



SURFACE VEHICLE RECOMMENDED PRACTICE

J3087™

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(R) Automatic Emergency Braking (AEB) System Performance Testing

RATIONALE

SAE J3087 was issued October 2017 and is due for Five-Year Review.

New test scenarios and test equipment have become prevalent in the assessment of AEB systems.

Request that the Active Safety System Standards Committee authorize work to review and update SAE J3087 accordingly with the following recommended scope:

1. Test Equipment Updates: Add new licensable vehicle test targets such as Global Soft Target, Powered Two-Wheeler, etc., and respective motive systems.
2. Test Scenario Updates: Modify rear impact test scenario combinations to reflect latest industry position and current global consumer metric and regulatory protocols. Recommend additional task forces for functions and scenarios that fall outside the SAE J3087 scope.
3. General Edits and Clarifications: As appropriate.

1. SCOPE

This document describes an SAE Recommended Practice for Automatic Emergency Braking (AEB) system performance testing which:

- Establishes uniform vehicle level test procedures
- Identifies target equipment, test scenarios, and measurement methods
- Identifies and explains the performance data of interest
- Does not exclude any particular system or sensor technology
- Identifies the known limitations of the information contained within (assumptions and “gaps”)
- Is intended to be a guide toward standard practice and is subject to change on pace with the technology
- Focuses on “Vehicle Front to Rear, In Lane Scenarios” expanded to include additional offset impacts

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This document describes the equipment, facilities, methods, and procedures needed to evaluate the ability of Automatic Emergency Braking (AEB) systems to detect and respond to another vehicle, in its forward path, as it is approached from the rear.

This document does not specify test conditions (e.g., speeds, decelerations, clearance gaps, etc.). Those values will be defined by the tester according to the intended purpose of a given test sequence. Informative examples are provided for reference in Appendix B.

The procedure includes three test scenarios:

- Stopped lead vehicle (Test 1): The vehicle being approached is stopped in the lane of the test vehicle.
- Slower lead vehicle (Test 2): The vehicle being approached is moving at a constant speed that is slower than the test vehicle.
- Decelerating lead vehicle (Test 3): The vehicle being approached is initially moving at the same speed as the test vehicle, but then slows.

2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

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

SAE J3063 Active Safety Systems Terms and Definitions

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E1136 Standard Specification for P195/75R14 Radial Standard Reference Test Tire

ASTM E1137-90 Standard Test Method for Determining Longitudinal Peak Braking Coefficient of Paved Surfaces Using Standard Reference Test Tire

2.1.3 ISO Publications

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

ISO 19206-1:2018 Road vehicles - Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions - Part 1: Requirements for passenger vehicle rear-end targets

ISO 19206-3:2021 Road vehicles - Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety function - Part 3: Requirements for passenger vehicle 3D targets

2.1.4 NHTSA Publications

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

“Crash Imminent Brake System Performance Evaluation for the New Car Assessment Program,” U.S. Department of Transportation National Highway Traffic Safety Administration (October 2015).

“Forward Collision Warning System Confirmation Test,” U.S. Department of Transportation National Highway Traffic Safety Administration (February 2013).

“Dynamic Brake Support Performance Evaluation Confirmation Test for The New Car Assessment Program,” U.S. Department of Transportation National Highway Traffic Safety Administration (October 2015).

2.1.5 Other Publications

“Autonomous Emergency Braking Test Protocol,” Insurance Institute for Highway Safety, Version I (October 2013).

“European New Car Assessment Programme (Euro NCAP) - Assessment Protocol - Safety Assist Collision Avoidance,” Implementation 2023, Version 10.2 (November 2022).

3. DEFINITIONS

3.1 ALERT

A signal to the driver regarding a particular condition. In the context of this document, an alert is used to warn the driver of a potential forward collision. FCW alerts are typically visual, auditory, or haptic or combinations of these. Refer to SAE J3063 for examples of other alert types.

3.2 AUDITORY ALERT

A warning modality in which a transducer produces a sound. These are typically implemented as a series of short, relatively high frequency bursts.

3.3 AUTOMATIC EMERGENCY BRAKING (AEB)

Refer to SAE J3063.

3.4 CRASH IMMINENT BRAKING (CIB)

Function of AEB Systems intended to mitigate the severity of rear-end collisions by automatically applying the vehicle's brakes shortly before the expected impact (i.e., without requiring the driver to apply force to the brake pedal).

3.5 CONVEYANCE SYSTEM

System used to move the surrogate vehicle in a predetermined manner according to a test scenario.

