CHAPTER 5

OBJECTIVE TEST METHODOLOGY FOR FORWARD COLLISION WARNING SYSTEMS

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5 OBJECTIVE TEST METHODOLOGY FOR FORWARD COLLISION WARNING SYSTEMS

5.1 Introduction

This chapter presents an objective test methodology to evaluate the compliance of a Forward Collision Warning (FCW) system with the minimum functional requirements developed in Chapter 4. The core of this methodology is a set of 26 vehicle-level test procedures that evaluate whether crash alerts are issued with acceptable timing in appropriate situations. The tests also evaluate whether crash alerts occur too frequently in situations that drivers are expected to find non-alarming. Because these are minimum requirements for the functionality described in Chapter 1, the countermeasure either passes or fails the testing and no relative rating is provided.

Possible users of the tests are assumed to include vehicle manufacturers, countermeasure suppliers, government organizations, and independent institutions. The tests are designed so they can be executed at a variety of vehicle proving grounds and test track facilities with minimum impact on the test results. To pass testing, a countermeasure must pass each of 17 individual crash alert tests and a set of nine out-of-path nuisance alert tests. The crash alert tests simulate situations in which an alert is required. These tests also evluate the FCW system based on in-path nuisance alerts. The out-of-path nuisance alert tests derive from the operational scenarios and involve simulating common driving conditions in which an alert should not occur, but that may challenge the system being tested. These tests include combining a variety of vehicle speeds, roadway geometries, pavement and lane marking conditions, environmental conditions, out-of-path objects, and more.

The proposed set of tests appear to be practical to execute. The execution time is estimated to be no more than four weeks, based on the experience of executing five of the tests (as reported later, in Chapter 7). The four week estimate does not include initial prop fabrication, set-up, and surveying of test sites. A completely exhaustive set of tests that would evaluate an FCW system in all conceivable circumstances would involve many more tests, and require much longer testing schedules. This is because there are an enormous variety of possible road/vehicle/environment/motion conditions that might affect an FCW system performance. The proposed test set is a best attempt to identify the key FCW performance behaviors in a testing time frame that is practical for government and industry, and is consistent with other safety-related testing regimens.

Regarding driver-vehicle interface requirements of Chapter 4, the objective test procedures presented here address alert onset timing in great depth, but do not address the alert modality. Such tests would follow from established industry practice.

If a countermeasure fails testing, there is a high probability that the system does not meet all the minimum functional requirements. If a countermeasure passes the tests, there is a high confidence that the system would meet the requirements over a wide set of conditions. Nevertheless, field operational testing will be required to learn about drivers' acceptance of the system and its potential effectiveness in the real world.

This chapter covers the test methodology concerned with instrumentation requirements, track and prop requirements, and the test driving maneuvers. An analysis is presented that describes the mapping between requirements and the tests. Chapter 6 covers the data analysis required to evaluate test data, as well as requirements for reporting on the tests. Chapter 7 describes an extensive set of activities undertaken to evaluate and validate the test methodology. This exercise resulted in changes to some important test design parameters and requirements.

The remainder of this chapter is organized as follows. First, an overview of the testing approach and high-level requirements are discussed. Second, definitions used throughout the chapter are presented, along with a set of standard (default) testing conditions. Third, the crash alert testing approach and detailed test procedures are described. Fourth, the out-of-path nuisance alert testing approach and detailed procedures are presented. Fifth, a chart is presented that maps the test procedures back to the functional requirements.

Throughout this report, the term "subject vehicle" (SV) refers to the vehicle on which the FCW is mounted, and "principal other vehicle" (POV) refers to another vehicle in the vicinity.

5.2 Test Methodology Overview

The objective test methodology presented in this chapter includes 26 vehicle level tests in which an FCW-equipped subject vehicle (SV) encounters situations in which a crash alert is either required or is not allowed. Detailed data collection and analysis is required in these tests to determine whether the countermeasure complies with the set of minimum functional requirements developed in Chapter 4.

The test methodology includes several elements that are presented in the remainder of this chapter, as well as in the following chapter. These elements include: test instrumentation requirements; test site and testing props requirements; driving maneuver instructions; and data reporting and analysis requirements. This chapter presents all but the final element, which is given in Chapter 6. The reader will note that beginning with Section 5.3, the methodology is presented as instructions to a party with responsibility for selecting test instrumentation, executing the tests, and analyzing the results to provide the final pass/fail result.

The process used to design the test procedures themselves was described in Chapter 1. Briefly, the functional requirements developed in Chapter 4 are tested in situations derived from the targeted scenarios of Chapter 2. The parameters of the scenarios, such as road geometry, environmental conditions, relative vehicle motions, and roadway scene, are selected from a set of independent variables that attempt to represent the diverseness of driving conditions. The tests are selected to exercise a variety of required FCW system behaviors, and sometimes the parameters of the scenarios are chosen to test important, known technical challenges FCW developers face. The human factors work of Chapter 3 drives the desired timing of the crash alert onset.

The objective test methodology includes two types of tests, which are called "crash alert tests" and "out-of-path nuisance alert tests." Crash alert tests are situations in which a crash alert must occur with acceptable alert onset timing. Out-of-path nuisance alert tests simulate common driving situations in which alerts are not desirable but may occur due to technical challenges.

The remainder of this section presents important concepts in test methodology approach and design.

5.2.1 Criteria for Passing the Testing

Successful countermeasure performance in testing is defined as passing each of four areas: crash alert tests; out-of-path nuisance alert tests; in-path nuisance alert tests; and driver-vehicle interface tests. Success in each of these areas is defined below. Detailed instructions for computations necessary to determine success in each area are presented in later sections.

5.2.2 Crash Alert Tests

Crash alert test procedures are driving maneuvers involving two or more vehicles. These maneuvers are designed such that the countermeasure-equipped subject vehicle (SV) encounters situations that should trigger a crash alert for a countermeasure system that meets the minimum functional requirements. (See Chapter 4 for these requirements). The significant data from each test trial is a comparison of the time (or position) at which the crash alert onset actually occurred (if they occurred) and the time (or position) at which the alerts were required to occur.

Five trials of each test are performed. Alert onsets should be neither "too late" nor "too early," as defined in the timing requirements of Chapter 4, Section 2, and the Alert Zone requirements of Chapter 4, Section 3. To pass the testing, a countermeasure must satisfy two criteria. First, in general, the crash alert onset cannot be *too late* for any trial of any test. (Exceptions from this rule are described in Section 5.4.4.) Second, the instances in which the alert onset occurs *too early* are weighted by test, and the weighted sum is compared to a threshold. If the threshold is exceeded, the countermeasure fails testing.

5.2.3 Out-Of-Path Nuisance Alert Tests

Out-of-path nuisance-alert tests determine whether a countermeasure produces too many alerts when confronted with common driving situations. The tests follow closely from the operational scenarios described in Chapter 2. The SV is driven past stationary or moving objects or vehicles that are kept outside the Alert Zone, so that any alert that occurs is an out-of-path nuisance alert. The tests are repeated a specific number of times to represent typical exposures of drivers to common objects, as described later.

The test descriptions include details for the selection and setup of the track and props, driving instructions, and data collection requirements. In general, a system that meets the minimum functional requirements should not produce any alerts during the execution of the tests. If a system does produce alerts during execution of some of the tests, then the specific conditions at the time of the alert are recorded. Again, a weighted sum of instances in which alerts occur are compared to a threshold. The weights and the threshold for out-of-path nuisance alert testing are chosen to estimate the frequency that this type of nuisance alert is likely to occur during typical driving patterns on public roads. If the threshold is exceeded, the countermeasure fails testing.

5.2.4 Driver-Vehicle Interface Tests

The FCW functional specifications in Chapter 4 describe recommendations for the driver-vehicle interface. The requirements for alert onset timing during an approach are tested extensively in the objective test procedures. For the other requirements, however, no specific testing procedures are provided here because the tests for these requirements are considered straightforward and within the realm of current industry practice.

5.2.5 FCW Systems With Multiple Alert Stages and/or Driver-Adjustable Timing

Throughout the remainder of this chapter and Chapter 6, “crash alert” refers to the most urgent level of alert. This is the only alert level for which specific timing requirements are developed in Chapter 4, and the only alert level addressed by the test procedures presented in Chapter 5.

If the FCW system provides any sensitivity adjustment, it should be tuned for testing to the minimum sensitivity to potential threats – that is, to the setting that minimizes the likelihood the unit would issue an alert in a given situation. (This setting might also be called the “latest,” “closest” setting.) Using this setting in testing ensures that a driver who turns down the sensitivity to minimize nuisances will still receive timely alerts in potentially alarming situations. FCW system suppliers may choose to allow the driver to adjust the timing of alerts to accommodate a subset of drivers who may prefer earlier alerts; that is, drivers may be willing to trade-off additional nuisance alerts for the ability to receive earlier alerts.

5.2.6 Independent Variables and Test Procedure Design

Designing a set of test procedures to evaluate a crash countermeasure involves selecting specific examples of key scenarios in which it is desirable to specify and measure countermeasure performance. The driving environment is complex and varied, and drivers are presumed to expect an FCW system to function properly, independent of their driving situation. Therefore, care has been used to ensure that the test procedures explore whether or not a countermeasure will perform with minimum functionality across the vast majority of conditions associated with driving in the U.S., while minimizing the number of tests for feasibility reasons.

Table 5-1 is a list of the independent variables varied over the course of the testing. Also shown are the values taken during at least one test. For example, ambient illumination conditions include daytime and nighttime (which are defined in the Definitions section). Overhead objects include an overhead road sign and an absence of overhead objects. Over 20 independent variables are shown. It is not feasible to test at all combinations. Instead, combinations of variables were selected to test countermeasures in challenging situations considered important for effectiveness and driver acceptance. All values are defined in this chapter.

For example, one test includes the countermeasure-equipped SV approaching a stopped vehicle stopped under a large overhead road sign. This situation is expected to challenge FCW systems that use sensor-processing technologies that lack resolution of targets in the vertical direction. Yet this driving situation is considered common enough and essential enough to successful deployment that the test is included.

Rare combinations of variables that may well confuse FCW systems and are not required for driver acceptance may not be included, in the interests of expediting the deployment of acceptable safety systems that may reduce harm due to crashes.

Table 5-1 Independent Variables that are Varied in the Test Procedures

Independent Variable	Values Required
Environmental Conditions and Visibility	
Ambient illumination	Daytime, nighttime
Atmospheric visibility	Good visibility, fog
POV rear-end retroreflectors	Clean, dusty
Roadway Geometry and Pavement Conditions	
Horizontal curvature	Straight, curved, transition from straight to curved, U-turn
Vertical curvature	Flat road, hill crest, hill sag
Painted lane markings	Good quality, poor quality, none
Road surface wetness	Dry, wet
Road unevenness	Pavement in good shape, poorly paved or unpaved
POVs and Objects in Scene	
Type of POVs	None, mid-sized sedan, motorcycle, truck
Type of object(s) on roadside or in adjacent lanes	None, guardrails, concrete barrier, mailboxes, road signs, slow vehicles
Type of object overhead or on the road surface	None, overhead sign, grating in road, retroreflectors on road, debris on road
Motions of SV and POV	
SV initial speeds	120 kph, 100 kph, 80 kph, 72 kph, 50-70 kph, 30-50 kph, 24 kph.
Initial closing speed (approaching POV)	0 kph, 24 kph, 33 kph, 40 kph, 68 kph, 72 kph, 100 kph
POV deceleration	None, -0.15 g, -0.4 g
Lateral maneuvers before alert	None, POV cut-in, SV lane change

5.2.7 Approach to Instrumentation Requirements

The approach used in the development of these procedures is to allow the testing organizations as much freedom as possible to develop their own approaches to test instrumentation, data processing, and vehicle control. The test procedures levy requirements only on the accuracy with which key *variables* need to be controlled or estimated. No requirements are used to stipulate the use of specific instrumentation, data-processing approaches, and so on.

One motive for this approach is to allow testing organizations the freedom to develop and use innovative approaches to implementing the test procedures. Performing the proposed test procedures will involve staging prescribed vehicle motions and measuring relative motions between vehicles and/or stationary props and/or roads. The testing involves the measurement, estimation, and control of many variables. It seems wise to provide a good testing framework without over-constraining its implementation. A second motive for not specifying highly detailed instrumentation requirements is that instrumentation choices may evolve as technology evolves.

To illustrate the approach, for example, some tests require a vehicle to be driven within a lane such that there is a 95% confidence level that the center of gravity (CG) strays laterally no further than 0.50m from the lane centerline. The user is then responsible to identify hardware and software approaches, and to document the uncertainties associated with the various measurements, and finally to demonstrate in a test report how the requirements given in the test procedures were satisfied. Thus, the testing organizations bear a burden of calibration, analysis, and documentation that would not exist if more specific instrumentation requirements were used.

This approach also has consequences for the recipient of a test report. The recipient of the report will need to examine and assess the validity of arguments in the report regarding measurement uncertainty and the satisfaction of requirements in the test procedures.

Table 5-2 Functions Assigned to Test Procedure Documents, Testing Organization, and Recipients of Test Reports

Test procedures specify the following, including allowable ranges of key variables, where appropriate:	Test conditions allowed (e.g., weather, and illumination). Test set-up, including props (e.g., road geometry, POV descriptions). Directions for executing tests, and required accuracy values for key parameters (e.g., a specified vehicle speed and an allowed deviation from that value). Requirements for the accuracy values of selected intermediate quantities used for countermeasure evaluation (e.g., the accuracy with which the difference in crash alert tests between the range at alert onset and the minimum required distance for an alert must be determined). Countermeasure performance metrics to be computed for each test trial, for use in countermeasure performance evaluation. Instructions for combining the results of individual test runs to determine whether the countermeasure performance meets minimum functional requirements.
The testing organization must select and/or develop the following components of testing:	Instrumentation. Any active control devices used to conduct tests. Calibration procedures. Data processing algorithms for testing purposes. Method of modeling and reporting uncertainties.
Testing organization's responsibilities include:	Identification of measurement, estimation, control, and modeling errors that contribute to uncertainties associated with variables that the test procedures levy requirements upon. Calibration of equipment, when necessary. Describing methods of data processing. Describing how uncertainties are determined. Demonstrating that requirements on test set-up and execution are satisfied, while including the effects of any significant uncertainties associated with instrumentation, control, or data processing. Evaluating appropriate uncertainties associated with test performance metrics.
Recipient of a test report bears these responsibilities:	Assessment of the validity of the testing organization's arguments concerning instrumentation choice and calibration approach. Assessment of the validity of the testing organization's arguments concerning the satisfaction of requirements on accuracy levels associated with test execution and measurement.

5.2.7.1 Handling Measurement Uncertainty Effects

This section describes the scope of the user's responsibility to understand and document effects of measurement uncertainty.

The user is required to show that all accuracy requirements given in this document are met. This may involve reporting calibration procedures as well as presenting work on modeling and analysis. Instructions in this chapter and Chapter 6 should be sufficient to guide the user through this process, but the following examples may provide first-time readers with an understanding of the approach taken in these procedures to dealing with the documentation of calibration and uncertainties.

Example: Roadway horizontal radius of curvature

Roadway horizontal curvature is another independent variable that is specified for each test. The specification is given in terms of a range of allowable radius of curvature values. Users of the test procedures must then report:

- The measured and/or estimated radius of curvature of the test site.
- The means of determining the radius of curvature, and the error in the determination.
- How the error value was found.

An argument for a 95% confidence level that the test site radius of curvature satisfies the requirement.

The recipient of the report might choose to examine the claims and justifications related to the actual measured value of the radius of curvature, as well as the argument that the measurement translates into an acceptable radius of curvature value (with 95% confidence).

Example: Computation of Crash Alert Performance Metric

For crash alert tests, the metric of countermeasure performance is the difference between the range at alert onset and the minimum required range at alert onset (which depends on the relative speed between the vehicles). The test procedures require that this metric be computed with an accuracy (95% confidence) equal to either 5% of the minimum required warning range, or 2.0 m, whichever is larger for the situation. Users of the test procedure must then report:

- The means of estimating the metric for each trial, including sensor descriptions, data-processing techniques and algorithms.

- A model of the estimation error associated with the computed metric and a justification for the model.
- Any calibration procedures used to arrive at the estimation error model.
- Any modeling and analysis that supports the algorithm development or the specification of the associated estimation error.

5.2.7.2 Instrumentation Non-interference

The instrumentation necessary for this test must be installed such that it does not hinder operation of the subject vehicle or countermeasure, or the operating characteristics of either.

5.3 Definitions and Standard Testing Conditions

This section presents detailed definitions of some technical terms used in the chapter. First, definitions are presented for some of the independent variables, which are quantities used to describe testing conditions. Second, additional definitions are given to aid the reader. Throughout this report, the term “subject vehicle” (SV) refers to the vehicle on which the FCW is mounted, and “principal other vehicle” (POV) refers to another vehicle in the vicinity.

5.3.1 Definitions of some Independent Variables

Part of the description of each test is the set of values taken on by a set of independent variables, which are listed in this section, along with definitions used to refer to particular conditions.

