Procedure for assessing the performance of Reverse Autonomous Emergency Braking (R-AEB) systems in rear collisions

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RCAR

CONTENTS

1 AIM

This procedure specifies a method for assessing the performance of Reverse Autonomous Emergency Braking (R-AEB) systems in avoiding or mitigating collisions whilst reversing.

2 SCOPE

The test scenarios in this procedure are applicable to passenger cars (category M1) with an R-AEB system fitted. The tests are conducted against a car target, a circular section bollard and a square section pillar. The design intent of the system must be to prevent or mitigate a collision with these objects in a typical real world reversing situation.

3 BACKGROUND AND RATIONALE

Analysis of insurance claims databases (UK, Germany, U.S.A, Korea, Australia and Japan) has shown that 15% to 40% of all insurance claims are associated to damage occurring whilst the driver is parking. This equates to 10% to 30% of all claims costs. Further analysis of accident data has identified that around three quarters of all of these parking claims occurred whilst the vehicle was reversing. In around three quarters of cases the impact partner was another vehicle and collisions with tall thin objects such as bollards and pillars were also common.

The rationale for the development of this test procedure was therefore to create a standardised set of conditions that would enable the objective and repeatable assessment of R-AEB systems within scope and allow the performance to be reliably quantified.

4 OBJECTIVE

To produce objective, repeatable and reproducible results that is able to quantify the performance of the R-AEB systems in circumstances representative of the most common real-world reversing collisions.

5 DEFINITIONS

Reverse Autonomous Emergency Braking (R-AEB) – braking that is applied automatically by the vehicle whilst in reverse in response to the detection of a likely collision when the driver has not made any manual application of the brakes.

Reversing Car-to-Car (RCC) – a crash scenario in which the rear of the test car collides with another car positioned in the path of the test car.

Reversing Car-to-Bollard (RCB) – a crash scenario in which the rear of the test car collides with a circular section bollard positioned in the path of the test car.

Reversing Car-to-Pillar (RCP) – a crash scenario in which the rear of the test car collides with a square section pillar positioned directly in the path of the test car.

Global Vehicle Target (GVT) – a vehicle target with an appropriate vehicle shape, radar and light reflective and visual signature intended for use in this protocol.

Time To Collision (TTC) – the instantaneous distance to the collision position divided by the instantaneous forward vehicle speed.

6 TARGETS

6.1 Car target

The car target used for the AEB tests should have the appropriate radar and light reflective and visual signature of that of a real vehicle, equivalent to that of the Global Vehicle Target (GVT) as described in [include reference when published by Euro NCAP/ISO Standard] as shown in Figure 1.

Figure 1 – Global Vehicle Target (GVT)

6.2 Bollard target

The bollard target used for these tests should be circular in section and constructed to represent a typical example found in urban areas. The design should minimise any damage caused to the test vehicle if the bollard is struck during testing. It must be black in colour, have a height of 1.0m above the test track surface and have a smooth, plain surface of diameter between 0.10 and 0.13m. A typical example is shown in

Figure 2.

Figure 2 – Bollard target

6.3 Pillar target

The pillar target used for these tests must be square in section and constructed to represent a typical multi-storey building supporting pillar. The design should minimise any damage caused to the test vehicle if the pillar is struck during testing. It should be light grey in colour, have a height of 2.0m above the test track surface and have a smooth, plain surface of size between 0.45 and 0.55m square. A typical example is shown in Figure 3.

Figure 3 – Pillar target

7 TEST VEHICLE PREPARATION

7.1 General

Tests must be undertaken using a new vehicle in the 'as received' condition. It is permitted that prior to being used for testing the vehicle may be driven a maximum of 5000km or equivalent as recorded by the odometer.

Prior to starting preparation and testing make sure:

1. All vehicle systems are activated to customer delivery format (i.e. the vehicle is not in pre-delivery mode).
2. All fluids are correctly filled to the vehicle handbook specification.
3. The vehicle fuel tank is to at least 90% of capacity, and fuel is maintained to at least 75% of capacity throughout the testing.
4. The vehicle is in a safe working order.