3.6 DIFFERENTIAL GLOBAL POSITIONING SYSTEM (DGPS)

An enhanced Global Positioning System that uses a network of fixed, ground-based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions (approximately 10 cm accuracy as compared to 15 m accuracy of a GPS).

3.7 DYNAMIC BRAKE SUPPORT (DBS)

Function of AEB Systems which supplement a driver's commanded brake input by increasing the output of the foundation brake system, for the purpose of mitigating the severity of - or, in some cases, avoiding - rear-end collisions. (Paraphrased from NHTSA DBS Test procedure.)

3.8 FORWARD COLLISION WARNING (FCW)

Refer to SAE J3063.

3.9 GLOBAL POSITIONING SYSTEM (GPS)

A navigational system involving satellites and computers that can determine the latitude and longitude of a receiver on Earth by computing the time difference for signals from different satellites to reach the receiver.

3.10 HAPTIC ALERT

A warning modality in which a transducer produces a tactile sensation to the driver. These are typically implemented as a vibration in either the driver's seat pan or the steering wheel.

3.11 CLEARANCE GAP

The longitudinal distance from the front most location of the SV to rear most point on the POV or to the fixed point on the ground longitudinally coincident with the rear most point on a stationary POV.

3.12 LATERAL OVERLAP

A percentage of the width of the SV that is subject to contact with the POV, where the reference line for the overlap definition is the centerline of the SV. In case of 100% overlap, the centerlines of the SV and POV are aligned.

3.13 LEAD VEHICLE (LV)

The vehicle ahead in a potential rear-end crash. May also be referred to as the Principal Other Vehicle (POV).

3.14 NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION (NHTSA)

An agency of the Executive Branch of the U.S. government, part of the Department of Transportation. NHTSA is charged with writing and enforcing Federal Motor Vehicle Safety Standards as well as regulations for motor vehicle theft resistance and fuel economy.

3.15 PRINCIPAL OTHER VEHICLE (POV)

The potential collision partner of the Subject Vehicle. For CIB and DBS tests, the POV is typically a Surrogate Vehicle.

3.16 PROGRAMMABLE BRAKE CONTROLLER

A device used to automatically actuate the brake pedal in a predetermined manner.

3.17 RADAR CROSS SECTION (RCS)

A measure of an object's reflectivity comparing the energy returned by an object to the energy transmitted from the radar.

3.18 REAR-END COLLISION

A crash in which the forward portion of a vehicle strikes the rearward portion of another vehicle in front of it which is heading in the same direction.

3.19 SUBJECT VEHICLE (SV)

The vehicle that is equipped with the system being evaluated. May also be referred to as the Vehicle Under Test (VUT).

3.20 SURROGATE VEHICLE

Strike-able artificial vehicles designed such that, in the event of a collision with a subject vehicle, damage to both is minimized or avoided. Surrogate vehicles and any utilized conveyance systems must also mimic key characteristics of typical road vehicles with respect to Active Safety sensor technology.

3.21 TIME FCW (t_{FCW})

The time at which the FCW alert is activated.

3.22 TARGET VEHICLE

See PRINCIPAL OTHER VEHICLE (POV).

3.23 TEST SCENARIOS

The SV and POV motion sequence used to test the performance of the CIB and DBS systems. Typically, scenarios are based on, or derived from, crash data and/or real-world occurrences.

3.24 TEST VEHICLE

See SUBJECT VEHICLE (SV).

3.25 TIME TO COLLISION (TTC)

Time interval, usually measured in seconds, required for one vehicle to strike another object.

3.26 VEHICLE UNDER TEST (VUT)

See SUBJECT VEHICLE (SV).

3.27 VISUAL ALERT

A warning modality which is visual in nature. These are typically implemented as a flashing light or text warning in the instrument panel or head-up display.

3.28 VEHICLE-TO-VEHICLE (V2V) COMMUNICATION

Technology that allows vehicles to exchange information with each other wirelessly.

4. TEST INSTRUMENTATION AND EQUIPMENT

4.1 Positioning System

A system for determining and recording the lateral and longitudinal position of the SV and POV, relative to an earth-fixed location, and having at least 1.6 inch (4.1 cm) static accuracy, 3.9 inch (10 cm) dynamic accuracy, and an update at a rate of at least 10 Hz.

4.2 Data Acquisition System

All analog data shall be sampled at 100 Hz.

Digitized data shall be minimum 16 bit.

Signal conditioning shall consist of amplification and digitizing. Amplifier gains shall be selected to maximize the signal-to-noise ratio of the digitized data.

Appropriate low pass Butterworth anti-aliasing filters shall be applied to data as it is collected.

4.3 Sensors

The required sensors are listed in Table 1.

