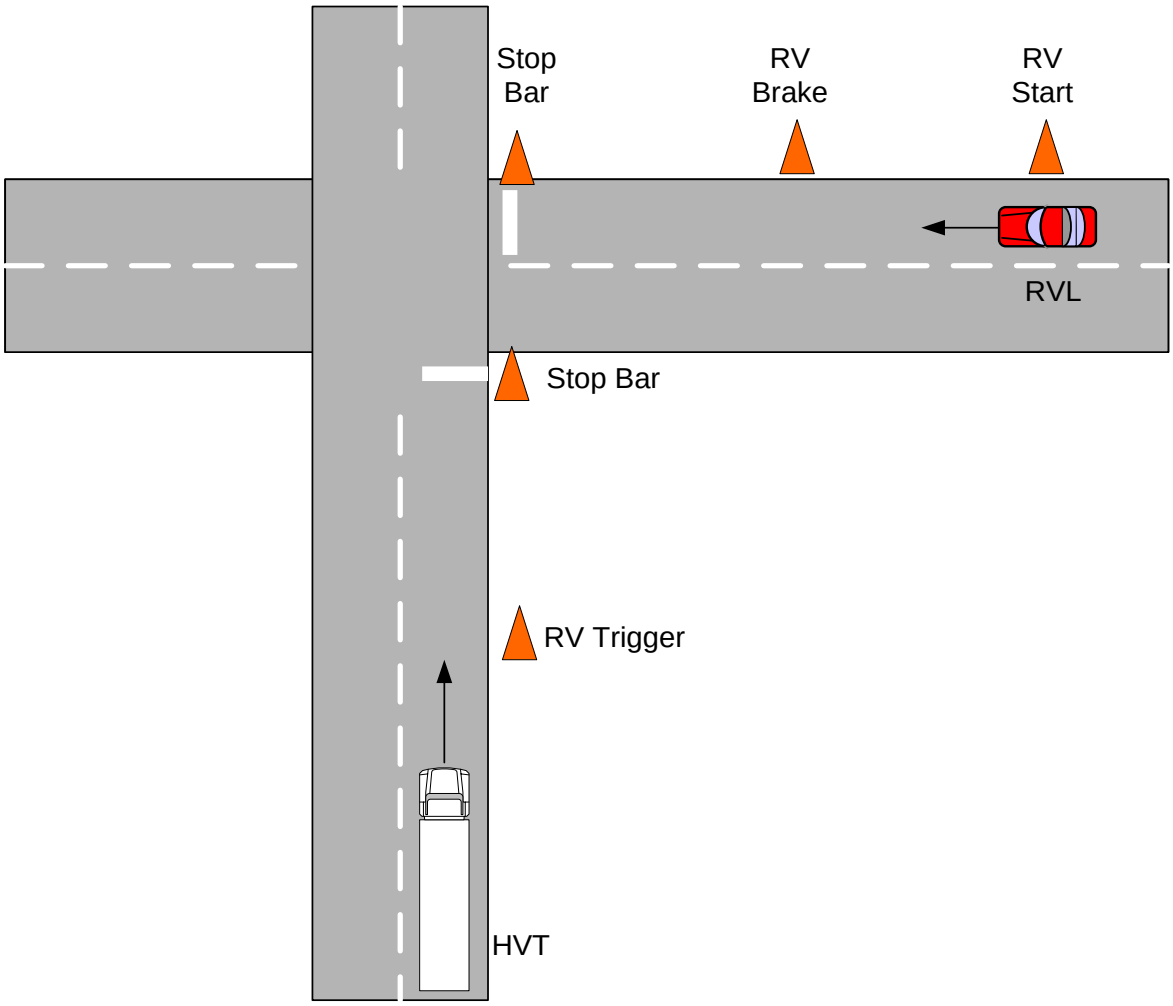
### Purpose

This test will verify that the IMA safety application issues a warning when both the HVT and the RVL are moving toward each other at an intersection. This situation is encountered at uncontrolled intersections.