7.2 Tyres

Tests must be undertaken using new, original equipment, all weather (not winter) tyres of the make, model, size, speed and load rating as fitted by the manufacturer to the majority of the vehicles produced of the particular variant tested. It is permitted to test using tyres which are supplied by the manufacturer or acquired at an official dealer representing the manufacturer if those tyres are identical make, model, size, speed and load rating to the original fitment.

Inflate the tyres to the vehicle manufacturer's recommended tyre inflation pressure(s) as specified on the tyre inflation pressure placard or in the vehicle handbook, acknowledging the vehicle loading condition for the testing.

7.3 Instrumentation

Install data measurement and acquisition equipment to sample and record test vehicle data with a minimum accuracy of:

Measurement	Range	Accuracy
Longitudinal and lateral position	Relative to local datum	0.03m
Forward speed	-10 to 10km/h	0.1km/h
Longitudinal acceleration (optional)	$\pm 20 m/s^2$	$0.1 m/s^2$
Yaw angle	± 180°	1.0 °
Steering wheel angle or velocity (optional)	± 720 º or ± 90 º/s	1.0 º or 1.0 º/s
Contact with target	-	Nearest data point

Table 1 – Instrumentation requirements

Sample and record all dynamic data at a frequency equal to or greater than 100Hz.

8 TEST ENVIRONMENT

8.1 Surface and markings

Conduct tests on a dry (no visible moisture on the surface), uniform, solid-paved surface with a consistent slope between level and 2%.

The surface must not contain any significant irregularities (e.g. large dips or cracks, manhole covers, or reflective studs) that may give rise to abnormal sensor measurements within the area on which the vehicle is tested.

8.2 Surroundings

Tests should be undertaken such that there are no other vehicles, highway furniture, obstructions or other objects protruding above the test surface that may give rise to abnormal sensor measurements within the area on which the vehicle is tested. Any overhead signs, bridges, gantries or other significant structures must be at a height of at least 5.0m above the test surface.

8.3 Ambient conditions

Test only in dry daylight conditions with ambient temperature between 5ºC and 40°C. Average wind speeds must be less than or equal to 10m/s to minimise target and test vehicle disturbance.

9 TEST VEHICLE PRE-TEST CONDITIONING

9.1 Brakes and tyres

Test the vehicle with the braking system and tyres in the normal operating condition. They may be prepared e in the following manner:

1. Perform ten stops from a speed of 56km/h with an average deceleration of approximately 0.5 to 0.6g.
2. Immediately following the series of 56km/h stops, perform three additional stops from a speed of 72km/h, each time applying sufficient force to the pedal to operate the vehicle's antilock braking system (ABS) for the majority of each stop.
3. Immediately following the series of 72km/h stops, drive the vehicle at a speed of 72km/h for five minutes to cool the brakes.

After conditioning maintain the tyres in the same position on the vehicle throughout the testing.

10 R-AEB SYSTEM TESTING

The performance of the test vehicle R-AEB system is evaluated in typical real world collision scenarios with the car, bollard and pillar targets whilst reversing straight and around a curve.

10.1 Reversing car-to-car test method

The reversing car-to-car test are comprised of three scenarios:

1. At the point of impact the longitudinal axes of the test vehicle and car target are parallel and the test vehicle overlaps 0.40m with the car target, as shown in Figure 3.