Table 1 - Sensor requirements

Sensed Variable	CIB	DBS	Application	Range	Resolution	Accuracy
Accelerator pedal or throttle position	X	X	SV	0-100% (normalized)	0.1%	0.1%
Brake pedal application force		X	SV	0-300 lbf (0-1.3 kN)	0.25 lbf (1.1 N)	±0.08% of full scale
Brake pedal stroke position (encoder)		X	SV	0-8 inches (20.3 cm)	3200 pulses per inch	0.04 inch (0.5 mm)
Brake temperature (rotor or pad)	X	X	SV	0-200 °C	±2 °C	±5 °C
Data flag (FCW Alert)	X	X	SV	N/A	N/A	N/A
Lateral and clearance gap (longitudinal) position	X	X	SV, POV	650 feet (200 m)	0.01 m	0.02 m
Longitudinal acceleration	X	X	SV, POV	±2 g	0.001 g	0.01 g
Longitudinal speed	X	X	SV, POV	0.1-62 mph (0.1-100 km/h)	0.03 mph (0.05 km/h)	0.06 mph (0.1 km/h)
Vehicle dimensions	X	X	SV, POV	N/A	0.04 inch (1 mm)	0.04 inch (1 mm)
Yaw rate	X	X	SV, POV	±100 deg/s	0.01 deg/s	0.1 deg/s

Note: Differentially corrected GPS may be used to provide data to calculate vehicle speed and yaw rate in lieu of direct measurement provided the resulting accuracy is comparable.

4.4 Surrogate Target and Conveyance System for AEB Testing

4.4.1 Physical Characteristics

- Design should allow offsets within the test tolerances specified in Table 3 to be safely executed.
- Lightweight: Both target and conveyance apparatus should be reasonably lightweight to allow handling and setup by one or two people.
- The material for the impact area should be “absorptive” or “compliant,” thereby permitting striking force to be damped or distributed.
- The target components that come in contact with the test vehicle should be durable and should easily distribute impact forces with only non-permanent deformation. Alternatively, the system can be capable of accepting and “distributing” subject (test) vehicle striking force into a more rigid structure that would maintain mechanical integrity and continue to be functional.
- Target components should be easily “swappable” so that damaged pieces can be easily replaced.
- Surrogate target and conveyance system should be constructed such that target movement minimizes rotation and traverses along the path of subject (test) vehicle travel (relative to center of gravity, wind loading, surface irregularities).
- The target, aside from performing its intended use, must also maintain safe conditions for the test driver. Target design should minimize component breakage that could lead to damage to subject (test) vehicle and/or injury to the driver.
- Target conveyance apparatus must minimize target lateral position variation both in setup and during testing runs to meet test procedure accuracy requirements.

- Target conveyance apparatus must be capable of appropriate velocities and decelerations and must allow the tow vehicle (if used) to be at a safe distance from the surrogate vehicle.
- Target conveyance apparatus should minimize the damage of the target and test track road surface.
- Tow vehicle and target longitudinal separation variation: If conveyance system utilizes a tow vehicle, the target conveyance apparatus must minimize any separation variation between the tow vehicle and the target to meet test procedure accuracy requirements.

Commonly used test targets and conveyance systems are shown in Table 2.

Table 2 - Common AEB test targets and conveyance systems

Category	Target Name	Reference	Usage
AEB Car to Car Rear (CCR)	Euro Vehicle Target (EVT)	ISO 19206-1:2018 Figure E.1 Euro NCAP AEB Test Protocol v1.0 Figure 3 https://www.euroncap.com/en	100% overlap car to car rear scenarios
Automatic Emergency Braking	Global Vehicle Target (GVT)	ISO 19206-3:2021 Figure C.6 Euro NCAP C2C Test Protocol v3.03 Figure 5-1 https://www.euroncap.com/en	360-degree car to car scenarios, AEB, Blind Spot Detection (BSD)
	Strikable Surrogate Vehicle (SSV)	NHTSA CIB System Performance Evaluation Figure E.2 https://downloads.regulations.gov/NHTSA-2015-0006-0025/attachment_1.pdf	100% overlap car to car rear scenarios
AEB Powered Two Wheeler (PTW)	Motorcycle	Euro NCAP AEB LSS VRU Test Protocol v4.3 Figure 5-1 https://www.euroncap.com/en	NCAP PTW test scenarios, BSD, Lane Support Systems (LSS) Euro NCAP
	eScooter	China NCAP Management Regulation 2021 Appendix C, Figure C.29	China NCAP PTW test scenarios
Target Carriers	Large target carrier system	AB Dynamics: https://www.abdynamics.com/ DRI: https://www.dynres.com/ 4active Systems: https://www.4activesystems.at/	NCAP AEB Car to Car scenarios, Straight Crossing Path (SCP), Turn Across Path (TAP), Head On (HO)
	Small target carrier system		NCAP VRU and PTW test scenarios
	Leading vehicle tow system	Moshon Data: https://brendelassociates.com/brands/moshon-data/	NCAP AEB Car to Car 100% overlap

