



# Automatic Emergency Braking Systems (AEBS)

Methods of determination of efficiency

Version 1.0

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## Introduction

The main function of the advance automatic emergency braking system (AEBS) is warning the driver about potential danger of collision with a motor vehicle (MV) which is ahead and reducing the severity of the consequences of their potential collision. In case that the driver evaluates the danger of possible collision inadequately (low deceleration level), the AEBS may increase the deceleration of the vehicle (“braking assist” function).

Check of efficiency of the AEBS foresees conduction of test runs for defining the parameters of movement of the objects of tests. For these purposes, a set of “test scenarios” is used. These scenarios simulate real road situations, which assume activation and intervention of the AEBS.

This document describes the motor vehicles test methods with respect to their AEBS.

## 1. Scope

This document contains information relating to the methods of testing of MV of categories M1 and N1, equipped with automatic emergency braking systems (AEBS).

## 2. Terms and definitions

- **Automatic emergency braking systems (AEBS)**  
— a system capable of automatic detecting a risk of a front collision, warning the driver hereof and activating the braking system for preventing the collision or decreasing the severity of its consequences.
- **Collision warning** — information communicated by AEBS to the driver, which means necessity of operative actions from the driver's side for preventing the collision with a MV in front or for decreasing the severity of its consequences. Such warning is generated before the dangerous situation occurs.
- **Object of testing (OT)** — a motor vehicle that is subjected to testing.
- **MV obstructing the traffic** — moving or stationary vehicles, considered as potential threat for collision with the OT, and which may be detected by the AEBS.
- **Collision warning stage** — the stage directly preceding the stage of emergency braking, during which the AEBS alerts the driver of the risk of frontal collision.
- **Automatic braking stage** — the stage beginning at the moment when deceleration is started in automatic mode (without participation of the driver) upon request from AEBS.
- **MV movement lane** — longitudinal section of the test site, having sufficient width for one-lane movement of vehicles.
- **Adjacent lane** — driving lane, which has one common border with the lane where the OT is moving.  
The vehicles in this lane are driving in the same direction.

- **AEBS visual warning signal** — a technical means of warning the driver about the possibility of a frontal collision by means of a visual signal.
- **Acoustic warning signal** — a technical means of warning the driver about the possibility of a frontal collision by means of an audible signal.
- **Tactile warning signal** — a technical means of warning the driver about the possibility of a frontal collision by means of a tactile signal, which is perceived by the driver (vibration of controls or of elements of the seat, pre-tensioning of the seat belts etc.).
- **Braking distance** — the distance passed by the OT from the moment of start of braking until the complete stop.
- **Target vehicle (TV, or “Target”)** — a mockup simulating the rear part of a real vehicle, which is used for testing the AEBS. Requirements for the TV are given in paragraph 7.2.
- **Functional stage of the test** — the period of time during which the OT moves with fixed speed towards the “Target”, and the parameters of its movement are registered.
- **Distance (D)** — the distance from the rear surface of TV to the nearest element of the object of tests (Fig. 1).

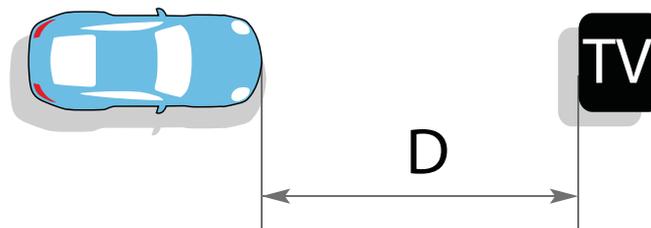


Fig. 1. Distance  $D$  between OT and TV

- **Collision with the Target** — a situation, which assumes contact between OT and TV.
- **Time to collision** — calculated time, obtained by dividing the Distance ( $D$ ) by the relative speed of movement of the given vehicle and the TV at the given moment of time.
- **Minimum speed** — the speed of movement of OT, at which the AEBS may perform its functions on prevention of collision.