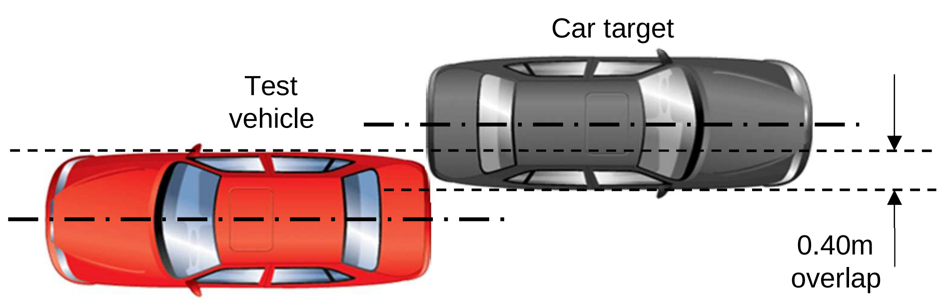

Figure 3 – Reversing car-to-car 0.40m overlap at impact position

2. At the point of impact the longitudinal axis of the test vehicle is at 45° to that of the car target and the rear corner of the test vehicle aligns with the rear centre of the car target, as shown in Figure 4.

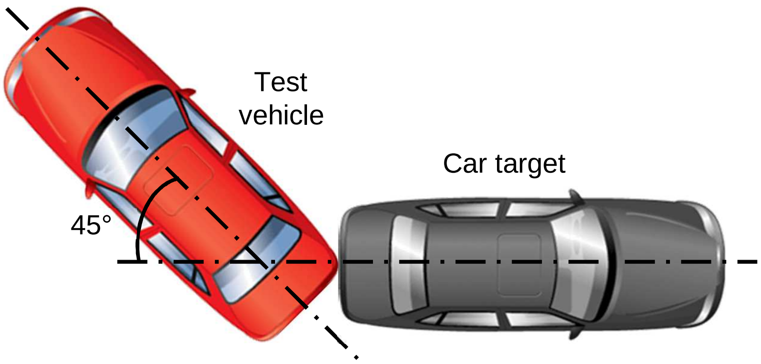

Figure 4 – Reversing car-to-car 45° centre at impact position

3. At the point of impact the longitudinal axis of the test vehicle is at 10° to that of the car target and the rear corner of the test vehicle aligns with the B pillar of the car target, as shown in Figure 6. The test vehicle impact point on the car target may not necessarily be the corner of the test vehicle as defined because of the vehicle geometry.

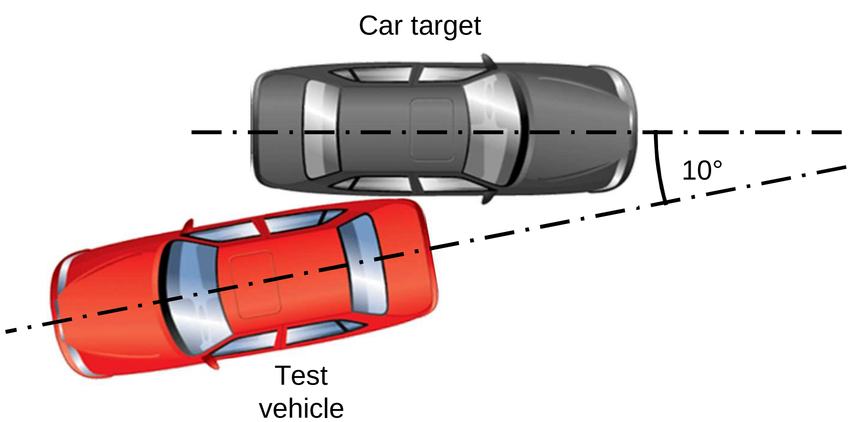

Figure 6 – Reversing car-to-car 10° side at impact position

Figure 3, Figure 4 and Figure 6 show the rear right corner of the test vehicle at the impact positon in all scenarios, however during testing the orientation of the scenario will be randomised to test using the left or right rear corner.

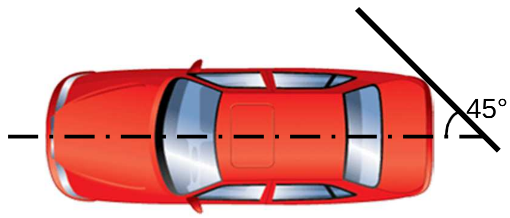

Figure 5 – Identifying the rear corner of the test vehicle

The rear corner of the test vehicle is identified as the point at which a vertical plane at 45° to the longitudinal axis across the rear corner of the test vehicle makes contact as shown in Figure 5.