4.4.2 Surrogate Target and Conveyance System Interaction with Test Track and Environmental Conditions

- The target and conveyance apparatus should be able to withstand variations in test track conditions (i.e., debris, minor cracks, bumps, etc.).
- System should be capable of testing on asphalt or concrete track surfaces which are reasonably level (between level and 1% grade) and have typical roadway crown conditions.
- The target and conveyance apparatus should not be substantially affected by outdoor weather conditions (i.e., temperature, rain, and mild wind conditions).

4.4.3 Handling and Transportability

- Ease of use in handling: Target should be handled easily by one or two persons. Consideration should be given to time required for resetting and repositioning targets.
- The “target assembly” and conveyance apparatus should be easily loaded and unloaded for transport and should not require a large commercial truck to transport.

4.4.4 Sensor and Instrumentation Characteristics

- Target should have features/characteristics for detection by radar, lidar, and vision sensors used on the subject (test) vehicle for Automatic Emergency Braking (Pre-Crash) systems.
- Overall target reflectivity: System should have a radar cross section (RCS) profile similar to that of typical road vehicles. Provisions for adjusting radar cross section profile would be desirable.
- System shape and appearance should be similar to a typical road vehicle.
- System must incorporate provisions for target ground truth data generation/collection of sufficient accuracy to meet test procedure requirements.
- If system is to be used for Vehicle-to-Vehicle (V2V) testing, it should include provisions for receiving/sending target GPS data of sufficient accuracy to meet test procedure requirements.

4.5 Programmable Braking Actuator

A programmable braking actuator is recommended to ensure deceleration test requirements can be met in a repeatable and accurate manner.

5. TEST FACILITIES AND CONDITIONS

5.1 Test Track

- 5.1.1 Conduct tests on a dry (no visible moisture on the surface), uniform asphalt or concrete surface with a typical roadway crown and consistent longitudinal slope between level and 1%. At the time of the test, the test surface shall have a peak friction coefficient (PFC) of at least 0.9 and not to exceed 1.1 when measured using an ASTM E1136 standard reference test tire, in accordance with ASTM Method E1337-90, at a speed of 40 mph (64.4 km/h), without water delivery.
- 5.1.2 The surface must be asphalt or concrete and may not contain any irregularities (e.g., large dips or cracks), manhole covers, or raised traffic control elements that may give rise to abnormal sensor measurements within a lateral distance of 3.7 m to either side of the centerline and with a longitudinal distance of 30 m beyond the position at which the test finishes. The test surface shall be at least 400 m long.
- 5.1.3 The presence of lane markings is allowed. If lane markings are present, the test shall be conducted in an orientation that is parallel to the lane lines. If a single lane line is used, the centerline of the SV and POV shall be 6.0 feet (1.8 m) from the inside edge of the line for the duration of the test. If two lane lines are present, the distance between the inside edges shall be at least 12 feet (3.7 m), and the vehicles shall remain in the center of the lane for the duration of the trial (see Figure 1).
- 5.1.4 Overhead signs, bridges, gantries, or other significant structures within the lane must be more than 5 m above the ground.
- 5.1.5 Test track physical layout environment should exclude any conditions which might result in false sensor targets (i.e., metal guardrails, poles, embedded objects, pavement markings).

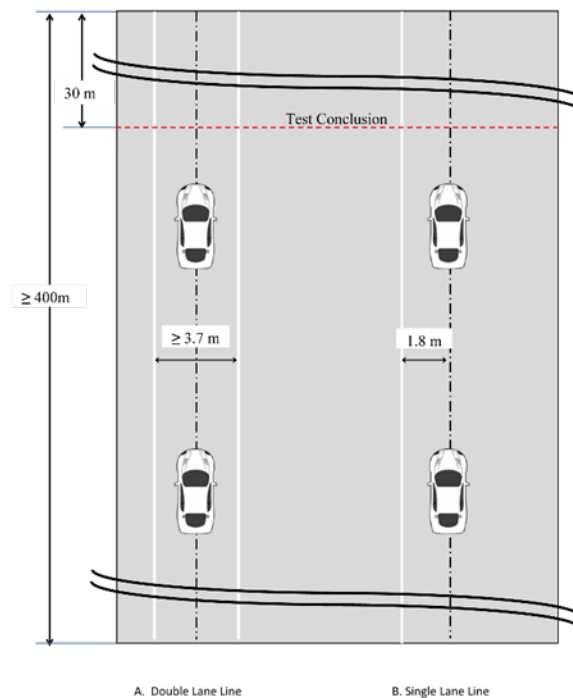


Figure 1 - Test area and orientation of vehicles in lanes

5.2 Environmental Conditions

5.2.1 Ambient Temperature

The ambient temperature shall be above 0 °C and below 38 °C.