For example, a “straight road” is defined as a road with a horizontal curvature of less than 0.1 deg/100m. Some conditions cannot be described so simply. For example, used to represent roadside objects, such as a speed limit sign, require a more lengthy description.

5.3.1.1 Environmental Conditions

“Daytime illumination” is defined as the natural outdoors illumination that occurs from 30 minutes after sunrise to 30 minutes before sunset.

“Nighttime illumination” is defined as the natural outdoors illumination available from the time beginning one hour after sunset and ending one hour before dawn.

“Good atmospheric visibility conditions” are defined as greater than 1-kilometer visibility using the Runway Visibility Rating (RVR) or similar methods.

“Poor atmospheric visibility” conditions are defined as less than 200-m visibility using the Runway Visibility Rating (RVR) or similar methods.

“Very windy conditions” exist if either sustained wind speeds exceed 30 kph or wind gusts exceed 40 kph.

5.3.1.2 Objects in the Scene

“Passenger car” is defined arbitrarily as a 1997 Chevrolet Lumina LTZ, or another similarly sized mid-sized sedan.

“Large truck” is one similar to the 24-foot bed enclosed moving trucks commonly available from rental agencies. An example is a 1995 Ford F-700.

“Motorcycle” is defined as a commercially available 350cc to 650cc-class motorcycle without alterations to its reflectors, lights, or fenders, and without after-market add-ons that might affect its visibility to countermeasure sensors.

5.3.1.3 Roadway Description

“Straight road” is tentatively set at a horizontal curvature of less than 0.1°/100m.

“Flat road” is set at a vertical curvature of greater than 600-m% change in grade.

“Smooth pavement” conditions describe any paved track surface with pavement in relatively good condition.

“Unpaved” conditions describe any surface that is not paved.

Painted Lane Markings

“Painted lane markings” refers to markings that are painted on the road surface or that consist of material laid down onto the surface such that the markings appear similar to painted markings. Three types are defined here: *no lane markings, poor quality painted lane markings,* and *good quality painted lane markings.* The test procedures for each test will require that the roadway have one of these particular types of lane markings. In general, test sites should have lane markings that are consistent with standard marking patterns.

The center of any marked lane must be parallel to the center of the road. Lane widths and variations should comply with AASHTO standards for highways and streets (AASHTO, 1995).

Note that these definitions are not intended to provide any sort of classification of actual public roadways, or to provide a comprehensive description of situations that do or do not challenge countermeasures that may sense lane markers.

No Lane Markings

For tests to be executed on roadways with "no lane markings," the roadway should have no painted lane markings and no raised pavement markings (e.g., retroreflectors indicating lane edges). The roadway should be no more than 7.4 m wide (equal to the width of two 12-foot lanes). The roadway width should also be approximately constant and surrounded by surfaces different enough from the roadway so that a driver can easily distinguish the road from the surrounding space. Therefore, for example, these tests cannot be executed on the wide expanses of pavement commonly used at automotive proving grounds for vehicle dynamics testing (sometimes called "black lakes").

Good Quality Painted Lane Markings

A test to be executed on a roadway with "*good quality*" painted lane markings must be executed on a roadway where all of the following conditions apply to the travel lane:

- The painted lane markings must be either single solid (continuous) lines or single dashed lines. Neither side of any lane used in the test can be marked with double-solid lines nor a combination of parallel solid and dashed lines, such as the markings found on a two-way, two-lane road, with no passing in one direction.
- The painted lane markings must be either yellow or white.
- Raised pavement markers are acceptable but not required.
- The painted lane markings must be between 3.5 and 5.5 inches wide.
- If a painted lane marker is dashed, the following must hold:
    - The length of all dashes must be between two and 10 meters.
    - The space between two dashes cannot be less than *twice* the length of either dash or greater than *four* times the length of either dash, where the length of each dash is its "ideal" length, which is not reduced by wear or torn off sections of marker.
- The integrity of the painted surfaces must be as follows: Let the area of an ideal painted marker be the area of a continuous strip with a width equal to the average width of the lane marker. For a solid line the area of paint or material that makes up the actual lane marker is then required to be at least 25% of the area of the ideal continuous strip. This should be true over any 20 m length of lane marking. For a dashed line, the area of actual paint should be at least 10% of an ideal continuous stripe. (Note that if the spaces between dashes are

four times the length of the dash, and each dash is missing half its original painted surface, the area of actual paint is 10% of an ideal continuous stripe.)

These requirements are based on engineering judgment. A computer vision image processing system that identifies lane markings typically use both intensity contrast between pavement and lane markings, as well as the continuity of the marker in each image and in an image sequence. Therefore, the difference in the percentage area requirements for solid and dashed lines, reflects an educated opinion; that systems in the near-term will have less difficulty identifying the appropriate contrast threshold for a solid line than for a dashed line, because the continuity of a solid line aids the process.

Poor Quality Painted Lane Markings

For tests to be executed with "poor quality painted lane markings," the roadway must meet all the conditions for good quality painted lane markings, except:

- No raised pavement markers are allowed.
- The integrity of the painted surfaces must be as follows: For solid lines, the area of the actual remaining marker should be between 5% and 25% of an ideal continuous stripe. For dashed lines, the area should be between 3% and 10% of an ideal continuous stripe. These values are again based on engineering judgment.

5.3.1.4 Vehicle Motions

"Vehicle speed" is identical to "Longitudinal velocity" in SAE J670e, "Vehicle dynamics terminology," (Last revision July 1976).

"Vehicle acceleration" refers to "Longitudinal acceleration" in the same reference.

"Range" is the distance from the front of the FCW-equipped vehicle to the rear of another vehicle.

5.3.2 Other Definitions

"Alert zone" is defined in Chapter 4, Section 4.3.

"Testing distance" for the out-of-path nuisance alert tests is defined when stationary objects are used. The testing distance begins when the SV is 200 m from the stationary object(s), and ends when the SV has passed the last stationary object used in the test.

5.3.3 Standard Testing Conditions

Unless specified otherwise, all tests should be run under the following conditions:

5.3.3.1 Standard Roadway Geometry and Conditions

For individual test trials, both the roadway geometry parameters and the roadway conditions must meet the specifications given in the testing procedures. Unless specified otherwise, the road surface should be dry (without visible moisture on the surface). Unless a particular test specifies otherwise, the roadway should be straight, flat, with pavement in good condition (where these properties are described in the Definitions section). The surface itself should be constructed from asphalt or concrete. The road surface should be free from potholes, bumps, and cracks that could cause the SV to pitch excessively.

Painted lane markings of "good quality" – as defined in the Definitions section – should exist on the roadway.

5.3.3.2 Standard Environmental Conditions

Unless a particular test specifies otherwise, the tests should be ran during daylight hours, with good visibility. There should not be very windy conditions, and the ambient temperature should be between –18 deg C (0 deg F) and 38 deg C (100 deg F). See the Definitions section for specific definitions of these conditions.

5.4 Crash Alert Test General Requirements

This section addresses issues common to a wide array of the crash alert tests. The first major subsection defines standard testing conditions that are to be used in the crash alert tests, unless otherwise specified later, under the description of the individual tests in the section Crash Alert Tests. For example, this section defines the default value for required ambient illumination as “Daytime illumination.” Later, in the detailed test procedures, a few crash alert tests stipulate “Night-time illumination.”

The second major subsection below addresses requirements for test instrumentation. The variables to be measured or estimated for most crash alert tests are listed; special needs for specific tests are given later in the Section 5.2.2. The level of specificity of the instrumentation requirements is consistent with the discussion in Section 5.2.6.

5.4.1 Track and Prop Preparation

5.4.1.1 Principal Other Vehicles

The test procedures specify the type(s) of principal other vehicles (POVs) to be used for each test. There are three types: Mid-size sedan, Motorcycle, and Truck. Readers should consult the Definitions for specific definitions of the POV types. Unless the POV type for a particular crash alert test is otherwise specified, the default value for the POV type in crash tests is Mid-size sedan.

Unless a specific crash alert test specifies otherwise, the POVs should be clean and without alterations that might affect the ability of a countermeasure to sense and track the vehicle.

5.4.1.2 Instructions for Preparing a Stopped-POV Test

Several crash alert tests involve a stationary POV. To prepare for these tests, park the POV in the center of a travel lane, with its longitudinal axis oriented parallel to the roadway edge, and the POV facing the same direction as the front of the SV, so the SV approaches the rear of the POV. The configuration should satisfy the following:

- The CG of the POV must be no more than 0.30-m, from the center of the lane of travel.

- The angle between the POV’s geometric longitudinal axis and the local road edge cannot exceed 2.5 degrees.

5.4.1.3 Other Objects in the Scene

Unless stated otherwise, all crash alert tests should be conducted such that there are no overhead signs, bridges, or other significant structures over, or near, the track for the duration of the test. (Test duration is defined in the detailed procedures of each test). The track setup and the test execution should also ensure that roadside clutter effects are negligible. For instance, the SV should not be driven on the outside lane of a track with guardrails located quite close to the lane, since guardrails are potential sources of out-of-path nuisance alerts, and those alerts are addressed in a different test set.

5.4.2 Instrumentation Requirements

5.4.2.1 Instrumentation Requirements for Test Validity Analysis

Instrumentation should support the determination that independent variables meet requirements (e.g., that the roadway satisfies the "flat road" specification). Instrumentation must also support the determination that the tolerances specified in the driving instructions for a particular test are satisfied during the execution of each test trial.

Any additional instrumentation requirements needed for a particular crash alert test are stated within the procedures for each test.

Additional instrumentation requirements to characterize countermeasure performance are described in the next section. Data rates are not specified: the user of these procedures selects the data rates.

5.4.2.2 Instrumentation Requirements For Determining Countermeasure Performance

Instrumentation for crash alert tests must support the determination of whether the crash alert occurs, and if so, whether the alert occurs for appropriate targets with appropriate timing. Each crash alert onset must occur at a range which is no less than the minimum allowable range at alert onset and still no greater than the maximum allowed range at alert onset (from considerations of in-path nuisance alerts, as discussed in Chapter 4).

The minimum and maximum allowed range at alert onset are discussed in Chapter 4, Section 2. Appendix B presents detailed instructions to compute these alert timing requirements, given measurements of vehicle speeds and accelerations.

Knowledge of the relative lateral position is used to determine whether the POV was within the Alert Zone at any instant of interest. The accuracy requirements for locating the lateral position of the POV relative to the SV, in road coordinates, near the time when an alert is expected, is suggested to be 0.2m (with 95% confidence).

Consider now accuracy requirements associated with determining whether an alert occurs at a range that satisfies the minimum functional requirements in Chapter 4. Let R denote the range from the SV to the POV at the time of an alert onset. Let $R_{warn,\min}$ denote the minimum range at which alert onset is allowed, under the prevailing kinematic conditions. (See Chapter 4 for the minimum required warning range and the maximum allowed warning range, expressed as a function of SV and POV speeds and accelerations.) Let ε_R be the difference between the range at alert onset and the minimum required alert range at that moment, $\varepsilon_R = R - R_{warn,\min}$. This is illustrated in the figure below. This difference ε_R is an essential metric used to evaluate countermeasure performance. Requirements are now levied on the accuracy with which this metric should be computed:

- The 3-sigma uncertainty in ε_R, the difference between the range at which the required crash alert occurs, and the minimum range for the required crash alert cannot exceed 5% of the minimum warning range or 2.0 m, whichever is greater.

These requirements will drive the accuracy needs associated with computing range, range rate, and the vehicle accelerations. Accuracy needs for other quantities, such as the vehicle speeds and the knowledge of the timing of the alert onset, may be driven by the above requirements.

Likewise, let $R_{warn,\max}$ be the maximum allowed range for the onset of an alert, given the instantaneous range, range rate, and relative longitudinal acceleration. Let ε_{IPNA} be the difference between the range at alert onset and the minimum required alert range at that moment, $\varepsilon_{IPNA} = R - R_{warm,\max}$. (The subscript "IPNA" stands for in-path nuisance alert.) Consider the following accuracy requirement:

- The 3-sigma uncertainty in ε_{IPNA}, the difference between the range at which the crash alert occurs and the maximum allowed range for the crash alert onset, cannot exceed 5% of the maximum allowed warning range, or 2.0 m, whichever is greater.

5.4.3 Data Analysis and Reporting

Data reported must demonstrate "test validity," that is, that the test run meets specifications given for each test in the Driving instructions. Reporting of these variables is required.

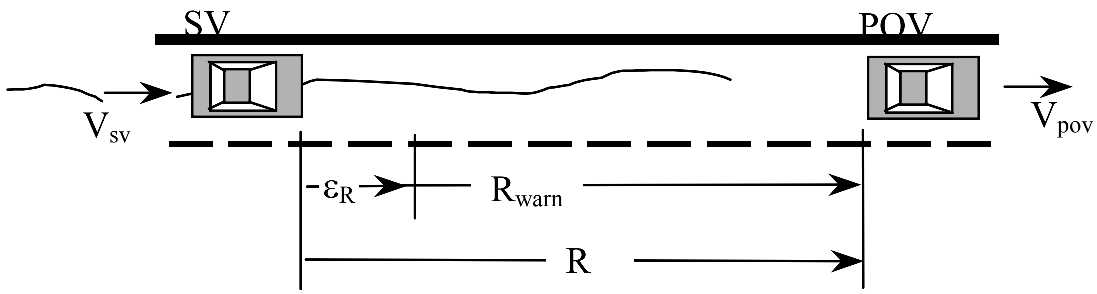

Figure 5-1 Metric for Countermeasure Performance for Crash Alert Tests

Data analysis must also evaluate and document the performance of the countermeasure for the required crash alerts. For test scenarios without significant lateral maneuvers, these four quantities generally suffice, unless stated otherwise in the Chapter 6:

- The performance metric ε_R, which is the difference between the range at which the alert occurs and the minimum range for the alert onset.
- The uncertainty associated with the metric ε_R.
- The performance metric ε_{IPNA}, which is the difference between the range at which the alert occurs and the maximum allowed range for the alert onset.
- The uncertainty associated with the metric ε_{IPNA}.

Individual tests may have special instructions in addition to these variables. See Chapter 6 for detailed instructions on all data reporting and analysis requirements.

5.4.4 Crash Alert Test Repetition Requirements

Each crash alert test must be executed five times, and possibly more, depending on the results of the five trials. For each test, the countermeasure must issue the alert “soon enough” for each trial. (Requirements for alert onset timing are described in Chapter 4; an algorithm to compute requirement values for specific speeds and accelerations is given in Appendix B.) Should the system be “late” on one trial, 15 additional trials are required with no allowed instances of being too late before the system can pass the testing. Fifteen trials are required to show that the “late” performance is a rare event (due, perhaps, to test instrumentation inaccuracies). If the system passes the additional trials, there is no need for an explanation or analysis of the single “late” trial.

The countermeasure should not issue alert onsets “too early,” either. A weighted sum of the instances in which alert onsets occur too early is compared to a threshold, as described in Chapter 6. If more than five trials are required for any test, the weighting method described in Chapter 6 allows the additional trials to be included in the weighted sum in a manner that does not penalize the need for extra trials.

5.5 Crash Alert Tests

Crash alert tests investigate the countermeasure's compliance with functional requirements that address the timing of crash alert onset timing and poor visibility functions. The list of crash alert tests is given below.

Test	Test name
C-1	100 kph to POV stopped in travel lane (night)
C-2	80 kph to POV at 16 kph (uneven surface)
C-3	100 kph to POV braking moderately hard from 100 kph
C-4	100 kph to POV stopped under overhead sign
C-5	100 kph to slowed or stopped motorcycle
C-6	SV to POV stopped in transition to curve (wet pavement)
C-7	SV to POV stopped in a curve without lane markings
C-8	SV to slower moving POV, in tight curve
C-9	POV at 67 kph cuts in front of 100 kph SV
C-10	SV at 72 kph changes lanes and encounters stopped POV
C-11	100 kph to stopped POV, with fog.
C-12	POV brakes while SV tailgates at 100 kph.
C-13	Greater size and equal distance (100 kph SV approaches 32 kph motorcycle that is alongside two 32 kph trucks)
C-14	Greater size and greater distance (100 kph SV approaches 32 kph motorcycle that is behind a 32 kph truck)
C-15	100 kph to 32 kph truck
C-16	SV to POV stopped in transition to curve (poor lane markings)
C-17	24kph SV to stopped POV.

Table 5-3 List of Crash Alert Tests

Test requirements and procedures are now given for each of these tests.

5.5.1 Test C-1 100 kph to POV Stopped in Travel Lane (Night)

5.5.1.1 Test Overview and Purpose

This test consists of a SV traveling on a straight, flat road at highway speed toward a vehicle which is parked in the middle of the lane of travel. The test should be performed at night. The test is to determine whether the countermeasure crash alert onset occurs at a range that is consistent with the alert onset timing requirements described in Chapter 4, Section 2. The test is also used to estimate the expected exposure to in-path nuisance alerts for the countermeasure. The test assures that the countermeasure functions appropriately at the maximum speed and sensing ranges described in Chapter 4. The test also ensures that the FCW functions appropriately even with nighttime lighting. .