In this scenario, the HVT is approaching the intersection at constant speeds of 15 and 30 mph. The RVL will also approach the intersection at speeds of 15 and 30 mph. After the HVT passes the Inform distance, the HVT will receive a Warn display.

This test is the most complicated test since the movement of two vehicles has to be coordinated. Therefore, it is recommended to extensively rehearse this test beforehand so that the test can be performed safely and repeatedly.

An illustration of this test procedure is shown in figure 20.




Source: MBRDNA and DENSO

**Figure 20. Illustration. Variable speed approaches with moving HVT and RVL.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: VDA.
- Lane of travel: coned or painted intersection on the VDA that has an escape on both sides of the lanes of travel and plenty of run off room.
- The intersecting roads will be at a 90 degree angle, with two 3.6m wide lanes crossing the lane of travel of the HVT.

Cones will be placed so the drivers are aware of the vehicle's location in reference to the intersection and the other vehicle. The cones will be located by the drivers during the practice sessions. Cone locations are:

- A cone is placed at the stop bar for both directions (labeled Stop Bar in the figure).
- A cone is placed at the starting point for the RVL (labeled RV Start).
- A trigger cone is placed at the point where when the HVT passes that the RVL should start into motion (labeled RV Trigger).
- A brake cone is placed where the RVL **must** brake to ensure the RVL easily stops before entering the intersection (labeled RV Brake).

**Cone Setting Procedure**

1. Set the stop bar cones.

2. Have the RVL approach the intersection several times at the test speed to establish the RV brake cone. This cone should be located where a sharply applied brake application (not limit braking) results in the RV stopping just short of the stop bar. This step needs to be repeated each time the RV approach speed changes.

3. Set the RV start cone so that the RV is at the test speed for at least 2 seconds before reaching the brake cone. This step needs to be repeated each time the RV test speed changes. This cone should be at least 150 meters from the stop bar so that the trail of breadcrumbs can be established.

4. Re-verify that both the start and stop cones are in the correct positions to allow safe and repeatable starting and stopping of the RV.

   NOTE: Begin the below step only after performing 3 verification tests at the particular RV test speed for each speed BEFORE performing the next step:

5. Have the HVT approach the intersection several times at the particular test speed to set the RV trigger cone so that the warnings are reliably generated.

**Target Conditions**

- HVT speed of 15 and 30 mph.
- RVL speed of 15 and 30 mph.

**Driving Instructions**

- The HVT exits the return loop and accelerates to the test speed.
- The HVT activates the cruise control.
- The RVL starts at the RV start cone when the HVT passes the trigger cone.

- The RVL brakes to a stop after passing the RV brake cone.
- The HVT passes through the intersection as the RVL stops.
- The vehicles will then move into position for another test run.

**Successful Criteria**

A Warning is presented to the HVT driver within maximum latency as specified in the Minimum Performance Requirements (500 ms) for positioning and speed errors.

**Unsuccessful Criteria**

A Warning message is not displayed on the HVT DVI, or the warning latency is outside the range specified in the Successful Criteria section for two or more runs.

**Evaluation Criteria**

| Number of Valid Test Runs | HVT Speed (mph) | RVL Speed (mph) | Number of Valid Runs | Warning Distance (m) | Number of Successful Test Runs |
|---|---|---|---|---|---|
| 2 | 15 | 15 | 2 | | |
| 2 | 30 | 15 | 2 | | |
| 2 | 15 | 30 | 2 | | |
| 2 | 30 | 30 | 2 | | |
| Total 8 (min) | | | | | Total ≥6 |

The vehicle speeds do not vary more than 5 mph from the target test speed. The test will be repeated until eight WARNs have been received to ensure that there have been eight valid runs. The data will be analyzed after the tests, and the first eight valid runs will be evaluated.