The reversing car-to-car scenarios are tested with three manoeuvres as shown in Figure 6:

1. Straight backwards with the steering wheel in the straight ahead position.
2. Backwards around a curve with maximum left steering applied.
3. Backwards around a curve with maximum right steering applied

For vehicles equipped with a hydraulic power assisted steering system, it is permitted to perform testing with slightly less than maximum steering applied to prevent causing damage to the steering system by applying full steering lock for extended periods of time.

The reversing car-to-car scenarios are tested from two ranges as shown in Figure 8:

1. Short range – for straight backwards testing with a separation of 2.0m between the test vehicle and car target at the impact position, and for maximum steering, driving through an arc of 30°, to achieve a speed of 3km/h with a tolerance of +1km/h
2. Long range – for straight backwards testing with a separation of 6.0m between the test vehicle and car target at the impact position, and for maximum steering, driving through an arc of 90°, to achieve a speed of 6km/h with a tolerance of +1km/h.

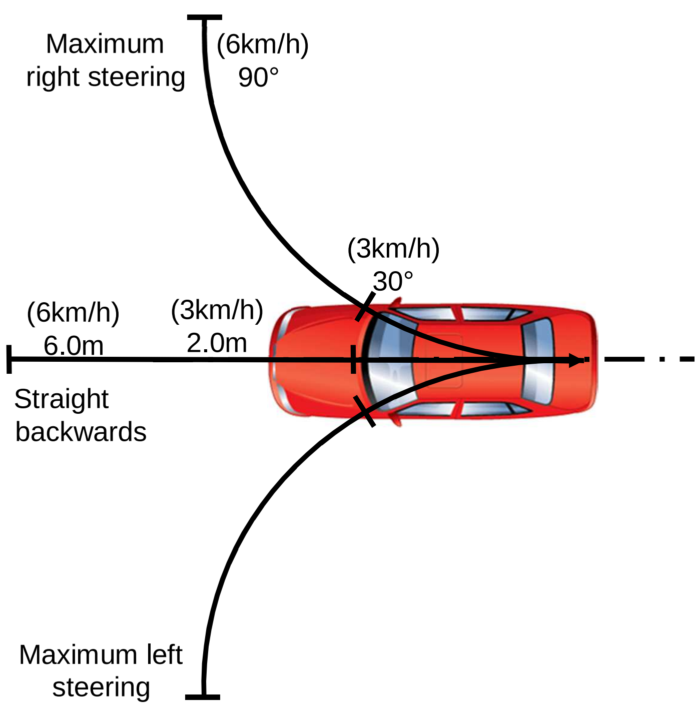

Figure 6 – Reversing car-to-car manoeuvres and ranges

Straight line tests are performed with the steering wheel held in the straight ahead position for the duration of the test according to the following method:

1. Position the test vehicle and the test target together at the appropriate impact position for the test scenario.
2. Holding the steering wheel in the straight ahead position, smoothly manoeuvre the test vehicle forwards to the test start position to achieve the necessary distance between the test vehicle and the test target for the short range or long range test.
3. Maintaining the same steering wheel position, commence the test reversing back towards the target as prescribed for the short range or long range test.

The maximum steering test method is similar to that for the straight line test method but taking into account that vehicles do not necessarily track along the same path when travelling forwards and reversing with the same steering wheel input applied. Therefore the following method is used to determine the offset required to account for this phenomenon as shown in Figure 7:

1. Align the centre rear of the test vehicle with the corner of the pillar target.
2. Holding the steering wheel in the maximum steering position, smoothly manoeuvre the test vehicle forwards through an arc of 30° (relative to the target) for short range and 90° for long range.
3. Maintaining the maximum steering wheel position, smoothly manoeuvre the test vehicle back towards the pillar target and bring the vehicle to a halt immediately before impact.
4. Determine the lateral offset between the centre of the rear of the test vehicle and the corner of the pillar target.
5. Repeat the above process for a total of three runs for both maximum left steering and maximum right steering respectively.
6. Calculate the average offset for maximum left steering and maximum right steering for short and long range test manoeuvres. Apply it as necessary during the testing to achieve the correct test configurations.