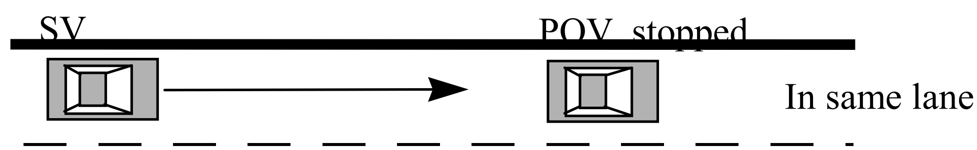

Figure 5-2 Test Maneuver Diagram for Test C-1

This test addresses Chapter 2 crash scenarios that include the following: Distracted driver rear-end (RE), Inattentive driver RE, and Aggressive driver RE.

5.5.1.2 Track and Prop Setup

Road Geometry and Conditions

Use standard conditions, per Section 5.3.3.

POV Description

POV type: Midsize sedan

5.5.1.3 Environmental Conditions

Use standard conditions, per Section 5.3.3.2, except run this test with nighttime illumination and no direct lighting (e.g., no “streetlights” are permitted).

5.5.1.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

Additional instrumentation requirements for this test include:

- The location and orientation of the stopped POV should be as stipulated in the general crash alert requirements.

5.5.1.5 Driving Instructions

The POV should be parked in the lane of travel, as described in Crash Alert Tests General Requirements. The position of the stationary POV should be determined, if necessary. (Only the relative position of the SV with respect to the POV is needed, and some measurement approaches will make absolute knowledge of the POV position unnecessary.)

Drive the SV at a nominal speed of 27.8 m/sec (100 kph) in the center of the lane of travel, toward the parked POV. The test begins when the SV is 200m from the POV and ends when either of the following occurs:

- The required crash alert occurs.
- The range to the POV falls to less than 90% of the minimum allowable range for the onset of the required crash alert.

After one of these events occurs, the SV driver must then steer and/or brake to keep the SV from striking the POV.

For the nominal SV speed, the maximum allowed alert onset range is 146.1m and the minimum allowed range for alert onset for the crash alert is 100.0m. (Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.)

For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than two kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal

to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).

- The SV driver cannot touch the brake pedal before the required crash alert occurs, or before the range falls to less than 90% of the minimum range allowed for onset of the required crash alert.

5.5.2 Test C-2 80 kph to POV at 16 kph on uneven road

5.5.2.1 Test Overview and Purpose

This test consists of a SV traveling on a straight, flat road toward a single POV, which is moving in the same lane at a much slower speed. The test is performed on a road that is either unpaved or poorly paved. The test is to determine whether the countermeasure crash alert occurs at a range that is consistent with the alert onset timing requirements of Chapter 4. The test is also used to estimate the expected exposure to in-path nuisance alerts for the countermeasure. The test also ensures that the FCW can operate on pavements that will induce pitching motions of the SV.

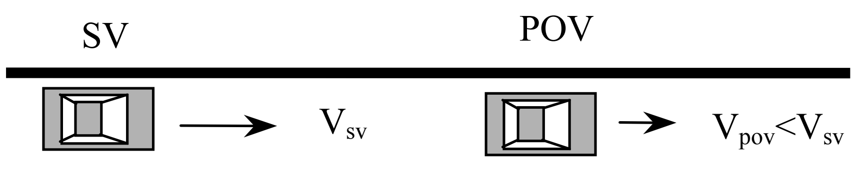

Figure 5-3 Test Maneuver Diagram for Test C-2

This test addresses Chapter 2 crash scenarios that include the following: Distracted driver RE, Inattentive driver RE, and Aggressive driver RE.

5.5.2.2 Track and Prop Setup

Roadway Geometry Conditions

Use standard conditions, per Section 5.3.3, except that an unpaved or poorly-paved road segment should be used. The purpose of this is to induce vehicle vibrations that may pose a challenge to some countermeasures. The term "poorly paved" is intended to suggest a public road in poor repair. This test is not intended to be executed on extremely uneven pavement situations, such as those available at many proving ground facilities for chassis testing.

POV Description

POV type: Midsize sedan

5.5.2.3 Environmental Conditions

Use standard conditions, per Section 5.3.3.2.

5.5.2.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

5.5.2.5 Driving Instructions

Throughout the test, the POV is to be driven at a constant 22.2 m/sec (80 kph) in the center of the lane of travel.

The SV is to be driven at 4.4 m/sec (16 kph) in the center of the lane of travel, toward the slower-moving POV. The test begins when the SV is 150m from the POV and ends when either of the following conditions is satisfied:

- The required crash alert has occurred.
- The range to the POV falls to less than 90% of the minimum allowable range at alert onset for the required crash alert.

After one of these events occurs, the SV driver is to steer and/or brake to keep the SV from striking the POV.

For the nominal SV speed, the maximum allowed alert onset range is 97.6 m and the minimum allowed range for alert onset for the crash alert is 62.9m. (Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.)

For the trial to be valid, the following must hold from the beginning until the end of the test:

- The POV vehicle speed cannot deviate from the nominal speed by more than two kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The SV vehicle speed cannot deviate from the nominal speed by more than two kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The CG of the POV cannot deviate more than 0.30m away from a line parallel with the lane centerline (with a confidence level of 95%).

- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).
- The SV driver cannot touch the brake pedal before the required crash alert occurs, or before the range falls to less than 90% of the minimum range allowed for onset of the required crash alert.

5.5.3 Test C-3 100 kph to POV Braking Moderately Hard from 100 kph

5.5.3.1 Test Overview and Purpose

This test begins with the SV traveling on a straight, flat road at highway speed. Ahead of the SV, in the same lane, is a single POV, which is initially traveling at the same speed as the SV. The SV is following at a moderate distance. The POV then begins to brake moderately hard, so that the SV begins closing on the POV. The SV maintains a constant speed until the required crash alert is triggered or the range decreases to less than the minimum allowed range for alert onset.

The test determines whether the countermeasure's required crash alert occurs at a range that is consistent with the alert onset timing requirements of Chapter 4. This test especially explores the ability of the countermeasure to issue timely warnings with a decelerating lead vehicle (see also Test C-12.) The test is also used to collect data for use in estimating expected exposure to in-path nuisance alerts for the countermeasure.

This test addresses Chapter 2 crash scenarios that include the following: Distracted driver RE; Inattentive driver RE; Aggressive driver RE.

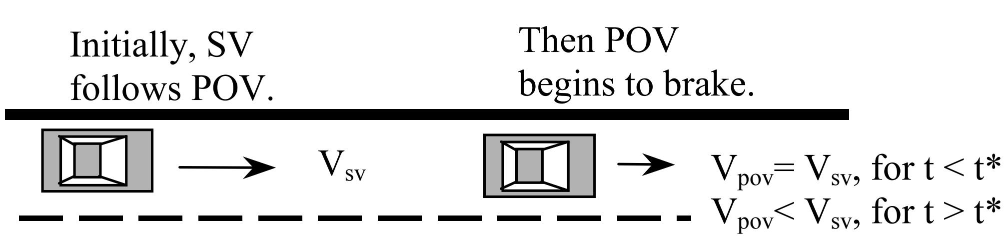

Figure 5-4 Test Maneuver Diagram for Test C-3

5.5.3.2 Track and Prop Setup

Roadway Geometry and Conditions

Use standard conditions, per Section 5.3.3.

POV Description

POV type: Midsize sedan.

For this test, the rear of the POV (and especially the brake lamps and retroreflective surfaces) should be dusty. This may challenge some countermeasure sensing systems.

5.5.3.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2.

5.5.3.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

5.5.3.5 Driving Instructions

To begin the test, the SV and the POV are each to be driven at a constant 27.8 m/sec (100 kph) in the center of the lane of travel. The headway from the SV to the POV should be 2.0 seconds. The POV then begins a braking maneuver of moderate intensity; the deceleration profile is described below. During the test, both vehicles should remain near the center of the lane. Allowable tolerances are given below.

The test begins seven seconds before the POV begins the braking maneuver, and ends when either of the following conditions is satisfied:

- The required crash alert has occurred.
- The range to the POV falls to less than 90% of the minimum allowable range at alert onset for the required crash alert.

After one of these events occurs, the SV driver is to steer and/or brake to keep the SV from striking the POV.

For the nominal initial speeds and assuming an *ideal* POV braking profile – a step change from constant speed to –0.32g – the maximum allowable range for onset of the crash alert would be 54.1 m and the minimum allowed range at alert onset would be 49.5 m.

(Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.)

For the trial to be valid, the following must be satisfied:

- The initial POV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The SV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The difference between the initial SV and POV speeds cannot be larger than 2 kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The range between the SV and POV, during the seven seconds before the POV begins to brake, must be equivalent to a headway of 1.85 to 2.15 seconds, based on the SV speed.
- The CG of the POV cannot deviate more than 0.30m away from a line parallel with the lane centerline during the entire test.
- The braking profile of the POV must satisfy the following:
    - 1.5 sec after the braking maneuver begins, the deceleration should nominally be -0.32g, with an acceptable error magnitude of 0.03g, until the test is over (see above for definition of the end of the test).
- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).
- The SV driver cannot touch the brake pedal before the required crash alert occurs, or before the range falls to less than 90% of the minimum allowable range for onset of the required crash alert.

5.5.4 Test C-4 100 kph to POV Stopped Under Overhead Sign

5.5.4.1 Test Overview and Purpose

This test consists of a SV traveling on a straight, flat road at highway speed toward a POV which is parked under an overhead sign, in the middle of the lane of travel. The test explores the countermeasure's ability to distinguish threats in the roadway from non-threatening objects over the roadway. The test is also used to collect data for use in estimating expected exposure to in-path nuisance alerts for the countermeasure.

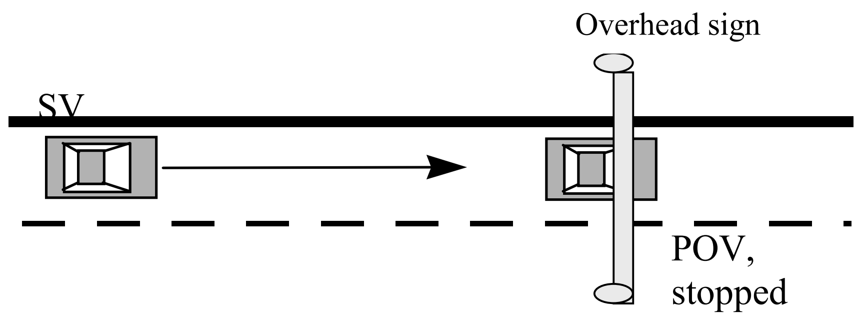

Figure 5-5 Test Maneuver Diagram for Test C-4

This test addresses Chapter 2 crash scenarios that include the following: Distracted driver RE, Inattentive driver RE, and Overhead object (operational scenario).

The countermeasure should provide the required crash alert at a range that is consistent with the alert onset timing requirements of Chapter 4.

5.5.4.2 Track and Prop Setup

Road Geometry and Conditions

Use conditions per Test N-1.

POV Description

POV type: Midsize sedan

Prop Description

Other Objects in the Scene: Overhead sign (see Test N-1).

5.5.4.3 Environmental Conditions Requirements

Use the same conditions as in Test N-1.

5.5.4.4 Instrumentation Requirements

Test Validity

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

Additional instrumentation requirements include:

- The location and orientation of the parked POV in the roadway, as stipulated in the general crash alert requirements.

5.5.4.5 Driving Instructions

The POV should be parked in the lane of travel, as described in Crash Alert Tests General Requirements. The position of the stationary POV should be determined, if necessary. (Only the relative position of the SV with respect to the POV is needed, and some measurement approaches will make absolute knowledge of POV position unnecessary.)

Drive the SV at a nominal speed of 27.8 m/sec (100 kph) in the center of the lane of travel, toward the parked POV. The test begins when the SV is 200m from the POV and ends when either of the following occurs:

- The required crash alert has occurred.
- The range to the POV falls to less than 90% of the minimum allowable range at alert onset, for the required crash alert.

After one of these events occurs, the SV driver must then steer and/or brake to keep the SV from striking the POV.

For the nominal SV speed, the maximum allowed alert onset range is 146.1m and the minimum allowed range for alert onset is 100.0m. (Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.)

For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than two kph (0.6 m/sec) during the test (with a confidence level of 95%).

- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).

- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).

- The SV driver cannot touch the brake pedal before the required crash alert occurs, or before the range falls to less than 90% of the minimum allowed range for onset of the required crash alert.

5.5.5 Test C-5 100 kph to Slowed or Stopped Motorcycle

5.5.5.1 Test Overview and Purpose

This test consists of a SV traveling on a straight, flat road at highway speed toward a stationary POV, which is a motorcycle with a rider. The test examines the countermeasure's ability to issue timely alerts to targets with small sensor cross-sections on an open roadway. The countermeasure should provide the required crash alerts at a range that is consistent with the alert onset timing requirements of Chapter 4. The test data is also used in estimating expected exposure to in-path nuisance alerts for the countermeasure.

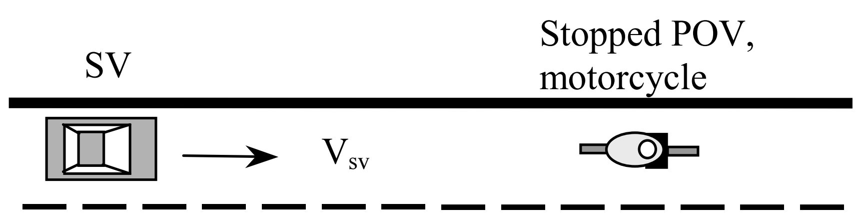

Figure 5-6 Test Maneuver Diagram for Test C-5

This test addresses Chapter 2 crash scenarios that include the following: Distracted driver RE and Inattentive driver RE.

5.5.5.2 Track and Prop Setup

Road Geometry and Conditions

Use standard conditions, per Section 5.3.3.

POV Description

POV type: Motorcycle with rider.

5.5.5.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2.

5.5.5.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

5.5.5.5 Driving Instructions

The POV should be parked in the lane of travel, as described in Crash Alert Tests General Requirements. The position of the stationary POV should be determined, if necessary. (Only the relative position of the SV with respect to the POV is needed, and certain measurement approaches may make absolute knowledge of POV position unnecessary.)

Drive the SV at a nominal speed of 27.8 m/sec (100 kph) in the center of the lane of travel, toward the parked POV. The test begins when the SV is 200m from the POV and ends when either of the following occurs:

- The required crash alert has occurred.
- The range to the POV falls to less than 90% of the minimum allowed range at the onset of the required crash alert.

After one of these events occurs, the SV driver must then steer and/or brake to keep the SV from striking the POV.

For the nominal SV speed, the maximum allowed alert onset range is 146.1m and the minimum allowed range for alert onset is 100.0m. (Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.)

For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than 2kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).

- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).
- The SV driver cannot touch the brake pedal before the required crash alert occurs, or before the range falls to less than 90% of the minimum range allowed for the onset of the crash alert.

5.5.6 Test C-6 Moderate-Speed SV to POV Stopped in Transition to a Curve (Wet Pavement)

5.5.6.1 Test Overview and Purpose

In this test, the SV approaches a POV parked in a zone of transition from a straight road segment to a curved road segment, as shown in Figure 5-7 below. Both vehicles should be near the center of the same lane; the pavement is wet. If successful, the countermeasure should issue the required crash alert at a range consistent with the alert onset timing requirements in Chapter 4. The test data is also used in estimating expected exposure to in-path nuisance alerts for the countermeasure.

The test studies the countermeasure's ability to track targets through changes in curvature. Wet pavement is used to ensure that countermeasures are able to identify curvature changes even in non-ideal situations. This test addresses Chapter 2 crash scenarios that include the Distracted driver RE and Inattentive driver RE scenarios.

5.5.6.2 Track and Prop Setup

Road Geometry and Conditions

Standard values per Section 5.3.3 apply, except the road surface should be wet and the roadway horizontal curvature must meet the requirements given below.

The test site for this test should consist of a straightaway of at least 200m followed by a sudden transition (less than 20m in length) to a constant curvature road section with a radius of curvature between 182 and 300 m. The lane in which the POV is stopped cannot have superelevation greater than 12% deg. (This superelevation limit is the maximum recommended by AASHTO for open highways in regions where snow and ice are not factors (see Policy on Geometric Design of Highways and Streets (1994)). This value is allowed here since proving ground facilities often do not have lower superelevation for curves of this radius.)

POV Descriptions

POV type: Midsize sedan.

5.5.6.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2.