- **Required deceleration** — minimum constant deceleration which, with the given distance, will allow the OT to avoid collision with the TV.
- **Lateral offset  $E_{lat}$**  — transversal distance between the longitudinal axis of the object of testing and the Target, measured in percent of the width of the OT (Fig. 2). If  $E_{lat}=100\%$ , this means that the TV is located in the adjacent lane with maximum offset from the side surface of the OT not more than 0.3 m (measured between the outside rearview mirrors).

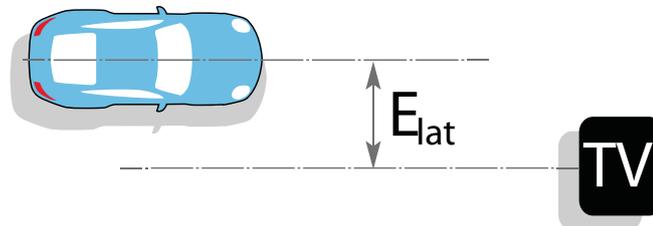


Fig. 2. Lateral offset  $E_{lat}$  between OT and TV

- **AEBS deactivation by the driver** — switching of the AEBS from active state to “OFF” state, initiated by the driver.
- **“Daylight” illumination conditions** — conditions of test when the illumination of the test site is not less than 1,000 lux (corresponds to natural illumination during a cloudy day).
- **“Night time” illumination conditions** — conditions of test when the illumination of the test site is less than 1 lux (corresponds to natural illumination during the night).

### 3. Conventional designations

- $T_1$  — moment of the start of the functional stage of the test (achieving and maintaining of the speed of OT prescribed by the test scenario).
- $T_2$  — moment when the AEBS sends the warning signal.
- $T_3$  — moment of the end of the functional stage of the test.
- $V_{\text{test.veh.}}$  — speed of the OT.
- $V_{\text{target}}$  — speed of the TV.
- $V_{\text{rel.impact}}$  — relative speed of OT and TV at the moment of collision.
- $V_{\text{test.veh.1}}$  — speed of OT at the moment  $T_1$ .
- $V_{\text{test.veh.2}}$  — speed of OT at the moment  $T_2$ .
- $V_{\text{test.veh.3}}$  — speed of OT at the moment  $T_3$ .
- $D_1$  — distance between OT and TV at the moment  $T_1$ .
- $D_2$  — distance between OT and TV at the moment  $T_2$ .
- $D_3$  — distance between OT and TV at the moment  $T_3$ .

## 4. Functional requirements concerning AEBS

AEBS shall ensure execution of the following functions:

- Warning about possible collision;
- Creating deceleration for avoiding the possible collision or decreasing the severity of its consequences.

AEBS also may perform the functions described below (but not limited to):

- Determination of presence of a moving and/or stationary vehicle (obstacle) in the trajectory of vehicle movement (only when moving forward);
- Determination of the speed of vehicle equipped with AEBS;
- Determination of the distance between the vehicle and the revealed obstacle, and of the relative speed of rapprochement;
- Activation and adjustment of the braking control of the vehicle, independent of whether the driver pushes the brake or not;
- Control of the stop lamps of the vehicle;
- Execution of assistance to the driver with regard to braking control, not limiting the actions of the driver in case of possible lane change to the adjacent lane (“braking assist”);
- Providing the driver opportunity to increase the deceleration of the vehicle up to the maximum possible value after the activation of the functions of AEBS on controlling the braking system of the MV;
- Adjustment (adaptation) of system operation depending on the road and climatic conditions.

## 5. Checking of main functions of AEBS

For checking the main functions of the AEBS, which define the total efficiency of the system, a set of tests is foreseen.

The tests are longitudinal, meaning that directly during the test run the OT shall be moving along a straight trajectory with a constant speed. In capacity of the “target”, a stationary TV shall be used.

### 5.1. Preliminary tests

The preliminary tests are performed with the purpose of determining the fact of activation of AEBS and choosing the range of speeds for conducting the functional tests.