5.2.2 Inclement Weather

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

5.2.3 Horizontal Visibility

The horizontal visibility at ground level shall be greater than 1 km.

5.2.4 Wind Speed

Wind speeds, including gusts, shall not exceed 10 m/s (22 mph) to minimize car target and test vehicle disturbance. Lower wind speed may be required depending upon target characteristics.

5.2.5 Ambient Illumination

Natural ambient illumination must be homogenous in the test area and in excess of 2000 lx for daylight testing with no strong shadows cast across the test area other than those caused by the car target and the test vehicle. Ensure testing is not performed driving toward or away from the sun when the sun altitude, as measured in degrees from the horizon, will be less than 15 degrees when testing is performed.

5.3 Surroundings

The general view ahead and to either side of the test area shall comprise of a wholly plain man-made or natural environment (e.g., further test surface, plain colored fencing, natural vegetation, or sky, etc.) and must not comprise any highly reflective surfaces or contain any vehicle-like silhouettes that may give rise to abnormal sensor measurements.

6. PRE-TEST PREPARATION

6.1 Brake Burnishing

Prior to conducting any tests, the brake system shall be conditioned to achieve full brake system capability and to ensure consistent performance. Different options for conditioning procedures exist. First, if brakes are not previously conditioned, follow the manufacturer's recommended procedure for burnishing brakes. In the absence of a manufacturer's recommended burnish procedure, the following procedure may be used to burnish new SV brake components. Alternative options are also presented in Appendix A.

1. Load the SV to its Gross Vehicle Weight Rating (GVWR).
2. From a speed of 49.7 mph (80 km/h), perform a minimum of 100 stops with an average deceleration of 0.31 g (3.0 m/s²) during each stop.
3. Each stop shall be performed with the transmission in gear.
4. The Initial Brake Temperature (IBT) shall be ≤ 100 °C (212 °F) at the onset of each stop. Note: The IBT is defined as the temperature measured within the pad or lining and is typically measured by means of a thermocouple. Other methods may be used for measuring brake temperature, for example, an infrared sensor may be used to measure brake rotor or drum temperature. Because of the different thermal properties of the brake components, there is a potential difference between pad or lining temperature measured by means of thermocouples and rotor/drum temperature measured by infrared means. Any such differences should be understood and accounted for.
5. The interval from the onset of one stop to the onset of the next is either the time necessary to reduce the IBT to ≤ 100 °C (212 °F), or the distance of 2 km (1.24 miles), whichever occurs first.
6. Accelerate to 49.7 mph (80 km/h) after each stop and maintain that speed until initiating the next.
7. Note that, among the various organizations conducting AEB tests, there is considerable variation in the methods used to condition the SV brakes. Several of these are described in Appendix A. Any alternative method used to condition brakes prior to testing shall be noted in the test record.

6.2 AEB System Settings

- 6.2.1 Automatic braking systems that have different settings for the timing of the braking application will be set to the default or normal setting.
- 6.2.2 Before AEB system performance can be properly assessed, some vehicles require a brief period of initialization. During this time, diagnostics to verify functionality and sensor calibrations are performed. If system initialization is required, obtain and perform the appropriate procedure from the vehicle manufacturer.
- 6.2.3 Repeat Activation protocol. Some AEB systems may display warnings or inhibit future AEB operation if there have been too many AEB activations within a set time window or ignition cycle. If this is the case, make an effort to obtain the appropriate procedure from the vehicle manufacturer such that this is avoided. If this is not able to be obtained, allow significant time between AEB activations and cycle the ignition after each test is performed.
- 6.2.4 Prior to testing, a check should be performed to verify that the AEB system recognizes the surrogate as a valid vehicle target. Most vehicles provide some feedback to the driver (e.g., driver information center icon) to signify that the system recognizes a vehicle ahead in the test vehicle's path. This type of feedback can be monitored as the test vehicle approaches the surrogate target to determine if the system recognizes the target at a headway which seems appropriate for the test vehicle speed (e.g., Time to Collision of approximately 2 seconds).