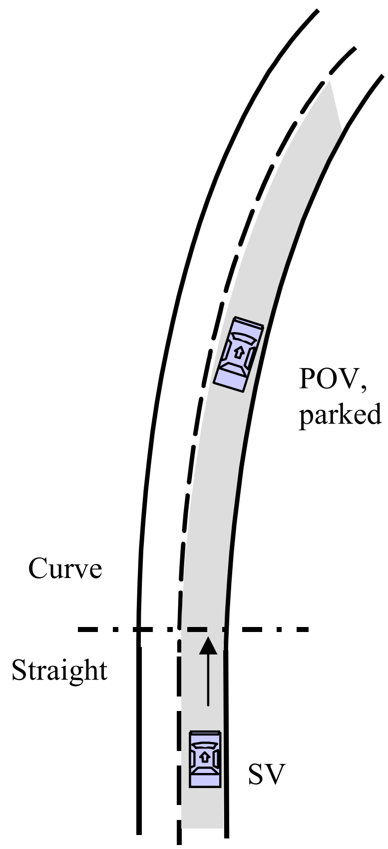

Figure 5-7 Schematic of Test Maneuver for Test C-6

5.5.6.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

Road curvature measurements must provide a 95% confidence that the test site meets specifications.

Instrumentation should support the determination that the POV is placed as required, relative to the transition of curvature, as given below in Driving Instructions.

5.5.6.5 Driving Instructions

The test begins with the POV stopped near the center of a lane of travel at a location just beyond the transition from a straight road segment to a curve. The SV travels at a constant speed, in the same lane as the POV, and approaches along the curve. The alert onset will be required in a region very near the transition, as described below.

The SV vehicle speed and POV location along the road depend on the curvature at the specific test site, as shown in the table below. The dependence on curvature is used to reduce the sensitivity of test results to the specific test site. The values in the table follow from two relationships. First, AASHTO guidelines are used to select the radius of curvatures that correspond to moderate speeds of 65 to 80 kph, which is the range of speeds of interest for the scenario. The radii in the table correspond approximately to the minimum radius recommended for a 4% superelevation curve for the corresponding speeds in the table, and therefore represent challenging but realistic road geometries. The second consideration leads to the required placement of the parked POV down-road from the transition. Based on the curve/speed selection, the POV is placed in slightly different locations. The values shown in the table all provide a maximum azimuth angle (angle between the SV's direction of travel and the line of sight from the SV to the POV) that is approximately the same across the allowed values of radii (8.2 deg). This requires the same sensor coverage to pass the test, independent of the test site.

Radius of curve	**Required SV speed**	**POV placement – rear-end location, down-road from the transition from straight to curve**
182 – 206 m	65 kph	58 m
207 – 250 m	70 kph	68 m
251 – 288 m	75 kph	77 m
288 – 300 m	80 kph	86 m

Table 5-4 Curve and SV Speed Requirements for Test C-6

The test begins when the SV is 150 m from the POV. The test ends when either of the following occurs:

- The required crash alert has occurred.
- The range to the POV falls to less than 90% of the minimum range allowed for the crash alert.

After one of these events occurs, the SV driver must then steer and/or brake to keep the SV from striking the POV.

The range at which alert onset occurs must be consistent with the timing requirements of Chapter 4. Depending on the exact SV speed during a test trial, the latest allowed alert will be somewhere between 60 and 90 m. Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.

For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than two kph (0.6 m/sec) (with a confidence level of 95%).
- The lateral distance of the CG of the POV and the heading angle of the POV must meet the requirements for a parked POV test situation, as described in Section 5.4.1.2.
- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.30 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.30deg) (with a confidence level of 95%).
- The SV driver cannot touch the brake pedal before the required crash alert occurs, or before the range falls to less than 90% of the minimum range allowed for onset of the crash alert.

5.5.7 Test C-7 Highway-Speed SV to POV Stopped in a Curve

5.5.7.1 Test Overview and Purpose

In this test, the SV, traveling through a curve at highway speed, approaches a stationary POV parked near the center of a lane in a curve, as shown below in Figure 5-8. Throughout the test, the SV travels near the center of the lane in which the POV is parked, and the SV remains at constant speed. The lane does not have painted lane markings. The test verifies the countermeasure's ability to identify a threat on a curved road segment without painted lane markings. If successful, the countermeasure would issue the required crash alert at a range consistent with the alert onset timing requirements of Chapter 4. The test data is also used in estimating expected exposure to in-path nuisance alerts for the countermeasure.

This test addresses Chapter 2 crash scenarios that include the Distracted driver RE and Inattentive driver RE scenarios.

5.5.7.2 Track and Prop Setup

Road Geometry and Conditions

Use standard conditions, per Section 5.3.3, except a moderate value for roadway horizontal curvature is desired, and the test should be run with “no lane markings,” a condition defined in detail in the Definitions section.

The test site for this test should be a constant curvature road section with a radius of curvature between 456 and 700 m. The lane in which the POV is stopped cannot have superelevation greater than 12% deg. (This superelevation limit is the maximum recommendation by AASHTO for open highways in regions where snow and ice are not factors (see Policy on Geometric Design of Highways and Streets (1994)). This value is allowed here since proving ground facilities often do not have lower superelevation for curves of this radius.)

POV Descriptions

POV type: Midsize sedan.

5.5.7.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2.

5.5.7.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

Road curvature measurements must provide a 95% confidence that the test site meets specifications.

5.5.7.5 Driving Instructions

The POV is parked in a curve, at least 400m from the beginning of the curve, near the center of a lane of travel. The SV, traveling in the same lane, approaches the POV at a speed that depends on the test site road curvature, as shown in the table below.

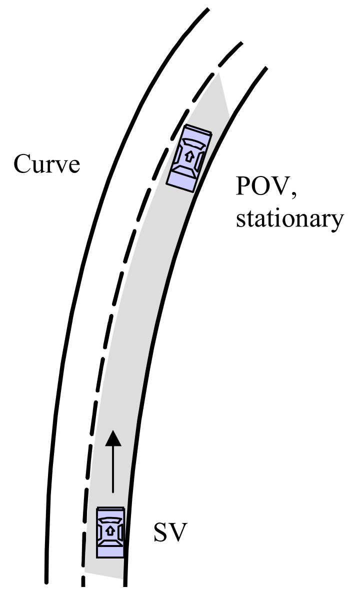

Figure 5-8 Schematic of Test Maneuver for Test C-7

The SV speed depends on the curvature at the test site in order to reduce the sensitivity of test results to the curvature of the test site, but still provide a realistic curvature scenario. Values in the table are chosen using two relationships. First, AASHTO guidelines are used to select radius of curvatures that correspond to speeds of 90 to 110 kph, which is the range of speeds of interest for the scenario. The radii in the table correspond approximately to the minimum radius recommended for a 4% superelevation curve for these speeds, and therefore represent challenging but realistic road geometries. The table shows that the azimuth angle (angle between the SV's direction of travel and the line of sight from the SV to the POV) at a range of 100m varies from approximately 4.1 to 6.3 deg. This variation should not affect repeatability across test sites since a countermeasure will need more azimuth coverage than this to pass another test, Test C-6, which requires approximately 8 deg azimuth to one side of the longitudinal axis.

Radius of curve	**Required SV speed**	**Approximate azimuth angle at 100 m range**
456 – 478 m	95 kph	6.3 deg
479 - 541 m	100 kph	5.7 deg
541 - 641m	105 kph	4.9 deg
640 - 700 m	110 kph	4.1 deg

Table 5-5 Curve and SV Speed Requirements for Test C-7

The test begins when the SV is 200 m from the POV. The test ends when either of the following occurs:

- The required crash alert has occurred.
- The range to the POV falls to less than 90% of the minimum allowed range for onset of the required crash alert.

The alert onset should occur at a range that is between the minimum and maximum allowed values, as described in the alert onset requirements of Chapter 4. These values depend on the actual SV speed during a test trial, but the minimum allowed value is likely to be the 100.0m limit on required warning range. See Appendix B for instructions on computing the alert onset timing requirements as a function of the actual SV speed.

For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) (with a confidence level of 95%).
- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.60 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.60deg) (with a confidence level of 95%).
- The SV driver cannot touch the brake pedal before either the required crash alert occurs or the range falls to less than 90% of the minimum allowable range for onset of the crash alert.

5.5.8 Test C-8 Moderate-Speed SV to Slower Moving POV, in Tight Curve

5.5.8.1 Test Overview and Purpose

In this test, the SV approaches a slower-moving POV in a tight curve. Both vehicles are traveling near the center of the same lane. The test investigates the countermeasure's ability to identify moving targets in tight curvature situations. If successful, the countermeasure would issue the required crash alert at a range consistent with the alert onset timing requirements of Chapter 4. The test data is also used in estimating expected exposure to in-path nuisance alerts for the countermeasure.

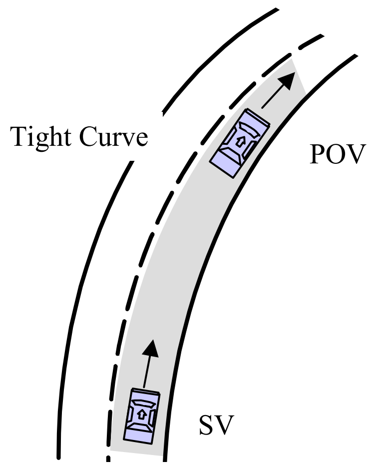

Figure 5-9 Schematic of Test Maneuver for Test C-8

This test addresses Chapter 2 crash scenarios that include the Distracted driver RE and Inattentive driver RE scenarios.

5.5.8.2 Track and Prop Setup

Road Geometry and Conditions

Use standard conditions, per Section 5.3.3, except for the roadway geometry.

The roadway geometry here is intended to represent a relatively tight curve, such as those found on cloverleaf interchanges. The test site for this test should consist of a straightaway of at least 200m followed by a sudden transition to a constant curvature road section with a radius of curvature between 182 and 300 m. The lane in which the POV is stopped cannot have superelevation greater than 12% deg. (This superelevation limit is the maximum allowed by AASHTO standards for public roads (see Policy on Geometric Design of Highways and Streets (1994)). This value is allowed here since proving ground facilities often do not have lower superelevation curves of this radius.)

POV Descriptions

POV type: Midsize sedan.

5.5.8.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2.

5.5.8.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

Road curvature measurements must provide a 95% confidence that the test site meets specifications.

5.5.8.5 Driving Instructions

The test begins with the SV and POV each traveling at constant speed near the center of the same travel lane. The initial speed of the SV depends on the curvature of the test site, as described below. The POV speed should be 40kph less than the SV speed. The maneuver should be executed so that the required crash alert is triggered while both vehicles are in the tightly curved section.

The SV speed should be based on the radius of curvature of the test site, as shown in the table below. This dependence is used to reduce the dependence of test results on the specific curvature at a test site, while still testing the countermeasure's performance in a realistic and challenging curve scenario. Values in the table are chosen using two relationships. First, AASHTO guidelines are used to select radius of curvatures that correspond to speeds of 65 to 80 kph, which is the range of speeds of interest for the scenario. The radii in the table correspond approximately to the minimum radius recommended for a 4% superelevation curve for these speeds. The table shows that the azimuth angle (angle between the SV's direction of travel and the line of sight from the SV to the POV) at the minimum allowed range for crash alert onset varies from 2.7 to 4.6 deg. This variation should not affect repeatability across test sites since a countermeasure will need more azimuth coverage than this to pass another test, Test C-6, which requires approximately 8 deg azimuth to one side of the longitudinal axis.

Radius of curve	Required SV speed	Required POV speed	Approximate azimuth angle at minimum allowed range for alert onset
182 – 206 m	65 kph	25 kph	4.6 deg
207 – 250 m	70 kph	30 kph	3.7 deg
251 – 288 m	75 kph	35 kph	3.1 deg
288 – 300 m	80 kph	40 kph	2.7 deg

Table 5-6 Curve and SV Speed Requirements for Test C-8

The test begins when the SV is 150 m from the POV. The test ends when either of the following occurs:

- The required crash alert has occurred.

- The range to the POV falls to less than 90% of the minimum range allowed at onset of the crash alert.

The onset of the crash alert should occur at a range that is between the minimum and maximum allowed alert onset distances, per the alert onset timing requirements of Chapter 4. Appendix B gives instructions for computing the alert onset timing requirements as a function of the speeds and accelerations of the vehicles during an actual test trial.

For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) (with a confidence level of 95%).

- The POV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) (with a confidence level of 95%).

- The lateral distance of the CG of the POV, relative to the center of the lane, in road coordinates, cannot exceed 0.30m (with a confidence level of 95%).

- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).

- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.60 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.60deg) (with a confidence level of 95%).

- The SV driver cannot touch the brake pedal before either the required crash alert occurs or the range falls to less than 90% of the minimum allowed range at onset of the required crash alert.

5.5.9 Test C-9 POV at 67 kph Cuts in Front of 100 kph SV

5.5.9.1 Test Overview and Purpose

In this test, the SV is initially traveling at constant speed in a given lane on a straight, flat road. A slower-moving POV, which is initially traveling in an adjacent lane, changes lanes so that it cuts in front of the SV.

The test determines whether the countermeasure crash alert occurs at an appropriate times. The appropriate time is a function of both the lateral position of the POV, relative to the SV, and the combination of range, range rate, and relative longitudinal acceleration between the two vehicles. The requirements are described in the alert onset timing requirements section of Chapter 4. The test data is also used in estimating expected exposure to in-path nuisance alerts for the countermeasure.

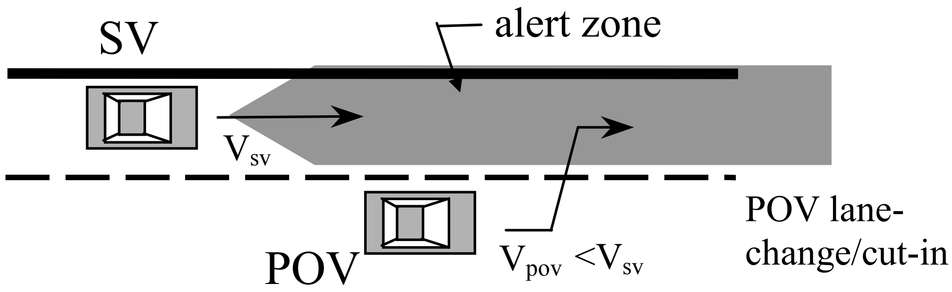

Figure 5-10 Test Maneuver Diagrams for Test C-9

This test addresses the Chapter 2 crash scenario: Lane Change RE (POV cut-in).

Criteria for Successful Countermeasure Performance

Chapter 4 describes the Alert Zone and the alert onset timing requirements. Given a test trial that meets the requirements given below, the onset of the crash alert must not violate either the requirements on allowable lateral locations of targets or the requirements on alert onset timing.

5.5.9.2 Track and Prop Setup

Roadway Geometry and Conditions

Use standard conditions, per Section 5.3.3.

POV Description

POV type: Midsize sedan

5.5.9.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2.

5.5.9.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

5.5.9.5 Driving Instructions

In this test, the SV is initially traveling at a constant speed of 27.8 m/sec (100 kph) near the center of a given lane on a straight, flat road. A slower-moving POV (at 18.6 m/sec, or 67 kph), which is initially traveling near the center of an adjacent lane, changes lanes so that it cuts in front of the SV. The closing speed is nominally 9.2 m/sec, or 33 kph. For the nominal speeds, the maximum allowed range at alert onset range is 41.6 m and the minimum allowed range for alert onset is 21.9 m. (Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.)

The initial lateral offset between the vehicle CGs should be a standard U.S. lane-width (3.66 m), with an allowable deviation of 0.50 m. There should be a confidence level of 95% that this condition is met for a 3.0 sec duration before the POV begins its cut-in.

The SV's Alert Zone is centered about the vehicle longitudinal axis and extends symmetrically to a width of 3.66m, as described in Chapter 4. The part of the SV's Alert Zone in which a crash alert must occur (assuming appropriate relative motion in the longitudinal direction) extends laterally to the edge of the SV's physical boundary. When the POV first begins to enter the Alert Zone, the range from the SV to the POV should be between 32m and 42m (95% confidence required). When entering the Alert Zone, the lateral speed of the POV should be between 0.75 and 1.5 m/sec, measured in the roadway coordinates. The POV should cross laterally into the part of the Alert Zone in which alerts are required at a range of between 24m and 34m.

The test begins when the SV is 90 m from the POV and ends when either of the following occurs:

- The required crash alert has occurred.
- The range to the POV falls to less than 90% of the minimum range allowed for the onset of the crash alert.

After one of these events occurs, the SV driver must then steer and/or brake to keep the SV from striking the POV.

For the trial to be valid, the following must hold for the duration of the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) during the test (with a confidence level of 95%).

- The POV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The variation in the lateral distance of the CG of the SV, relative to the travel lane centerline, cannot exceed 0.50 m (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).
- The SV driver cannot touch the brake pedal before either the required crash alert occurs or the range falls to less than 90% of the minimum allowed range for the onset of the crash alert.

5.5.10 Test C-10 SV at 72 kph Changes Lanes and Encounters Stopped POV

5.5.10.1 Test Overview and Purpose

This test begins with a SV traveling at 72 kph near the center of a lane on a straight, flat road. A stationary POV is parked in an adjacent lane. When the SV is not far from the parked POV, it abruptly changes lanes, in an imitation of an aggressive driver. The test examines the countermeasure's ability to quickly identify threats and warn the driver in situations in which the SV itself is performing maneuvers. This test addresses the Aggressive driver RE crash scenario.