**Test Results**

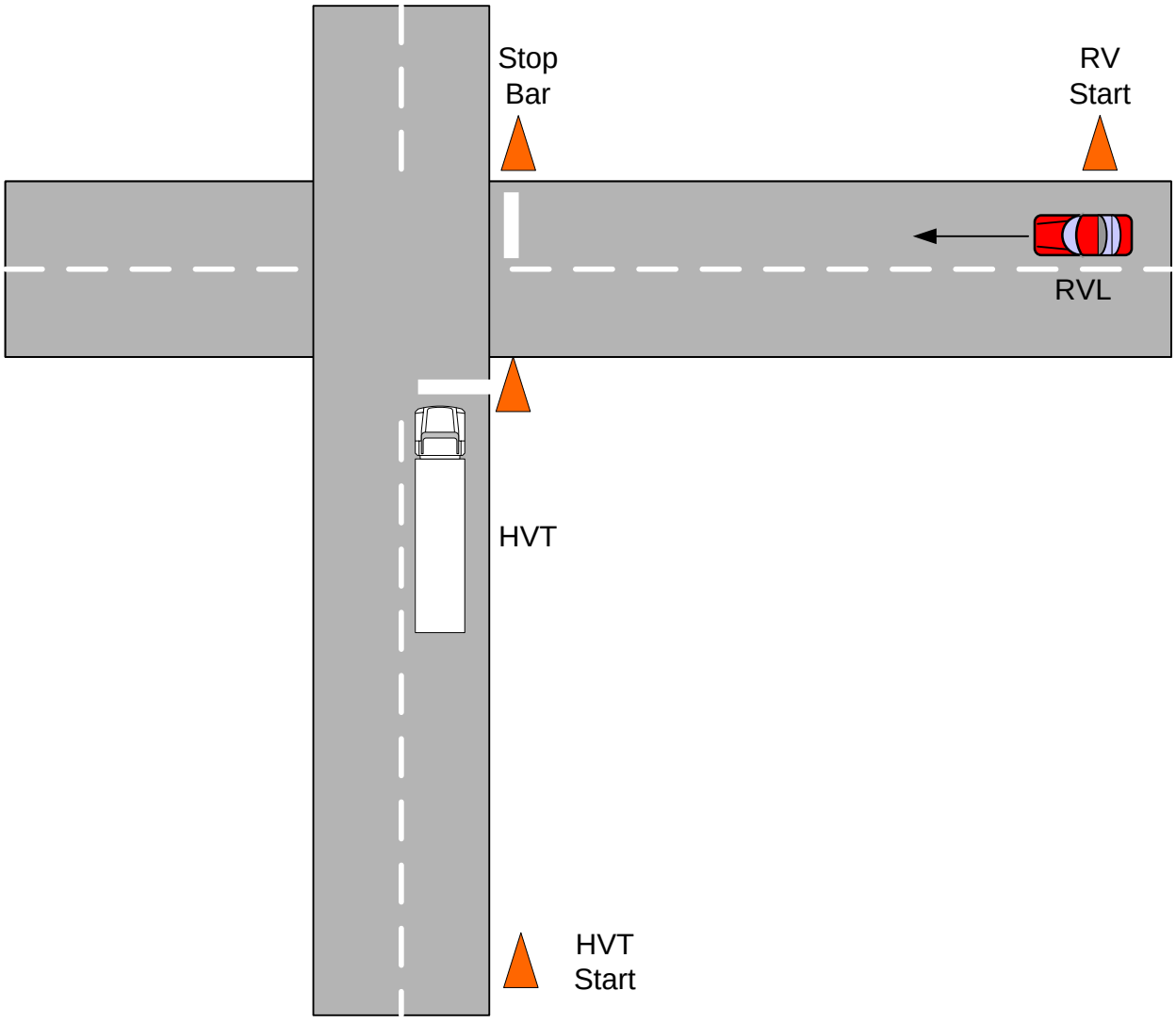
| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the IMA-T1 Success and Evaluation Criteria for at least four out of five test runs | | |

## IMA-T2: STOPPED HVT STARTS TO MOVE WHILE INTERSECTING RVL IS APPROACHING

### Purpose

This test will verify that the IMA safety application issues a warning when the HVT is stopped at an intersection, then starts to enter the intersection while an intersecting RV is approaching the intersection.

An illustration of this test procedure is shown in figure 21.