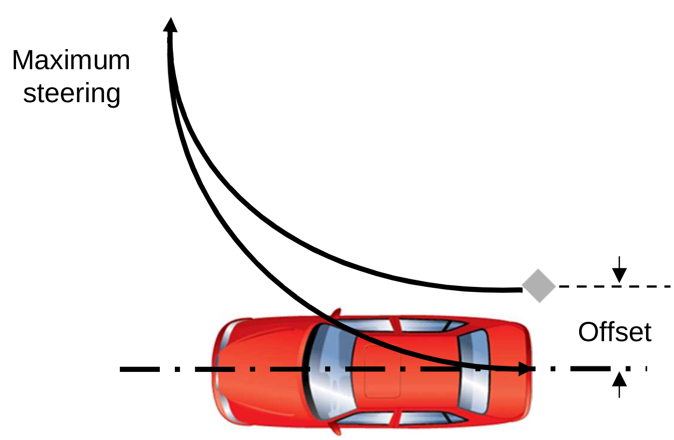

Figure 7 - Offset determination method (effect exaggerated)

Full steering lock tests are performed with the steering wheel held in the full lock position for the duration of the test according to the following method:

1. Position the test vehicle and car target together at the appropriate impact position for the test scenario, acknowledging and applying the offset calculated previously.
2. Holding the steering wheel in the full lock position, smoothly manoeuvre the test vehicle forwards to the test start position to achieve the necessary angle between the test vehicle and car target as specified in the short and long range criteria.
3. Maintaining the same maximum steering position, commence the test reversing back towards the target at the speed prescribed by the short and long range criteria. No further steering inputs should be necessary to maintain the test vehicle tracking along the test path.

For vehicles with an automatic transmission attempt the test manoeuvres with the vehicle creeping, however a minor smooth application of the accelerator pedal may be required to achieve the test speed before automatic braking occurs. For vehicles with a manual transmission it may be necessary to apply minor smooth accelerator pedal inputs and slip the clutch to achieve the test speed before automatic braking occurs.

Do <u>not</u> apply the test vehicle brakes at any time throughout an AEB system test unless necessary to maintain a safe testing environment. The application of the brakes at any time throughout an R-AEB system test run invalidates the test run.

The end of the test is when the test vehicle either impacts the test target or comes to a halt thus avoiding an impact plus a further 2.0 seconds of data to confirm the test vehicle action immediately after automatic braking.

The result for a test run is either:

- Pass – collision with the test target avoided as a result of R-AEB
- Fail – impact occurred with the test target, even at reduced speed.

Each test is performed twice and the overall result is the aggregate of the two individual results. If the results of the two tests are inconsistent a third test is performed and the overall result is taken as the majority result of the three individual results, i.e. pass, fail and then pass achieves an overall pass for the test, pass, fail and then fail achieves an overall fail.

10.2 Reversing car-to-bollard

The reversing car-to-bollard test comprises of two scenarios:

1. At the point of impact the centreline of the bollard is aligned with the longitudinal centreline of the test vehicle, as shown in Figure 8.
2. At the point of impact the centreline of the bollard is 0.40m inbound from the side of the test vehicle, as shown in Figure 10.

The reversing car-to-bollard tests are performed from both the short and the long range reversing straight backwards only, following the method described for the car-to-car straight backwards test scenario and applying the same result pass/fail criteria.