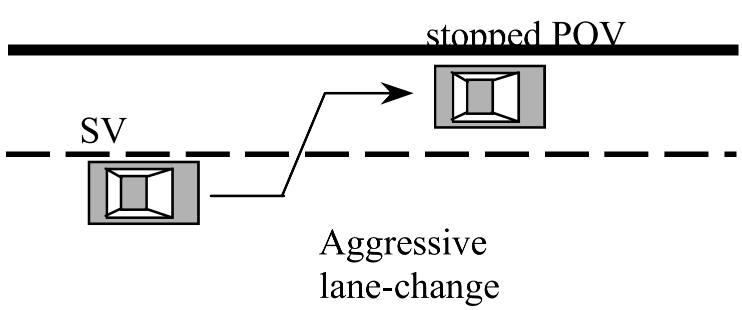

Figure 5-11 Test Maneuver Diagram for Test C-10

Criteria for Successful Countermeasure Performance

The countermeasure should provide the required crash alert when two conditions are satisfied: (1) the range to the POV is within the bounds of the alert onset timing requirements (Chapter 4), and (2) the POV has crossed laterally into that part of the Alert Zone in which crash alerts are required when condition (1) is satisfied. (See Chapter 4 for a description of the regions of the Alert Zone in which the crash alert is required, allowed, and not allowed.)

The test data is also used in estimating expected exposure to in-path nuisance alerts for the countermeasure.

5.5.10.2 Track and Prop Setup

Road Geometry and Conditions

Use standard conditions, per Section 5.3.3.

POV Descriptions

POV type: Midsize sedan.

5.5.10.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2.

5.5.10.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

Instrumentation needs for this test also include measuring:

- Location and orientation of the parked POV with respect to either the lane of travel, or the roadway, whichever applies, as stipulated in the general crash alert requirements.

5.5.10.5 Driving Instructions

The POV should be parked in the lane of travel, as described in Crash Alert Tests General Requirements. The position of the stationary POV should be determined, if necessary. (Only the relative position of the SV with respect to the POV is needed, and certain measurement approaches may make absolute knowledge of POV position unnecessary.)

Drive the SV toward the parked POV at a nominal speed of 20.0 m/sec (72 kph); the SV should be kept near the center of a lane adjacent to the lane in which the stopped POV is parked. The SV should change lanes early enough so that there is overlap in the lateral direction between the edges of the SV and the POV at a range of more than 100m, but less than 120m. The test begins when the SV is still 200m from the POV and ends when either of the following occurs:

- The required crash alert occurs.
- The range to the POV falls to less than 90% of the minimum range allowed for the onset of the crash alert.

After one of these events occurs, the SV driver must then steer and/or brake to keep the SV from striking the POV.

For the nominal SV speed, the alert onset timing requirements of Chapter 4 call for the alert to begin at a range that is between 77.9 and 94.2 m.

For the trial to be valid, the following must hold throughout the entire test:

- The SV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The SV driver cannot touch the brake pedal before either the required crash alert occurs or the range falls to less than 90% of the minimum range allowed for the onset of the crash alert.

In addition, the following must hold in the initial few seconds of the test, before the SV begins to change lanes:

- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 3.66+0.50m = 4.16m (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).

Finally, the SV lane-change should be such that:

- When the SV is within 70m of the POV, the lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot be larger than 0.50 m (with a confidence level of 95%).

5.5.11 Test C-11 100 kph to Stopped POV, With Fog

5.5.11.1 Test Overview and Purpose

This test consists of a SV traveling on a straight, flat road at highway speed toward a vehicle which is stopped in the middle of the lane of travel. The atmospheric visibility is poor, due to fog. The test investigates whether the countermeasure complies with the minimum functional requirement (from Chapter 4) that states that the FCW must either (1) operate without reduced operating range, or (2) signal the driver that it is unable to function to its fullest operating range

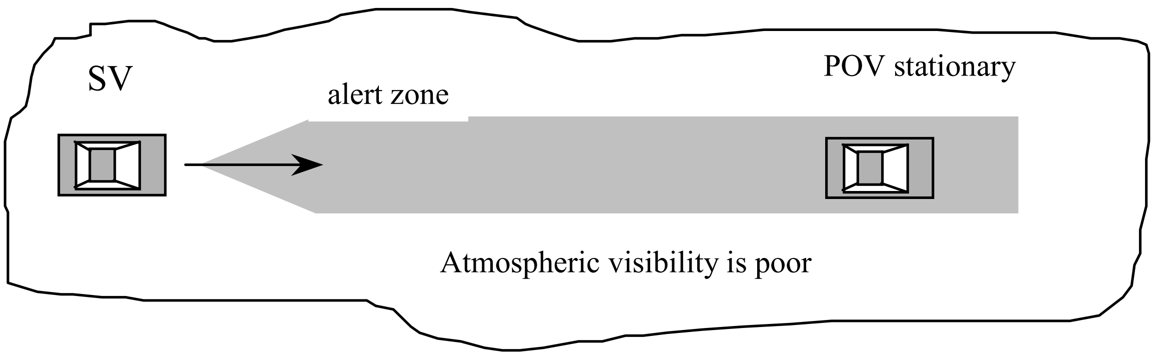

Figure 5-12 Test Maneuver Diagram for Test C-11

This test addresses the Chapter 2 crash scenario: Visibility RE

Criteria for Success of Test

The countermeasure should have one of two responses. The first acceptable response is that the countermeasure provides the crash alert such that its onset is consistent with the timing requirements of Chapter 4, and is within 10% of the nominal warning ranges the system has under these conditions (see Test C-1). The second acceptable response is that the system signals the driver that it cannot operate to its full operating range.

5.5.11.2 Track and Prop Setup

Road Geometry and Conditions

Use standard conditions, per Section 5.3.3, except – due to the need for fog – the roadway is allowed to be wet if necessary, as long as the safety of the test is not compromised

POV Descriptions

POV type: Midsize sedan

5.5.11.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2, except the atmospheric visibility should be poor (see Definitions for a precise description of allowable visibility measures). For this test, the visibility should be poor due to naturally occurring or artificially created fog.

5.5.11.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

Additional instrumentation requirements for this test include:

- Location and orientation of the parked POV with respect to either the lane of travel, or the roadway, whichever applies, as stipulated in the general crash alert requirements.

Instrumentation should support that the local atmospheric conditions satisfy the definition of “poor visibility,” as described in Definitions. This will involve a measurement of the instantaneous visibility at the specific testing site. Also, it is necessary to detect whether the countermeasure signals the driver that it is unable to function to its full range due to the reduced visibility. Determining whether the system is signaling in such a way can be a manual function requiring no instrumentation.

5.5.11.5 Driving Instructions

The POV should be parked in the lane of travel, as described in Crash Alert Tests General Requirements. The position of the stationary POV should be determined, if necessary. (Only the relative position of the SV with respect to the POV is needed, and some measurement approaches will make absolute knowledge of POV position unnecessary.) Atmospheric visibility should be “poor,” as defined in the Definitions section.

Drive the SV at a nominal speed of 27.8 m/sec (100 kph) in the center of the lane of travel, toward the parked POV. The test begins when the SV is 200m from the POV and ends when any of the following occurs:

- The required crash alert occurs.

- The range to the POV falls to less than 90% of the minimum range allowable for the onset of the crash alert.

- The countermeasure signals the driver that it cannot operate at its full range.

After one of these events occurs, the SV driver must then steer and/or brake to keep the SV from striking the POV.

For the nominal SV speed, the maximum allowed range at alert onset is 146.1m and the minimum allowed range for alert onset is 100.0m. (Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.) For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).
- The SV driver cannot touch the brake pedal before either the required crash alert occurs or the range falls to less than 90% of the minimum range allowed for the onset of the crash alert.

5.5.12 Test C-12 POV Brakes While SV Tailgates at 100 kph

5.5.12.1 Test Overview and Purpose

This test begins with a SV following a POV that is traveling at constant speed on a straight, flat road. The POV begins to brake while the SV maintains its speed. The test determines whether the countermeasure issues the crash alert with a timing that is consistent with the alert onset timing requirements described in Chapter 4. This test especially explores the ability of the countermeasure to issue timely warnings with a decelerating lead vehicle (see also Test C-3.) The test data is also used to estimate the expected exposure to in-path nuisance alerts for the countermeasure.

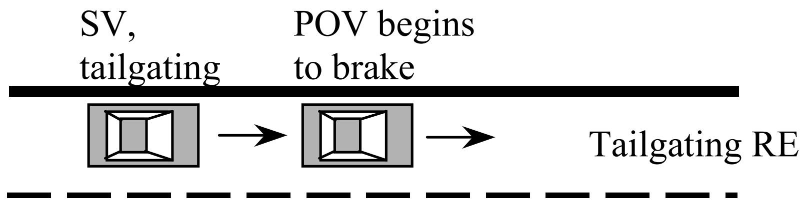

Figure 5-13 Test Maneuver Diagram for Test C-12

This test addresses the Chapter 2 crash scenario: Tailgate RE

5.5.12.2 Track and Prop Setup

Road Geometry and Conditions

Use standard conditions, per Section 5.3.3.

POV Descriptions

POV type: Midsize sedan

5.5.12.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2.

5.5.12.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

5.5.12.5 Driving Instructions

Drive the POV at a nominal speed of 27.8 m/sec (100 kph) in the center of the lane of travel. The SV should also be at the same constant speed, at a headway of 1.0 seconds. After this configuration is held for at least 5.0 seconds, the POV should begin a deceleration with a nominal value of –0.15g. The test ends when one of the following occurs:

- The required crash alert occurs.
- The range to the POV falls to less than 90% of the minimum range allowable for onset of the required crash alert.

After one of these events occurs, the SV driver must then steer and/or brake to keep the SV from striking the POV.

For the nominal initial speeds and assuming an *ideal* POV braking profile – a step change from constant speed to -0.15g – the maximum allowable range for onset of the crash alert would be 24.9 m and the minimum allowed range at alert onset would be 17.9 m. (Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.)

For the trial to be valid, the following must hold before the POV braking maneuver begins:

- The POV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The headway between the SV and POV, during the seven seconds before the POV begins to brake, should be between 0.85 to 1.15 seconds.

The braking profile of the POV must satisfy the following:

- 1.5 seconds after the POV begins to decelerate, its deceleration should remain within 0.03 g of the nominal deceleration level of –0.15g. This should continue until the test is over (see above for definition of the end of the test).

For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The lateral position of the CG of the POV, relative to the road edge, cannot exceed 0.30 m (with a confidence level of 95%).
- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).
- The SV driver cannot touch the brake pedal before either the required crash alert occurs or the range falls to less than 90% of the minimum range allowed at the onset of the crash alert.

5.5.13 Test C-13 Greater Size and Equal Distance

5.5.13.1 Test Overview and Purpose

This test includes a POV with a small sensor cross-section (a motorcycle) traveling between two POVs with large sensor cross-sections (trucks). All three POVs are traveling at the same speed and each POV is near the center of its lane, as shown in the figure below. The SV is moving faster, and approaches the three POVs at constant speed while traveling in the same lane as the small sensor cross-section POV. The test determines whether the countermeasure issues the crash alert at a range that is consistent with the alert onset timing requirements of Chapter 4. The test data is also used to estimate expected exposure to in-path nuisance alerts for the countermeasure.

This test is one of two tests that explore the countermeasure's ability to resolve in azimuth a target with a small sensor cross-section, while traveling in traffic. (The other test is an out-of-path nuisance alert test, without the motorcycle.)

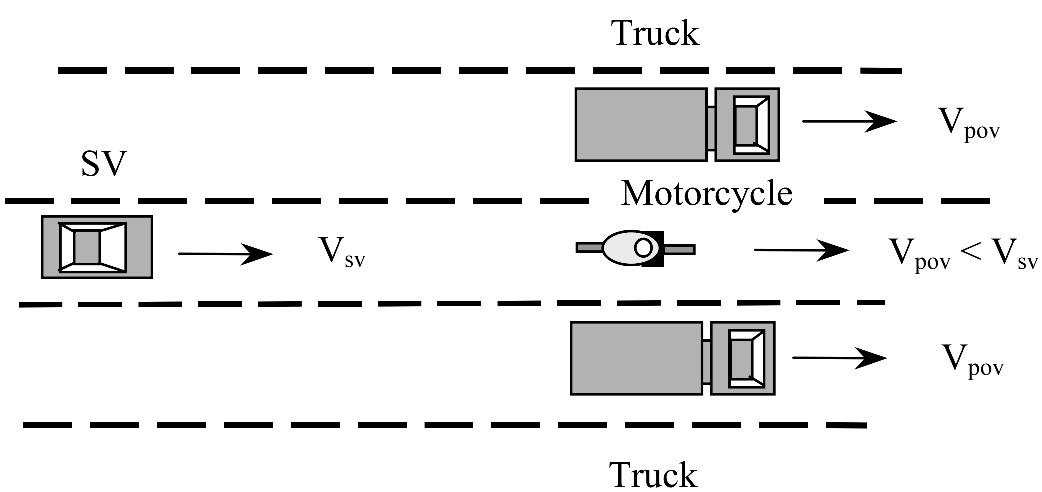

Figure 5-14 Schematic of Test Maneuver for Test C-13

This test addresses Chapter 2 crash scenarios Distracted driver RE and Inattentive driver RE, as well as the operational scenario Greater size and Equal Distance RE.

5.5.13.2 Track and Prop Setup

Road Geometry and Conditions

Use standard conditions, per Section 5.3.3.

POV Descriptions

POV types: Trucks (2), Motorcycle (1).

5.5.13.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2.

5.5.13.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

5.5.13.5 Driving Instructions

The test begins with the three POVs traveling side-by-side at a constant speed of 8.9 m/sec (32 kph), each in the center of their respective lanes of travel. The SV approaches the POVs at 27.8 m/sec (100 kph), also traveling near the center of its lane. The test begins when the SV is 150 m from the POVs. The test ends when either of the following occurs:

- The required crash alert occurs.
- The range to the POV falls to less than 90% of the minimum range allowable for the onset of the required crash alert.

For the nominal speeds, the alert onset range should be between 65.4m and 104.9m. (Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.)

For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) (with a confidence level of 95%).
- The vehicle speed of each of the three POVs cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).

- The lateral distance of the CG of the primary POV (the motorcycle), relative to the centerline of its respective lane, in road coordinates, cannot exceed 0.30 m (with a confidence level of 95%).
- The lateral distance of the CG of the secondary POVs (the trucks), relative to the centerline of its respective lane, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- The lateral position of the CG of the SV, relative to the lateral position of the primary POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- The longitudinal position of the rear-most point on each of the three vehicles must all fall within 3.0m of each other (with a confidence of 95%).
- The SV driver cannot touch the brake pedal before either the required crash alert occurs or the range falls to less than 90% of the minimum range allowed for onset of the crash alert.

5.5.14 Test C-14 Greater Size and Greater Distance

5.5.14.1 Test Overview and Purpose

This test includes a POV with a small sensor cross-section (a motorcycle) traveling behind a POV with a large sensor cross-section (a truck). The two POVs are traveling at the same speed and each POV is near the center of the same lane, as shown in the figure below. A faster-moving SV approaches the POVs from behind, at constant speed, traveling in the same lane. The test determines whether the countermeasure can distinguish between the two POVs, identify the motorcycle as the immediate target, and issue the required crash alert at a range consistent with the Chapter 4 alert onset timing requirements. The test data is also to estimate the expected exposure to in-path nuisance alerts for the countermeasure.

This test explores an aspect of the countermeasure's ability to resolve targets with small sensor cross-sections in traffic.

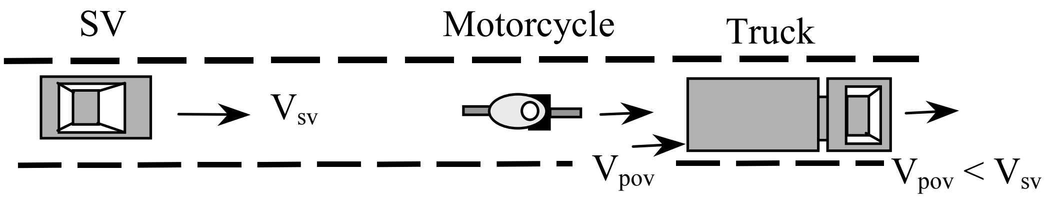

Figure 5-15 Schematic of Test Maneuver for Test C-14

5.5.14.2 Track and Prop Setup

Road Geometry and Conditions

Use standard conditions, per Section 5.3.3.

POV Descriptions

POV types: Truck (1), Motorcycle (1).

5.5.14.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2.

5.5.14.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

5.5.14.5 Driving Instructions

The test begins with the two POVs each traveling at the same constant speed of 8.9 m/sec (32 kph). The motorcycle follows the truck at a nominal range of 20 m (with tolerances given below), and both POVs remain near the center of the lane of travel.