Source: MBRDNA and DENSO

**Figure 21. Illustration. Stopped HVT and moving RVL.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: VDA.
- Lanes of travel: coned or painted intersection on the VDA that has an escape on both sides of the lanes of travel and plenty of run off room.
- The intersecting roads will be at a 90 degree angle, with two 3.6m wide lanes crossing the lane of travel of the HVT.
- A cone is placed at the stop bar for both directions (labeled Stop Bar in the figure).
- A cone is placed at the starting point for the RVL and HVT 150 m from their respective stop bars.

**Target Conditions**

- RVL speeds of 20 and 40 mph.

**Driving Instructions**

- The HVT leaves the start cone and accelerates to 15 mph.
- The HVT comes to a stop with its front bumper at or behind the stop bar.
- The HVT driver places the HVT transmission in a low forward moving gear with the service brakes applied.
- The RVL starts at the RV Start cone after the HVT has stopped.
- The RVL accelerates to the test speed and activates its cruise control.
- Once the RVL has passed the RV Brake cone, but before the RVL reaches the RV Stop Bar cone, the HVT driver releases the service brake and accelerates forward, moving at least one meter, but less than three meters.
- The RVL passes through the intersection.
- The vehicles will then move into position for another test run.

**Successful Criteria**

A valid warn message from the HVT DVI within the maximum latency as specified in the Minimum Performance Requirements (500 ms) for at least 4 out of 5 runs.

**Unsuccessful Criteria**

A warning message is not displayed on the HVT DVI for two or more runs.

**Evaluation Criteria**

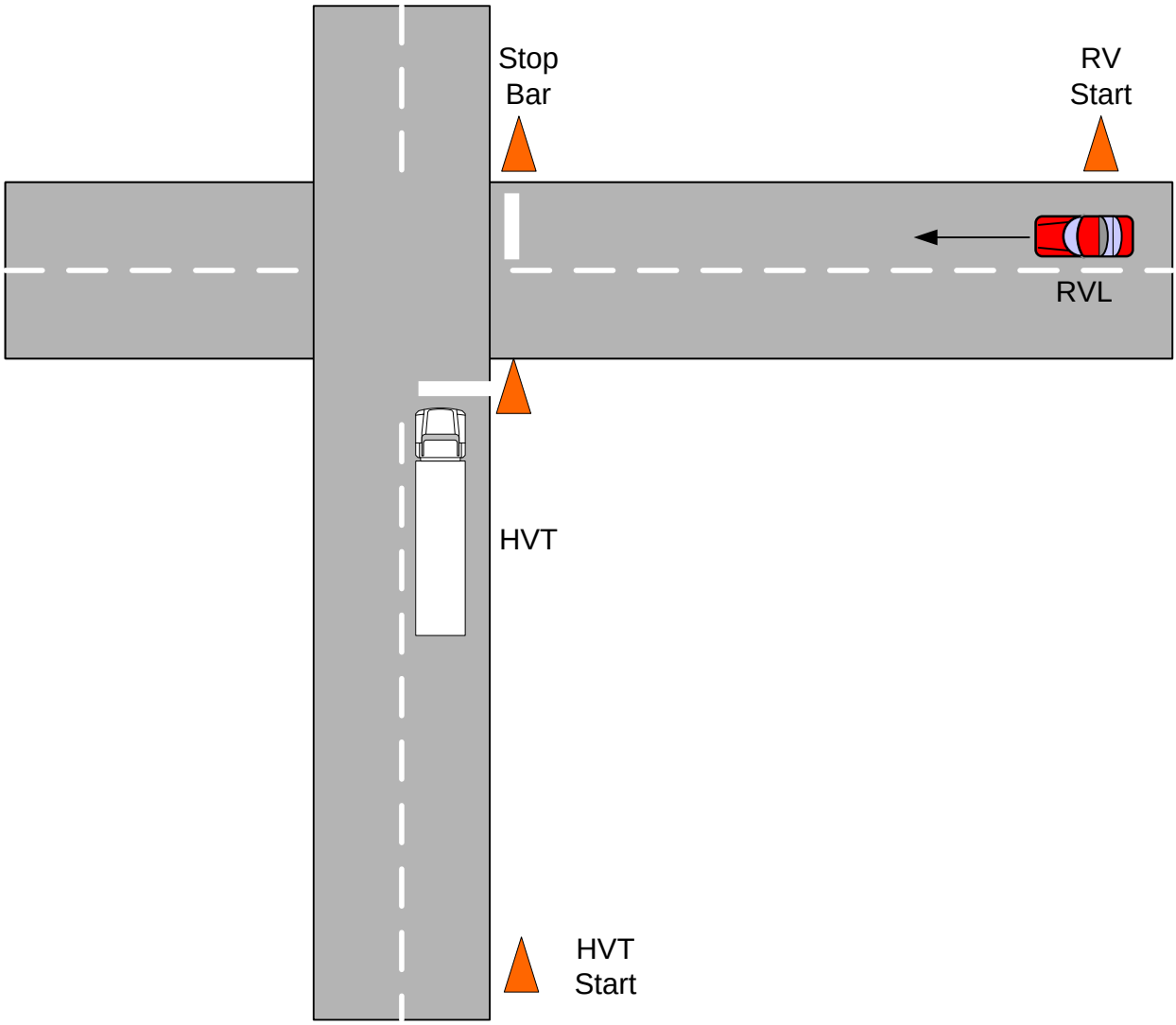
| RVL Speed (mph) | HVT Speed | Number of Valid Tests | Number of Successful Tests to Pass |
|---|---|---|---|
| 20 | 0 | 5 | $\geq 4$ |
| 40 | 0 | 5 | $\geq 4$ |