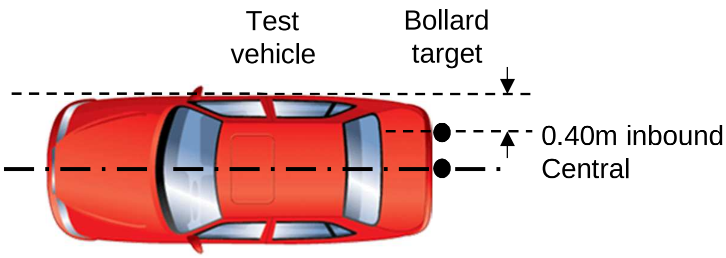

Figure 8 – Reversing car-to-bollard central and 0.40m inbound at impact position

10.3 Reversing car-to-pillar

The reversing car-to-pillar test comprises of two scenarios:

1. At the point of impact the corner of the pillar is aligned with the longitudinal centreline of the test vehicle, as shown in Figure 9.
2. At the point of impact the corner of the pillar is 0.40m inbound from the side of the test vehicle, as shown in Figure 11.

The faces of the pillar target should be orientated at 45° to the longitudinal centreline of the test vehicle.

The reversing car-to-bollard tests are performed from both the short and the long range reversing straight backwards only, following the method described for the car-to-car straight backwards test scenario and applying the same result pass/fail criteria.

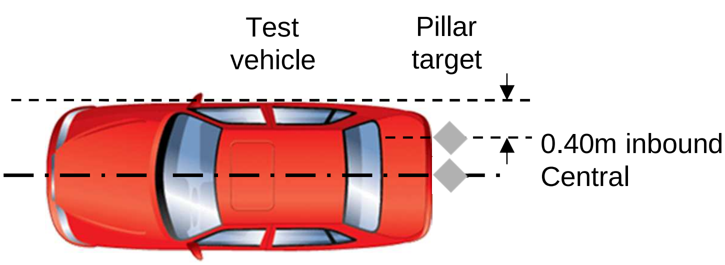

Figure 9 - Reversing car-to-pillar central and 0.40m inbound at impact position

11 DATA PROCESSING AND ANALYSIS

11.1 Speed

Use data as recorded.

11.2 Longitudinal acceleration

Filter the unfiltered longitudinal acceleration data with a 12 pole phaseless Butterworth filter with a cut off frequency of 6Hz. Zero the filtered data to remove sensor offset using the static pre-test data. Correct longitudinal acceleration relevant to the ground plane by removing the effects of vehicle body pitch under braking.

To determine when continuous pre-impact braking starts, find the first data point where the filtered and zeroed longitudinal acceleration is less than $-1.0 m/s^2$ to confirm the vehicle is decelerating, and then inspect previous data points to find the first data point where the longitudinal acceleration is less than $-0.3m/s^2$. The first data point where the longitudinal acceleration is less than $-0.3m/s^2$ is the start of automatic braking.

11.3 Yaw angle

Use data as recorded.

11.4 Lateral and longitudinal position

Use data as recorded.

11.5 Steering wheel angle (optional)

Use data as recorded.

11.6 Accelerator pedal position (optional)

Use data as recorded.

12 TEST RESULTS

The result for a test run is either:

- Pass – collision with the test target avoided as a result of R-AEB
- Fail – impact occurred with the test target, even at reduced speed.

Each test is performed twice and the overall result is the aggregate of the two individual results. If the results of the two tests are inconsistent a third test is performed and the overall result is taken as the majority result of the three individual results, i.e. pass, fail and then pass achieves an overall pass for the test, pass, fail and then fail achieves an overall fail.

13 SYSTEM PERFORMANCE REQUIREMENTS

In order to be recognised the R-AEB system must:

- Be automatically engaged and active whenever reverse is selected when the vehicle is in operating in a mode for driving on solid paved surfaces. A means by which the driver can deactivate the system is permitted providing that the system is automatically activated the next time reverse is selected.
- Visualise to the driver the location of the collision partner relative to the test vehicle.
- Continue to hold the vehicle stationary for a period of at least 1.0s after the R-AEB system has been brought the vehicle to a halt in the tests where a collision is avoided. This function may be overridden if the driver applies a substantial accelerator demand.

Not have its performance adversely affected by typical light soiling of the sensors.