The SV approaches the POVs at 27.8 m/sec (100 kph), also traveling near the center of the same lane as the POVs. The test begins when the SV is 150 m from the POVs. The test ends when either of the following occurs:

- The required crash alert occurs.

- The range to the POV falls to less than 90% of the minimum range allowed for onset of the crash alert, where the appropriate target is the motorcycle.

For the nominal SV speed, the maximum allowed range at alert onset is 104.9m and the minimum allowed range for alert onset is 65.4m. (Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.)

For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) (with a confidence level of 95%).
- The vehicle speed of each of the two POVs cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) (with a confidence level of 95%).
- The distance at which the motorcycle follows the truck cannot deviate from the nominal range by more than 5.0m (with a confidence level of 95%).
- The lateral distance of the CG of the SV, relative to the CG of the primary POV (the motorcycle), in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- The lateral distance of the CG of the primary POV (the motorcycle), relative to the centerline of its respective lane, in road coordinates, cannot exceed 0.30 m (with a confidence level of 95%).
- The lateral distance of the CG of the secondary POVs (the trucks), relative to the centerline of its respective lane, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).
- The SV driver cannot touch the brake pedal before either the required crash alert occurs or the range falls to less than 90% of the minimum range allowed for onset of the required crash alert.

5.5.15 Test C-15 100 kph to 32 kph Truck

5.5.15.1 Test Overview and Purpose

This test includes a POV with a large sensor cross-section (a truck). A faster-moving SV approaches the POVs from behind, at constant speed, traveling in the same lane. This test serves as a complement to Test C-14, since this test determines the range at alert onset for the truck alone. For successful performance, the countermeasure should issue the alert at a range consistent with the alert onset timing requirements of Chapter 4. The test data is also used to estimate expected exposure to in-path nuisance alerts for the countermeasure.

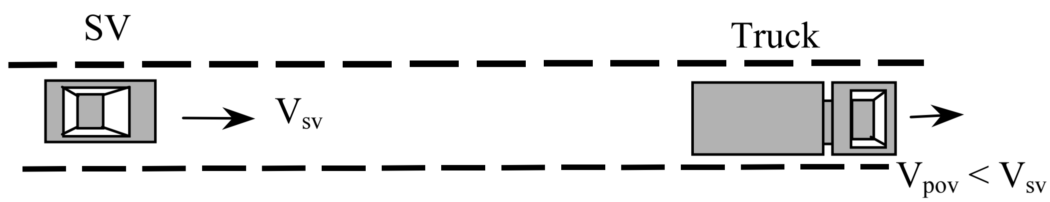

Figure 5-16 Schematic of Test Maneuver for Test C-15

5.5.15.2 Track and Prop Setup

Road Geometry and Conditions

Use standard conditions, per Section 5.3.3.

POV Descriptions

POV types: Truck (1).

5.5.15.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2.

5.5.15.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

5.5.15.5 Driving Instructions

The test begins with the large POV traveling at a constant speed of 8.9 m/sec (32 kph), and remaining near the center of the lane of travel.

The SV approaches the POV at 27.8 m/sec (100 kph), also traveling near the center of the same lane as the POV. The test begins when the SV is 150 m from the POV. The test ends when either of the following occurs:

- The required crash alert occurs.
- The range to the POV falls to less than 90% of the minimum range allowed for the onset of the crash alert.

For the nominal SV speed, the maximum allowed range at alert onset is 104.9m and the minimum allowed range for alert onset is 65.4m. (Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.)

For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) (with a confidence level of 95%).
- The vehicle speed of each of the POV cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) (with a confidence level of 95%).
- The lateral position of the CG of the POV, relative to the road edge, should not vary by more than 0.30m. (with a confidence level of 95%).
- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).
- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).
- The SV driver cannot touch the brake pedal before either the required crash alert occurs or the range falls to less than 90% of the minimum range allowed at the onset of the required crash alert.

5.5.16 Test C-16 SV to POV Stopped in Transition to Curve (Poor Lane Markings)

5.5.16.1 Test Overview and Purpose

This test is similar to Test C-6, except here the test should be executed on dry pavement with poor lane markings. In this test, the SV approaches a POV stopped in a zone of transition from a straight road segment to a curved road segment, as shown earlier in Figure 5-7. Both vehicles should be near the center of the same lane. The test studies the countermeasure's ability to track targets through changes in curvature. If successful, the countermeasure should issue the required crash alert at a range consistent with the alert onset timing requirements in Chapter 4. The test data is also used in estimating expected exposure to in-path nuisance alerts for the countermeasure.

This is a common driving situation that may challenge some countermeasures' ability to detect curvature changes. This test addresses Chapter 2 crash scenarios that include the Distracted driver RE and Inattentive driver RE scenarios.

5.5.16.2 Track and Prop Setup

Road Geometry and Conditions

Standard values per Section 5.3.3.1 apply, except the roadway horizontal curvature and the quality of the lane markings.

The roadway geometry should meet the same requirements given for Test C-6.

"Poor quality lane markings" should be used. A detailed definition of this condition is given in the Definitions section. Note that good quality lane markings can be made into poor quality lane markings (as defined in this chapter) by obscuring the lane markings, for example, by sand.

POV Descriptions

Same requirements as for Test C-6.

5.5.16.3 Environmental Conditions Requirements

Same requirements as for Test C-6.

5.5.16.4 Instrumentation Requirements

Instrumentation requirements are identical to those of Test C-6.

Countermeasure Performance Evaluation

Same as for Test C-6.

5.5.16.5 Driving Instructions

Same as for Test C-6.

5.5.17 Test C-17 24 kph to Stopped POV

5.5.17.1 Test Overview and Purpose

This test consists of a SV traveling on a straight, flat road at low speed toward a vehicle which is parked in the middle of the lane of travel. The test is to determine whether the countermeasure crash alert onset occurs at a range that is consistent with the alert onset timing requirements described in Chapter 4. The test is also used to estimate the expected exposure to in-path nuisance alerts for the countermeasure.

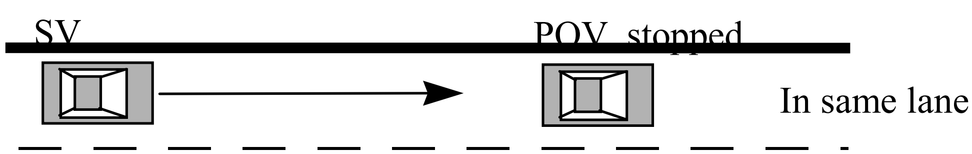

Figure 5-17 Test Maneuver Diagram for Test C-17

This test addresses Chapter 2 crash scenarios that include the following: Distracted driver RE; and Inattentive driver RE.

5.5.17.2 Track and Prop Setup

Road Geometry and Conditions

Use standard conditions, per Section 5.3.3.1.

POV Description

POV type: Midsize sedan

5.5.17.3 Environmental Conditions

Use standard conditions, per Section 5.3.3.2.

5.5.17.4 Instrumentation Requirements

The standard instrumentation requirements for crash alert tests are given in Section 5.4.2.

In addition, instrumentation accuracies should support the determination of whether or not the location and orientation of the stopped POV are as stipulated in the general crash alert requirements.

5.5.17.5 Driving Instructions

The POV should be parked in the lane of travel, as described in Crash Alert Tests General Requirements. The position of the stationary POV should be determined, if necessary. (Only the relative position of the SV with respect to the POV is needed, and some measurement approaches will make absolute knowledge of the POV position unnecessary.)

Drive the SV at a nominal speed of 6.7 m/sec (24 kph) in the center of the lane of travel, toward the parked POV. The test begins when the SV is 100m from the POV and ends when either of the following occurs:

- The required crash alert occurs.
- The range to the POV falls to less than 90% of the minimum allowable range for the onset of the required crash alert.

After one of these events occurs, the SV driver must then steer and/or brake to keep the SV from striking the POV.

For the nominal SV speed, the maximum allowed alert onset range is 21.6m and the minimum allowed range for alert onset for the crash alert is16.5m. (Appendix B gives instructions for computing alert onset timing requirements for the crash alert tests as a function of the actual speeds and accelerations measured during a test trial.)

For the trial to be valid, the following must hold throughout the test:

- The SV vehicle speed cannot deviate from the nominal speed by more than 2 kph (0.6 m/sec) during the test (with a confidence level of 95%).
- The lateral distance of the CG of the SV, relative to the CG of the POV, in road coordinates, cannot exceed 0.50 m (with a confidence level of 95%).

- Either (1) the variation in the heading angle of the SV, measured relative to the travel lane centerline, cannot exceed 0.75 degrees (with a confidence level of 95%), or (2) the variation in the component of the SV CG's velocity normal to the road edge cannot exceed the SV vehicle speed multiplied by sin(0.75deg) (with a confidence level of 95%).

- The SV driver cannot touch the brake pedal before the required crash alert occurs, or before the range falls to less than 90% of the minimum range allowed for onset of the required crash alert.

5.6 Nuisance Alert Test General Requirements

5.6.1 Other Objects in the Scene

The out-of-path nuisance-alert tests should be conducted with no other traffic on the track, except the vehicles needed for the test itself. (Exceptions are allowed if other traffic is more than 400 m from all vehicles during the testing itself). Unless required for the tests, there should be no overhead objects such as signs or bridges near the testing zones. Roadside objects such as signs and markers should be minimized. The locations of roadside objects near the track that cannot be removed should be documented. Unless otherwise required, tests should be run in lanes that are not adjacent to concrete barriers and guardrails.

5.6.2 Instrumentation Requirements

In general, instrumentation and data processing should be adequate to show a 95% confidence level that the setup and execution of each test satisfies the specifications for the test. This includes both the specifications for the vehicle maneuvers and prop setup given with each test.

If an alert occurs the instrumentation and data recording must be adequate to verify that the object(s) that caused the alert were the objects intentionally placed in the scene for the purposes of the test.

5.6.3 Nuisance Alert Test Repetition Requirements

In general, each out-of-path nuisance alert test must be repeated to provide an estimate of the probability that an alert will occur under each test condition. The number of repetitions required depends upon the expected exposure of FCW systems to each combination of conditions. In addition, where appropriate, the out-of-path objects are presented to the FCW system at a variety of distances. Chapter 6 includes a detailed development of the specifications for the required number of repetitions and the required distribution of distances for each out-of-path nuisance-alert test. Briefly, the number of repetitions is designed to expose the FCW system to potential sources of out-of-path nuisances equivalent to 3 weeks worth of driving (approximately 600 miles of driving). The number of trials and the acceptable number of alerts are based upon the projected exposure and a statistical analysis of the number of exposures required to achieve adequate confidence in the test results. The typical exposure estimates are based upon a pilot experimental study performed by CAMP. The details of the pilot experimental study and the statistical analysis are provided in Chapter 6.

5.7 Nuisance Alert Tests

Out-of-path nuisance alert tests investigate the countermeasure's compliance with functional requirements that address operational scenarios. The list of out-of-path nuisance alert tests is given below. Test requirements and procedures are now given for each of these tests.

Out-Of-Path Nuisance Alert Tests	
N-1	Overhead sign at crest of hill
N-2	Road surface objects on flat roads
N-3	Grating at bottom of hill
N-4	Guard-rails and concrete barriers along curve entrance
N-5	Roadside objects along straight and curved roads (dry & wet pavement)
N-6	U-turn with sign directly ahead
N-7	Slow cars in adjacent lane, in transition to curve
N-8	120 kph between two 60 kph trucks in both adjacent lanes
N-9	Slow cars in adjacent lane at a curve (poor lane markings)

Table 5-7 List of Out-of-Path Nuisance-Alert Tests

5.7.1 Test N-1: Overhead Sign at Crest of a Hill

5.7.1.1 Test Overview and Purpose

This test is used to determine the sensitivity of an FCW system to objects commonly found over the traffic lanes of roads. The test covers the difficult condition wherein a crest curve causes the overhead object to appear directly ahead of the SV. The test is conducted using an overhead sign, which is used to representative both signs and bridges commonly found over urban and rural roads.

This test also verifies that the Alert Zone is at least as high as the top of the vehicle.

When the sign is at normal heights, the countermeasure should not produce alerts as the SV approaches and then passes under the overhead object. When the sign is set just above the height of the vehicle an alert should occur as the SV approaches the sign. The results of this test are to be compared with Test C-4, 100 kph to POV stopped under overhead sign, in which an alert is required to occur.

5.7.1.2 Track and Prop Setup

Roadway Geometry and Conditions

Select a hill with a vertical curvature that allows the sign to be directly ahead of the SV as the SV approaches the crest. The preferred vertical curvature is the 15th percentile for vertical curves on public roads. The actual vertical curvature of the track should be measured before testing begins. The horizontal curvature, superelevation, and crown of the track should meet the definition of a straight road.

The maximum vertical curvature will determine the speed at which the SV is driven over the hill. The track should be long enough so that the SV can reach the desired speed before coming within 200 m of the test object.

Use the following table to determine the speed at which the test is run. Choose the speed that is associated with the entry in the table that is closest to the minimum value of K found on the crest curve.

Rate of Vertical Curvature, K, (length (m) per % change in grade)	SV Speed (km/h)
3	30
5	40
9	50
14	60
22	70
32	80
43	90
62	100
80	110
102	120

Table 5-8 Vertical Curvature and SV Speed Requirements for Test N-1

Overhead Sign

This test requires an overhead sign that is similar in both optical and radar characteristics to the large direction and intersection information signs found on interstate highways. A standard design should be used to minimize variation in test results. Until a standard design is developed, the following guidelines are suggested. The sign itself should be approximately 2 m high by 4 m wide. It should be made with a metal back and coated with green retroreflective material with white lettering. There should be a vertical support on either side of the road. The vertical support structure on each side should be constructed using a single cylindrical pole. The horizontal support structure should be constructed from one or two cylindrical poles. If the sign is movable it may be held in place using guy wires that are attached at the top of the vertical poles and extend away from the road.

Place the overhead sign so that it is directly ahead of the SV and perpendicular to its direction of travel as the SV approaches the crest of the hill. Measure the position of the sign relative to the road and crest.

Measure the height of the bottom-center of the sign above the road. Measure the tilt of the sign relative to vertical and the angle of the sign relative to the direction of the road. Document the devices and techniques used to make these measurements.

5.7.1.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2 except run this test with nighttime illumination, as specified in the Definitions section.

5.7.1.4 Instrumentation Requirements

As the SV travels the "testing distance", instrumentation must support a 95% confidence level that the following variables remain within their allowed values (as specified in the Driving Instructions):

- SV speed
- Lateral position of the SV relative to the sign, in road coordinates
- Heading angle of the SV relative to the road
- SV brake pedal application (the pedal cannot be applied during testing, since this may disable the alerts for some FCW systems).

5.7.1.5 Driving Instructions

Begin with the SV at a location so that the required speed can be achieved before the SV is within 200 m of the sign. Accelerate to the required speed. Align the SV so that the center of the vehicle is at the same lateral position on the road as the center of the sign. Hold the required speed within ±2 km/h and keep the lateral position within ±0.5 m of the center of the sign until you pass under it. Note whether any alerts are generated by the FCW system.

5.7.1.6 Test Repetitions

The test is repeated with the sign at four different heights using the height and exposure distribution below. To test that the Alert Zone is at least as high as the SV, the test is then repeated once with the sign low enough to be sure an alert occurs but high enough to miss the top of the vehicle and any antennas on the vehicle.

Sign Height Above Road (meters)	4.4-4.65	4.65-4.9	4.9-5.15	5.15-5.4
Average Exposure per day	7	7	7	7
Number of Exposures for Test N-1	147	147	147	147

Table 5-9 Overhead Sign Height Exposure Requirements for Test N-1

5.7.1.7 Data Reporting and Analysis

Data reported must demonstrate the validity of the test run. The reported measurements and analysis must demonstrate the following:

1. The road geometry met the requirements for the test
2. The SV speed was within the required limits for the vertical curvature from the time it came within 200 m of the sign until it passed under it.
3. The SV lateral offset was within the specified limits from the time the SV came within 200 m of the sign until it passed under it.

If an alert occurs, the data analysis and reporting must demonstrate whether the sign caused it.

5.7.2 Test N-2: Road Surface Objects on Flat Roads

5.7.2.1 Test Overview and Purpose

This test is used to determine the sensitivity of an FCW system to road surface markings and small objects that vehicles frequently drive over. The representative objects include lane-marking retro-reflectors, a railroad crossing or similar painted marking, tire debris, beverage cans, and a piece of wood. The test is conducted on a straight section of track.

The countermeasure should not produce alerts as the SV approaches and then drives over these objects.

5.7.2.2 Track and Prop Setup

Roadway Geometry and Conditions

Select a flat, straight, track that is at least two lanes wide and 0.5 km long. The horizontal curvature, vertical curvature, superelevation, and crown of the track should meet the definition of a straight, flat road.

Retroreflectors and Road Surface Markings

The retroreflectors should have optical characteristics equivalent to those of Stimsonite Model 88AW white construction-work-zone markers.