**IMA-T2: STOPPED HVT WITH INTERSECTING RVL APPROACHING**

**Purpose**

This test will verify that the IMA safety application does NOT issue a warning when the HVT is stopped at an intersection and an intersecting RV is approaching the intersection.

An illustration of this test procedure is shown in figure 22.




Source: MBRDNA and DENSO

**Figure 22. Illustration. Stopped HVT and moving RVL.**

**Test Setup**

- HVT.
- RVL.
- Test Surface: VDA.
- Lanes of travel: coned or painted intersection on the VDA that has an escape on both sides of the lanes of travel and plenty of run off room.
- The intersecting roads will be at a 90 degree angle, with two 3.6m wide lanes crossing the lane of travel of the HVT.

- A cone is placed at the stop bar for both directions (labeled Stop Bar in the figure).
- A cone is placed at the starting point for the RVL and HVT 150 m from their respective stop bars.

**Target Conditions**

- RVL speeds of 20 and 40 mph.

**Driving Instructions**

- The HVT leaves the start cone and accelerates to 15 mph.
- The HVT comes to a stop with its front bumper at or behind the stop bar.
- The HVT driver remains stopped with the service brakes applied.
- The RVL starts at the RV Start cone after the HVT has stopped.
- The RVL accelerates to the test speed and activates its cruise control.
- The RVL passes through the intersection.
- The vehicles will then move into position for another test run.

**Successful Criteria**

A warning message is not displayed on the HVT DVI.

**Unsuccessful Criteria**

A warning message is displayed on the HVT DVI.

**Evaluation Criteria**

| RVL Speed (mph) | HVT Speed | Number of Valid Tests | Number of Successful Tests to Pass |
|---|---|---|---|
| 20 | 0 | 2 | 2 |
| 40 | 0 | 2 | 2 |