There should be retroreflectors along both sides of the test lane at approximately 80-ft. intervals consistent with lane demarcation. If there are also lines delineating lane boundaries they should be broken lines with dimensions in accordance with Chapter 3 ("Markings") of the U.S. DOT Federal Highway Administration's Manual of Uniform Traffic Control Devices (see References). The MUTCD suggests lines that are 4" to 6" wide with broken lines formed by segments and gaps in a 1:3 ratio (typically 10-foot segments and 30-foot gaps).

There should be 2 separate regions; one with retroreflectors interspersed between white lane markings (3 m white paint lines separated by 9 m spaces), a second with retroreflectors spaced as in the first but without the markings. Each region should be at least 100 m long.

There should be a railroad crossing or similarly sized sign on the surface using highly reflective adhesive tape or paint (see Figure 5-18). The sign should conform to the shape and size guidelines as suggested in the MUTCD.

Survey the locations of the line segments and retroreflectors. Document the devices and techniques used to make these measurements.

Debris

Place a beverage can, piece of tire, and a piece of wood along the lane with at least 100 m separation.

The beverage can should be an empty 12 fl. oz. (355 ml) can that is not crushed. Place the can in the center of a lane so that the axis of the cylinder is horizontal and perpendicular to the direction of travel. The can may be held in place as long as the mechanism is not visible from the vehicle as it approaches the can.

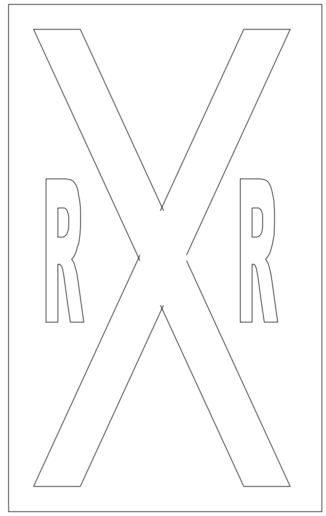

Figure 5-18 Typical Railroad Crossing Warning on Pavement

The piece of tire should be a section of truck tire tread 30 cm long by 10 cm wide. Place the piece of tire in the center of the lane so that it rests naturally on the road with its long axis perpendicular to the direction of travel.

The piece of wood should be approximately 2 cm by 5 cm by 30 cm. Place it in the center of the lane so that its long axis is horizontal and perpendicular to the direction of travel.

Measure the location of each piece of debris. Document the devices and techniques used to make these measurements.

5.7.2.3 Environmental Conditions Requirements

Use standard conditions, per Section 5.3.3.2 except run this test at night.

5.7.2.4 Instrumentation Requirements

As the SV travels the "testing distance", instrumentation must support a 95% confidence level that the following variables remain within their allowed values (as specified in the Driving Instructions):

- SV speed.
- Lateral position of the SV relative to the debris and retroreflectors, in road coordinates.

- SV brake pedal application (the pedal cannot be applied during testing, since this may disable the alerts for some FCW systems).

5.7.2.5 Driving Instructions

Begin at a location so that the required speed can be achieved before you are within 200 m of the first debris item. Accelerate to 100 km/h while following the center of the test lane. Hold the speed within ±2 km/h of 100 km/h as you drive through the testing distance. After entering the "testing distance" drive the car in a weaving pattern so that it passes completely into the next lane and back, going over the retroreflectors. Drive the car over each of the pieces of debris so that they pass approximately under the center of the vehicle.

Note whether any alerts are generated by the FCW system.

5.7.2.6 Test Repetitions

The following table indicates an estimated distribution for exposure to road surface objects during a typical day of driving and the resulting number of exposures that should be used in the tests. The number of times the FCW system is run through the course will depend upon the number of reflectors and debris passed each time.

	Road Surface Retroreflectors	**Debris**
Average Exposure Per Day	100	0.5
Number of Exposures for Test N-2	2100	11

The number of trial exposures for each type of object (retroreflectors or debris) is the number of each type of object on the course multiplied by the number of passes through the course.

5.7.2.7 Data Reporting and Analysis

Data reported must demonstrate the validity of the test run. The reported measurements and analysis must demonstrate the following:

- The road geometry met the requirements for the test
- The retroreflectors and debris were located within the required limits.
- The SV speed was within the required limits from the time it came within 200 m of the test area until it passed the last piece of debris or retroreflector.
- The debris passed under the SV within 0.5 m of the front-center of the vehicle.

- The SV passed over at least 4 retroreflectors.

If an alert occurs the data analysis and reporting must demonstrate which retroreflector or piece of debris caused it.

5.7.3 Test N-3: Grating at Bottom of Hill

5.7.3.1 Test Overview and Purpose

This test is used to determine the sensitivity of an FCW system to metal road surface objects, such as a grating, that vehicles frequently drive over. The test is conducted under the difficult condition where a sag vertical curve increases the visibility of the road surface ahead of the FCW system.

The countermeasure should not produce alerts as the SV approaches and then drives over the grating.

5.7.3.2 Track and Prop Setup

Roadway Geometry and Conditions

Select a section of track that has a sag curve. The preferred a change of grade is the 85th percentile for the change of grade in sag curves on public roads. The preferred vertical curvature is the 15th percentile for vertical curves on public roads. Measure the vertical curvature of the track before testing begins. The horizontal curvature, superelevation, and crown of the track should meet the definition of a straight road. Document the devices and techniques used to make these measurements.

The maximum vertical curvature will determine the speed at which the SV is driven over the curve. The track should be long enough so that the SV can reach the desired speed before coming within 200 m of the test object that is placed just after the sag curve.

Use the following table to determine the speed at which the test is run. Choose the speed that is associated with the entry in the table closest to the minimum value of K found on the sag curve.

Rate of Vertical Curvature, K, (length (m) per % change in grade)	SV Speed (km/h)
4	30
8	40
11	50
15	60
20	70
25	80
30	90
37	100
43	110
50	120

Table 5-10 Overhead Sign Height Exposure Requirements for Test N-3

Grating

This test requires a road surface that is similar in both optical and radar characteristics to the metal grating sometimes used on bridges over rivers. A standard design should be used to minimize variation in test results. Until a standard design is developed the following guidelines are suggested. The grating itself should be at least as wide as the lane and at least the length of a car. It should be made with metal slats running perpendicular to the road direction. The grating should be of a thickness common to those used for bridges (perhaps 2 or 3 cm). A shallow wedge shaped ramp should be put in front of the grating so that the front edge of the grating is not exposed to the FCW sensor as the SV approaches it and so that the SV can easily drive over the grating.

Place the grating immediately after the location with the maximum vertical curvature so that it is directly ahead of the SV and perpendicular to its direction of travel as the SV approaches the sag curve. Measure the position of the grating relative to the road and sag curve. Document the devices and techniques used to make these measurements.

5.7.3.3 Environmental Conditions Requirements

Use standard conditions per Section 5.3.3.2.

5.7.3.4 Instrumentation Requirements

As the SV travels the "testing distance", instrumentation must support a 95% confidence level that the following variables remain within their allowed values (as specified in the Driving Instructions):

- SV speed
- Lateral position relative to the grating, in road coordinates
- Heading angle of the SV relative to the road.
- SV brake pedal application (the pedal cannot be applied during testing, since this may disable the alerts for some FCW systems).

5.7.3.5 Driving Instructions

Begin at a location so that the required speed can be achieved before you are within 200 m of the grating. Accelerate to the required speed. Align the car so that it is on the road so that its center of the vehicle is at the same lateral position on the road as the center of the grating. Hold the required speed within ±2 km/h and keep the lateral position within ±0.5 m of the center of the grating until you pass over it. Note whether any alerts are generated by the FCW system.

5.7.3.6 Test Repetitions

The following table indicates an estimated distribution for exposure to gratings in a road during a typical day of driving and the resulting number of exposures that should be used in the tests.

	Gratings In Road
Average Exposure per Day	1
Number of Exposures for Test N-3	21

5.7.3.7 Data Reporting and Analysis

Data reported must demonstrate the validity of the test run. The reported measurements and analysis must demonstrate the following:

- The road geometry met the requirements for the test
- The SV speed was within the required limits for the vertical curvature from the time it came within 200 m of the grating until it passed over it.

- The SV lateral offset was within the specified limits from the time the SV came within 200 m of the grating until it passed over it.

If an alert occurs the data analysis and reporting must demonstrate whether the grating caused it.

5.7.4 Test N-4: Guardrails and Concrete Barriers

5.7.4.1 Test Overview and Purpose

This test is used to determine the sensitivity of an FCW system to roadside barriers that vehicles frequently pass. The representative barriers include metal guardrails and concrete dividers. The test is conducted on a section of track that transitions from straight to curved to represent the difficult conditions of a highway exit where the barriers are directly in front of the vehicle as it approaches the curve.

The countermeasure should not produce alerts as the SV approaches and then drives past these objects.

5.7.4.2 Track and Prop Setup

Roadway Geometry and Conditions

Select a track that includes a flat, straight section that transitions to a curve. The straight section should be long enough so that the SV can reach the desired speed before coming within 200 m of the roadside barriers. The preferred minimum radius of curvature in the curve is the 15^{th} percentile for curves in highway interchanges that use a cloverleaf. The curve should be at least 90 degrees with a superelevation of no more than 4%. Current engineering judgment suggests this radius of curvature should be appropriate for a design speed of 50 km/h to 70 km/h. According to AASHTO guidelines this corresponds to radius of curvature values from 100 m (for 50 kph with 4% superelevation) to a curvature of 2000 m (for 70 kph with no superelevation). For additional details on the relationship between design speed, superelevation, and radius of curvature, see Tables III-7 to III-11 of the AASHTO Policy on Geometric Design of Highways and Streets (1994).

Survey the road to determine the actual minimum radius of curvature and superelevation of the curve. The actual minimum radius of curvature in the turn will determine the speed at which the SV is driven around the curve. Determine the design speed for the measured combination of minimum radius of curvature and superelevation.

Barriers

The concrete barrier should be placed alongside the straight part of the track for a length of 50 m that ends just before the curve. The barrier should start at a safe distance from the side of the lane (for the start of a barrier). It should taper toward the lane to a distance equivalent to the 15^{th} percentile of the distance of concrete barriers from traffic lanes on public roads (thought to be about 1m).

The concrete barrier should include retroreflectors that extend from the side approximately every 12 m at an elevation of approximately 1 m from the road.

The metal barrier for this test should have optical and radar characteristics similar to semi-rigid longitudinal barriers used along highways and major arteries to redirect errant vehicles. A standard design should be used to minimize variation in test results. Until a standard design is developed the following guidelines are suggested. The barrier should be constructed with wooden posts and a metal cushion. The cushion should be the same height above the road surface as is typical for this kind of barrier (thought to be about 20 cm). Reflectors should be placed on the cushion approximately every 12 m. The barrier may be built in sections and with a plate at the bottom of each post so that it is portable. The plates must be of a design that does not significantly change the optical or radar characteristics of the mailbox.

The metal barrier should be placed on the outside of the curve. The metal barrier should begin before the beginning of the curve and extend at least far enough so that it is directly ahead of the vehicle as it approaches on the straight part of the track. The beginning of the barrier should be a safe distance from the side of the lane. It should taper to the 15^{th} percentile of distances of barrier from traffic lanes on cloverleaf intersections (thought to be 3m).

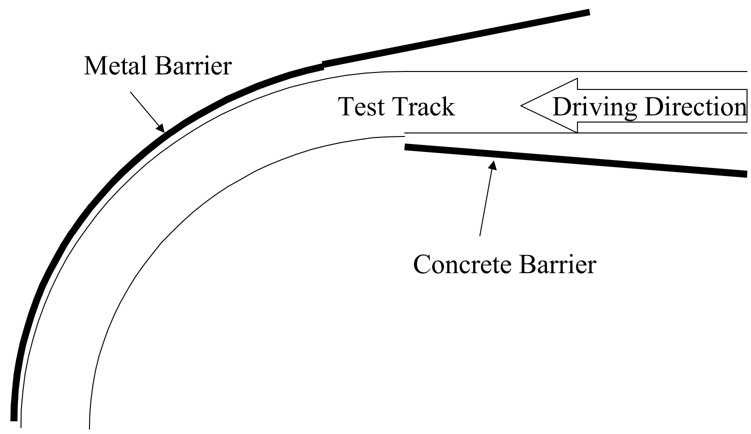

Figure 5-19 Barriers on Curve

The design and location of the barriers must be documented. Document the devices and techniques used to measure the locations of the barriers relative to the roadway.

5.7.4.3 Environmental Conditions Requirements

Use standard conditions per Section 5.3.3.2.

5.7.4.4 Instrumentation Requirements

As the SV travels the "testing distance", instrumentation must support a 95% confidence level that the following variables remain within their allowed values (as specified in the Driving Instructions):

- SV speed
- Lateral position of the SV relative to the lane in road coordinates
- SV brake pedal application (the pedal cannot be applied during testing, since this may disable the alerts for some FCW systems).

5.7.4.5 Driving Instructions

Begin at a location so that the required speed can be achieved before you are within 200 m of the concrete barrier. Accelerate to the required speed. Align the car so that it is in the center of the lane. Hold the speed within ±2 km/h of the design speed of the curve and keep the center of the car within ±0.5 m of the center of the lane. Follow the lane until you have passed turned 90 degrees through the curve.

Note whether any alerts are generated by the FCW system.

5.7.4.6 Test Repetitions

The following table indicates an estimated distribution for exposure to guardrails and barriers during a typical day of driving and the resulting number of exposures that should be used in the tests.

Distance of object from Alert Zone (meters)	0.5-1.5	1.5-2.5	2.5 to 3.5	3.5 to 4.5
Guardrails (typical exposure per day)	5	5	5	5
Number of Guardrail Exposures for Test N-4	105	105	105	105
Concrete Barriers (typical exposure per day)	1	1	1	1
Concrete Barrier Exposures for Test N-4	21	21	21	21

Table 5-11 Requirements for Exposure to Extended Roadside Objects for Test N-5

5.7.4.7 Data Reporting and Analysis

Data reported must demonstrate the validity of the test run. The reported measurements and analysis must demonstrate the following:

- The road geometry and barrier locations met the requirements for the test
- The SV speed was within the required limits for the horizontal curvature and superelevation of the curve from the time it came within 200 m of the first barrier until it passed through 90 degrees of the curve
- The SV lateral offset was within the specified limits from the time the SV came within 200 m of the first barrier until it passed through 90 degrees of the curve.

If an alert occurs the data analysis and reporting must demonstrate whether one of the barriers caused it. If one of the barriers caused the alert the data analysis and reporting must determine whether the alert occurred on the straight road, in the transition, or along the curve.

5.7.5 Test N-5: Roadside Objects by Straight and Curved Roads

5.7.5.1 Test Overview and Purpose

This test is used to determine the sensitivity of an FCW system to common roadside objects that vehicles frequently pass. The representative objects include small and large signs, mailboxes, and construction barricades. The test is conducted on a track that includes straight and curved sections. The placement of the objects is as close to the road as permitted for business and residential districts under the FHWA Manual on Uniform Traffic Control Devices (see References)

The countermeasure should not produce alerts as the SV approaches and then drives past these objects.

5.7.5.2 Track and Prop Setup

Roadway Geometry and Conditions

Select a track that includes a flat, straight section that transitions to a curve. The straight section should be long enough so that the SV can reach the desired speed before coming within 200 m of the roadside props. The preferred radius of curvature in the curve is the 15^{th} percentile for curves on roads in residential and business districts. The curve should be at least 90 degrees.. The rate of curve should be the 95^{th} percentile in terms of degrees of turn per 100m on public roads. Current engineering judgment suggests this radius of curvature should be appropriate for a design speed of 40 km/h to 60 km/h. The AASHTO Policy on Geometric Design of Highways and Streets recommends that the minimum radius of curvature for roads designed for these speeds are 800 m to 1520 m when there is no superelevation.

Survey the road to determine the actual minimum radius of curvature and superelevation of the curve. The actual minimum radius of curvature in the turn will determine the speed at which the SV is driven around the curve. Determine the design speed for the measured combination of minimum radius of curvature and superelevation.

At least 15% of the length of the test course should have “no lane markings.” This condition is defined in detail in the Definitions section. Any testing that occurs near transitions in curvature should have “good quality painted lane markings,” per the Definitions section.

Props

The mailboxes for this test should have optical and radar characteristics similar to roadside mailboxes used along residential streets in suburban and rural areas. A standard design should be used to minimize variation in test results. Until a standard design is developed or a particular manufacturers part number is selected, the following guidelines are suggested. The mailbox should be of metal construction approved by the U.S. postal service. Seven digits of reflective numbering at least 5 cm high should be put on the side facing traffic. The mailboxes should be mounted on a 1.5 m vertical wooden post. A base may be attached to the post so that the mailbox is portable. The base must be of a design that does not significantly change the optical or radar characteristics of the mailbox.

Mailboxes should be placed every 20 m along the straight and curved part of the track. The mailboxes should be placed so that the front of the mailbox is 0.5 m from the edge of the lane.