# CHAPTER 8. CURVE SPEED WARNING

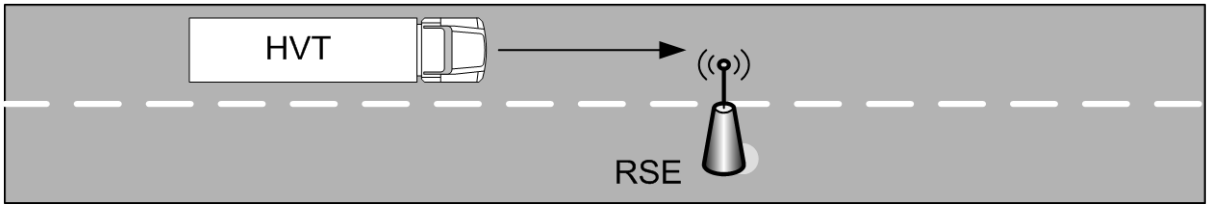
Curve Speed Warning (CSW) shall Inform or Warn the HVT driver if the HVT speed is faster than the advised speed when it is approaching a curve. The CSW will also give the driver the current distance to the curve. The CSW requires that roadside equipment (RSE) broadcast the traveler information message (TIM) with the advised speed for the curve. The truck does this maneuver in a straight line for safety. The advised speed in the TIM will be for an imaginary curve. The RSE could be the WSU suitcase or the OBE of another vehicle configured to send out only the TIM.

## CURVE SPEED WARNING TEST

### Purpose

This test will determine whether the CSW issues inform or warning messages at the appropriate times.

An illustration of this test procedure is shown in figure 23.




Source: MBRDNA and DENSO

**Figure 23. Illustration. Curve speed warning.**

### Test Setup

- HVT.
- Test surface: Skid Pad.
- Lane of travel: any.
- RSE: set up to send TIM with the advised curve speed of 15 mph.

### Target Conditions

- HVT speed of 35 mph.

**Driving Instructions**

- The HVT exits the skid pad return loop and accelerates to the test speed.
- The HVT sets the cruise control and drives past the RSE.
- The HVT moves into position for the next test run.

**Successful Criteria**

The HVT DVI issues the inform and Warn message at the appropriate times.

**Unsuccessful Criteria**

The HVT DVI does not issue the Inform and Warn messages at the correct times.

**Evaluation Criteria**

| Number of Valid Test Runs | Number of Instances HVT Shows: | | Number of Successful Test Runs |
|---|---|---|---|
| | Inform | Warning | |
| 5 | $\geq 4$ | $\geq 4$ | $\geq 4$ |

**Test Results**

| Test Step | Test Action | Actual Result | Test Status Pass/Fail |
|---|---|---|---|
| 1 | Test meets the Curve Speed Warning Success and Evaluation Criteria for at least four out of five test runs | | |

## ACKNOWLEDGEMENTS

This work was conducted by DENSO International America, Inc.—North America Research and Development, California Office, as part of the Connected Commercial Vehicles—Retrofit Safety Device Kit Project. The Connected Commercial Vehicles Team is led and managed by Battelle. The team includes DENSO, the University of Michigan Transportation Institute (UMTRI), Mercedes-Benz Research and Development North America, Inc. (MBRDNA), and Meritor WABCO.

Oversight from the United States Department of Transportation was provided by Kate Hartman of the Research and Innovative Technology Administration Intelligent Transportation Systems Joint Program Office, Alrik Svenson of the National Highway Traffic Safety Administration, and Cem Hatipoglu of the Federal Motor Carrier Safety Administration.

## REFERENCES


1. Wells, B., and Berg, R. (2014) *Connected Commercial Vehicles—Retrofit Safety Device Kit Project: Safety Applications and Development Plan,* FHWA-JPO-14-106, Federal Highway Administration, Washington, DC.

2. Bogard, S., and LeBlanc, D. (2014) *Connected Commercial Vehicles—Retrofit Safety Device Kit Project: Applications Performance and Functional Test Report*, FHWA-JPO-14-108, Federal Highway Administration, Washington, DC.

3. Kiefer, R., LeBlanc, D., Palmer, M., Salinger, J., Deering, R., and Shulman, M. (1999) *Development and Validation of Functional Definitions and Evaluation Procedures For Collision Warning/Avoidance Systems*, DOT HS 808 964, National Highway Traffic Safety Administration, Washington, DC.

U.S. Department of Transportation
Federal Highway Administration
Office of Freight Management and Operations
1200 New Jersey Avenue, SE
Washington, DC 20590
http://ops.fhwa.dot.gov/FREIGHT/
March 2014
Publication No. FHWA-JPO-14-107