The construction barricades should be a Type I barricade with an A-frame construction as defined in the FHWA Manual on Uniform Traffic Control Devices (see References). A series of 6 barriers should be placed on either side of the straight part of the track at 20 m intervals. The first one should be at 3 m from the edge of the lane and with subsequent barricades placed a successively closer distances to a minimum of 0.0 m from the lane. Place these barricades perpendicular to the direction of travel.

The signs should correspond to the 85th percentile dimensions for signs found adjacent to public roads. They should be placed every 50 m along the straight and curved part of the track. They should be placed at the 15th percentile distance for signs found along public roads. Tentatively, engineering judgment suggests the signs should be a 24" x 30" no-parking sign and a 36" x 36 " diamond-shaped road-narrows symbol like W4-2 in the FHWA Manual on Uniform Traffic Control Devices (see References). The tentative distance is 0.5 m from the road edge at that Manual’s recommended height of 1.5 m measured from the bottom of the sign to the ground.

The design and location of each prop must be documented. Document the devices and techniques used to measure the locations of the props relative to the roadway.

5.7.5.3 Environmental Conditions Requirements

Use standard conditions per Section 5.3.3.2.

5.7.5.4 Instrumentation Requirements

As the SV travels the "testing distance", instrumentation must support a 95% confidence level that the following variables remain within their allowed values (as specified in the Driving Instructions):

- SV speed.
- Lateral position of the SV relative to the lane in road coordinates.
- SV brake pedal application (the pedal cannot be applied during testing, since this may disable the alerts for some FCW systems).

5.7.5.5 Driving Instructions

Begin at a location so that the required speed can be achieved before you are within 200 m of the first roadside object. Accelerate to the required speed. Align the car so that it is in the center of the lane. Hold the speed within ±2 km/h of the design speed of the curve and keep the center of the car within ±0.5 m of the center of the lane. Follow the lane until you have passed turned 90 degrees through the curve.

Note whether any alerts are generated by the FCW system.

5.7.5.6 Test Repetitions

The following table indicates an estimated distribution for exposure to roadside objects during a typical day of driving.

Distance of Object from Alert Zone (Meters)	0.5-1.5	1.5-2.5	2.5 to 3.5	3.5 to 4.5
Small signs per day	50	50	50	50
Large signs per day	16	16	16	16
Mailboxes per day	11	11	11	11
Construction barricades per day	24	24	24	24

Table 5-12 Estimated Distribution for Exposures to Discrete Roadside Objects

The following table indicates the number of exposures that should be used in the tests. The number of times the FCW system is run through the course will depend upon the number of reflectors and debris passed each time.

Distance of Object from Alert Zone (Meters)	0.5-1.5	1.5-2.5	2.5 to 3.5	3.5 to 4.5
Small signs for Test N-5	1050	1050	1050	1050
Large signs for Test N-5	336	336	336	336
Mailboxes for Test N-5	121	121	121	121
Construction barricades for Test N-5	504	504	504	504

Table 5-13 Requirements for Exposures to Roadside Objects in Test N-5

The number of trial exposures for each type of object (retroreflectors or debris) is the number of each type of object on the course multiplied by the number of passes through the course.

5.7.5.7 Data Reporting and Analysis

Data reported must demonstrate the validity of the test run. The reported measurements and analysis must demonstrate the following:

- The road geometry and prop locations met the requirements for the test.
- The SV speed was within the required limits for the horizontal curvature and superelevation of the curve from the time it came within 200 m of the first prop until it passed through 90 degrees of the curve.
- The SV lateral offset was within the specified limits from the time the SV came within 200 m of the first barrier until it passed through 90 degrees of the curve.

If an alert occurs, the data analysis and reporting must demonstrate whether one of the props caused it. If one of the props caused the alert, the data analysis and reporting must determine whether the alert occurred on the straight road, in the transition, or along the curve.

5.7.6 Test N-6: U-Turn With Sign

5.7.6.1 Test Overview and Purpose

This test is used to determine the sensitivity of an FCW system to signs found near U-Turn lanes in the median of a road. The signs are placed so that they are directly in front of the SV as it approaches the U-Turn, at a distance of 3 meters from the edge of the roadway. The SV approaches the U-turn at a high speed (80 kph), decelerates at the last moment, and then negotiates the turn.

The U-Turn should have a curvature consistent with a design speed between 20 and 50 kph. The SV approaches the U-Turn at 80 kph, brakes at 0.5g to reach the design speed just before entering the U-Turn, and then negotiates the turn.

5.7.6.2 Track and Prop Setup

Roadway Geometry and Conditions

Select a track that includes a straight segment leading into a very tight curve. The curve should represent a U-turn through a median between 12 m and 15 m wide, corresponding to a U-turn for passenger cars, busses, and medium semi-trailers in a divided road with 2 lanes in each direction (see AASHTO Figure IX-69, see References). There should be a curb on the outer edge of the U-turn curve.

Survey the road to determine the actual minimum radius of curvature and superelevation of the curve. The actual minimum radius of curvature in the turn will determine the speed at which the SV is driven around the curve. Determine the design speed for the measured combination of minimum radius of curvature and superelevation.

Signs

Place a 36" by 12"one-way sign on the outside of the curve so that it is directly ahead of the vehicle as it travels the straight part of the track. Place the sign perpendicular to the straight section of the track 1m away from the curb.

The design and location of the sign must be documented. Document the devices and techniques used to measure the locations of the sign relative to the roadway.

5.7.6.3 Environmental Conditions Requirements

Use standard conditions per Section 5.3.3.2.

5.7.6.4 Instrumentation Requirements

As the SV travels the "testing distance", instrumentation must support a 95% confidence level that the following variables remain within their allowed values (as specified in the Driving Instructions):

- SV speed.
- Lateral position of the SV relative to the lane in road coordinates.
- SV brake pedal application (the pedal cannot be applied during testing, since this may disable the alerts for some FCW systems).

5.7.6.5 Driving Instructions

Begin at a location so that 80 km/h can reach before you are within 200 m of the U-turn. Accelerate to the required speed. Align the car so that it is in the center of the lane. Hold the speed steady within ±2 km/h and keep the center of the car within ±0.5 m of the center of the lane. At the last moment, brake at a comfortable-hard rate (tentatively set at 0.5g ±0.05g) to make the widest turn possible while staying on the track, and come to a stop after completing the turn.

Note whether any alerts are generated by the FCW system.

5.7.6.6 Test Repetitions

The following table indicates an estimated number for exposure to the U-turn scenario and during a typical day of driving and the resulting number of exposures that should be used in the tests.

	U-Turns
Average Exposure per Day	2
Number of Exposures for Test N-6	42

5.7.6.7 Data Reporting and Analysis

As the SV travels toward and through the turn, instrumentation must support a 95% confidence level that the following variables remain within their allowed values (as specified in the Driving Instructions):

- SV speed and deceleration rate.
- Lateral position of the SV relative to the lane in road coordinates.
- SV brake pedal application. The pedal can be applied only once during the test and, once applied, must be held steady until the vehicle comes to a stop.

5.7.7 Test N-7: Slow Cars in Adjacent Lane at a Curve (Wet Pavement)

5.7.7.1 Test Overview and Purpose

This test determines the sensitivity of an FCW system to slower moving traffic in adjacent lanes. The test is difficult because, before the SV enters the curve, the slower vehicles in the adjacent lane are already directly ahead of the SV. The wet pavement makes it more difficult for some systems to properly handle this situation.

The countermeasure should not produce alerts as the SV approaches and then passes the traffic in the adjacent lane.

5.7.7.2 Track and Prop Setup

Roadway Geometry and Conditions

Select a track that is at least two lanes wide and that includes a straight segment that transitions to a curve. The curve should have a curvature and superelevation consistent with the AASHTO Policy on Geometric Design of Highways and Streets. The preferred radius of curvature in the curve is the 15^{th} percentile for curves on public roads. Current engineering judgment suggests this radius of curvature should be appropriate for a design speed of 50 km/h to 70 km/h. According to AASHTO guidelines, this corresponds to radius of curvature values from 100 m (for 50 kph with 4% superelevation) to a curvature of 2000 m (for 70 kph with no superelevation). For additional details on the relationship between design speed, superelevation, and radius of curvature, see Tables III-7 to III-11 of the AASHTO Policy on Geometric Design of Highways and Streets (1994).

There should be a straight segment leading into the curve that is at least 200 m long. The straight segment should have a crown, curvature, and superelevation consistent with a straight, flat road.

The road surface should be wet. The standard lane marking condition – "good quality painted lane markings" – should be used (see Definitions section).

Survey the road to determine the actual minimum radius of curvature and superelevation of the curve. The actual minimum radius of curvature in the turn will determine the speed at which the SV is driven around the curve. Determine the design speed for the measured combination of minimum radius of curvature and superelevation.

Traffic

Several midsize passenger vehicles should be used.

5.7.7.3 Environmental Conditions Requirements

Use standard conditions per Section 5.3.3.2.

5.7.7.4 Instrumentation Requirements

As the SV travels toward and through the curve, instrumentation must support a 95% confidence level that the following variables remain within their allowed values (as specified in the Driving Instructions):

- SV and POV speeds.
- Lateral position of the SV relative to the POVs, in road coordinates
- Heading angle of the SV relative to the road.
- SV brake pedal application (the pedal cannot be applied during testing, since this may disable the alerts for some FCW systems).

5.7.7.5 Driving Instructions

Drive a row of POVs around the track at half the design speed of the curve. Hold the speed within ±2 km/h of this speed. Maintain a lateral position within ±0.5 m of the center of the outer of the two lanes. Maintain a headway time of 1.5 s ±0.1 s between the POVs.

Drive the SV at the design speed for the inner lane of the curve. Maintain a lateral position within ±0.5 m of the center of the inner of the two lanes. The distances between the POVs and SV should be timed so that the SV approaches the curve while the POVs are on the part of the curve that is directly ahead of the straight part of the track.

The speeds and lateral positions of the POVs and SV should be maintained until the SV passes the POVs. Note whether any alerts are generated by the FCW system as it passes the slower traffic.

5.7.7.6 Test Repetitions

The following table indicates an estimated distribution of exposures to slow moving cars in adjacent lanes during a typical day of driving and the resulting number of exposures that should be used in the tests. If the test is run with a line of POVs then the number of exposures is calculated by multiplying the number of runs past the line of POVs by the number of POVs in the line.

Distance from Alert Zone (meters)	0.0-0.5	0.5-1.0	1.0-1.5
Average Exposure per Day	9	9	9
Number of Exposures for Test N-7	189	189	189

Table 5-14 Requirements for Exposure to Slow Cars in Adjacent Lane, Test N-7

5.7.7.7 *Data Reporting and Analysis*

Data reported must demonstrate the validity of the test run. The reported measurements and analysis must demonstrate the following:

- The road geometry met the requirements for the test.
- The POVs maintained the required speed, lateral, and longitudinal positions.
- The SV speed and lateral position was within the required limits from the time it came within 200 m of the curve until it passed the leading POV.

If an alert occurs the data analysis and reporting must demonstrate whether it was caused by the slower moving vehicles and which one caused it.

5.7.8 Test N-8: Trucks in Both Adjacent Lanes

5.7.8.1 *Test Overview and Purpose*

This test is used to determine the sensitivity of an FCW system to slower traffic that is at the same distance in both adjacent lanes. The test is difficult because the adjacent vehicles may be mistakenly interpreted as one vehicle directly ahead of the SV.

The countermeasure should not produce alerts as the SV approaches and then passes between the traffic in the adjacent lanes.

5.7.8.2 *Track and Prop Setup*

Roadway Geometry and Conditions

Select a flat, straight, track that is at least three lanes wide and 0.5 km long. The horizontal curvature, vertical curvature, superelevation, and crown of the track should meet the definition of a straight, flat road.

Principal other vehicles

The POVs should be two large trucks (Section 5.3.1.2 characterizes large trucks).

5.7.8.3 *Environmental Conditions Requirements*

Use standard conditions per Section 5.3.3.2.

5.7.8.4 Instrumentation Requirements

As the SV travels toward and passes between the trucks, the instrumentation must support a 95% confidence level that the following variables remain within their allowed values (as specified in the Driving Instructions):

- SV and POV speeds
- Lateral position of the SV relative to the POVs, in road coordinates
- Heading angle of the SV relative to the road
- SV brake pedal application (the pedal cannot be applied during testing, since this may disable the alerts for some FCW systems).

5.7.8.5 Driving Instructions

Drive the trucks at 60 km/h so that they are aligned with the center of the lanes adjacent to the lane the SV will use. Maintain the lateral positions within ±0.5 m of the center of each lane. Maintain the speeds so that they are within ±2 km/h of 60 km/h and within ±1 km/h of each other. Maintain the longitudinal positions of the trucks so their rear ends are within 0.5 m of each other.

Begin with the SV at least 200 m behind the trucks traveling at 120 km/h. Align the center of the SV with the center of the center lane. Maintain the lateral position of the SV within ±0.5 m of the center of its lane. Maintain the speed of the SV within ±2 km/h of 120 km/h as it approaches and then passes between the trucks.

Note whether any alerts are generated by the FCW system as it passes the slower traffic.

5.7.8.6 Test Repetitions

The following table indicates an estimated distribution of exposures to the scenario during a typical day of driving and the resulting number of exposures that should be used in the tests.

Distance from Alert Zone (Meters)	0.0-0.5	0.5-1.0	1.0-1.5
Average Exposure per Day	1	1	1
Number of Exposures for Test N-8	21	21	21

Table 5-15 Requirements for Exposure to Trucks in Adjacent Lanes, Test N-8

5.7.8.7 *Data Reporting and Analysis*

Data reported must demonstrate the validity of the test run. The reported measurements and analysis must demonstrate the following:

- The road geometry met the requirements for the test.
- The POVs maintained the required speed, lateral, and longitudinal positions.
- The SV speed and lateral position was within the required limits, from the time it came within 200 m of the POVs until it passed between them.

If an alert occurs, the data analysis and reporting must demonstrate whether it was caused by the slower moving vehicles.

5.7.9 Test N-9: Slow Cars in Adjacent Lane at a Curve (Poor Lane Markings)

5.7.9.1 *Test Overview and Purpose*

This test is used to determine the sensitivity of an FCW system to slower moving traffic in adjacent lanes. The test is difficult because, before the SV enters the curve, the slower vehicles in the adjacent lane are already directly ahead of the SV. The poor quality lane markings make it more difficult for some systems to properly handle this situation. This test is identical to Test N-7 except that (1) the pavement should be dry for this test, and (2) “poor quality painted lane markings” should be used (as described in the Definitions section). All other requirements and instructions are the same as Test N-7. Note that good quality lane markings can be made into poor quality lane markings (as defined in this chapter) by obscuring the lane markings, for example, by putting sand onto the surfaces.

5.7.9.2 *Test Repetitions*

The following table indicates an estimated distribution of exposures to the scenario during a typical day of driving and the resulting number of exposures that should be used in the tests.

Distance from Alert Zone (meters)	0.0-0.5	0.5-1.0	1.0-1.5
Average Exposure per Day	3	3	3
Number of Exposures for Test N-9	63	63	63

Table 5-16 Requirements for Exposure to Roadside Objects, Test N-9

5.8 Requirements Coverage Analysis

The purpose of the objective test methodology is to create a set of vehicle-level tests that evaluate whether or not a FCW system complies with the minimum functional requirements of Chapter 4. The only driver-vehicle interface requirements addressed by these tests involve crash alert onset timing (as stated in Sections 5.1 and 5.3). This section presents a chart that shows that all other requirements are all addressed by the proposed tests procedures.

Down the left column of Table 5-17 on the following page are the indices of the minimum functional and performance requirements that are taken from the requirements summary of Chapter 4, Section 7. Across the top of the table are the test numbers. The shaded boxes indicate which test procedures address each requirement. The driver-vehicle interface requirements not addressed in these tests are Requirements 1 and Requirements 3 through 12. These are not included on the chart.

The table shows that the test procedures address all of the intended functional requirements.

5.9 Summary

This chapter presents a set of objective test procedures that describe vehicle-level testing activities to evaluate the compliance of a FCW countermeasure with the minimum functional requirements developed in Chapter 4. Seventeen crash alert tests and nine out-of-path nuisances alert tests are described. The chapter reviews instrumentation requirements, track and prop set-up instructions, driving maneuver requirements, and data recording requirements. A coverage analysis shows the mapping from individual tests to the functional requirements in Chapter 4.

This test methodology is designed to provide repeatable countermeasure evaluations, and the sensitivity of results to the test site (proving ground) is minimized in the design. Test execution is estimated to require two to four weeks, not including initial prop fabrication, set-up, and surveying of test sites. Possible users of the tests may include vehicle manufacturers, countermeasure suppliers, government organizations, and independent institutions.

The following chapter, Chapter 6, covers the data analysis required to evaluate test data, as well as requirements for reporting on the tests. Chapter 7 describes an extensive set of activities undertaken to evaluate and validate the test methodology. This exercise resulted in changes to some important test design parameters and requirements.

Table 5-17 Functional Requirements and Associated Tests

Rquire- ment	C-, Crash Alert Test number																	N-, Nuisance Ale				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	1	2	3	4	5
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