This test method foresees testing of the functional capabilities of the AEBS with a stationary TV, positioned with zero lateral offset  $E_{lat}$  (see paragraph 2).

The OT shall be moving towards the TV with a constant speed. The driver shall not take any measures for reducing the speed, the position of the speed controls shall remain constant. For avoiding the contact with the Target at this stage of the tests, the driver shall perform the TV avoiding maneuver at the minimum possible distance between the OT and TV.

The test runs shall be conducted on a dry asphalt-concrete road under illumination conditions “Daylight” and “Night time”.

The test runs shall start from speed ( $V_{test.veh}$ ) 30 km/h. Subsequently, the speed of the OT is increased by steps of 5 km/h, up to 90 km/h. Three test runs shall be conducted with each speed. Availability of collision warning signal and activation of the stop lamps of the OT before the Target avoiding maneuver shall be registered.

Basing on the results of the preliminary tests, the range of speeds shall be determined which may be used for the functional tests.

The range of speeds, which may be used for the functional tests, shall include speeds 30 km/h, 35 km/h, 40 km/h, if during the preliminary tests activation of the collision warning signal was observed, and speeds from 45 km/h to 90 km/h, if during the preliminary tests the activation of the collision warning signal and of the stop lamps was observed.

The range of speeds, which may be used during the functional tests, shall be defined for illumination conditions “Daylight” and “Night time” separately.

## 5.2. Functional tests

The main types of functional tests are given in Table 1.

Table 1.

### Types of functional tests

Test	Illumination conditions	Target	Speed of the Object of tests $V_{\text{test.veh.}}$ , km/h	Road surface
1	“Daylight”	TV	According to the results of preliminary tests	Dry asphalt-concrete
2	“Night time”	TV	According to the results of preliminary tests	Dry asphalt-concrete

### Test 1

This test (Fig. 3) foresees the testing of functional capabilities of the AEBS. The TV shall be located in the lane of movement of the OT with zero offset ( $E_{\text{lat}} = 0\%$ ). After receiving the warning signal about possible collision, the driver shall not take actions for decreasing the speed. The test runs shall be performed on dry asphalt-concrete road under illumination conditions “Daytime”.

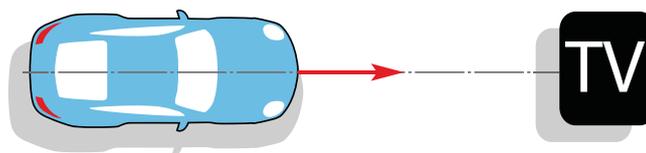


Fig. 3. Scheme of performing Test 1

## Test 2

This test (Fig. 3) foresees the testing of functional capabilities of the AEBS. The TV shall be located in the lane of movement of the OT with zero offset ( $E_{lat} = 0 \%$ ). After receiving the warning signal about possible collision, the driver shall not take actions for decreasing the speed. The test runs shall be performed on dry asphalt-concrete road under illumination conditions “Night time” and with passing beam headlamps of OT switched on.

## 6. Registered parameters

During each test run, the following parameters and indicators of the object of testing shall be registered:

- time (t);
- driven distance (S);
- longitudinal speed ( $V_{\text{test.veh.}}$ );
- longitudinal deceleration of the MV ( $j_x$ );
- geographic coordinates according to data from GPS/GLONASS;
- moment of sending of acoustic, visual or tactile warning signal about possible collision;
- moment of switching on of the stop lamps;
- speed of the OT at the moment of contacting the TV;
- effort at the brake pedal;
- distance between the OT and TV after the stop.

In addition to the registration of the parameters, it is recommended to perform video recording by not less than three video cameras. One camera shall be located in the passenger compartment and register the moments of sending the acoustic and/or visual warning signal about the possible collision; the other two cameras shall be installed on the test site (Fig. 4). The external video cameras shall register the moments of switching on the stop lamps, moment of the possible contact between the OT and TV, or the moment of stop of the OT before contacting the TV.

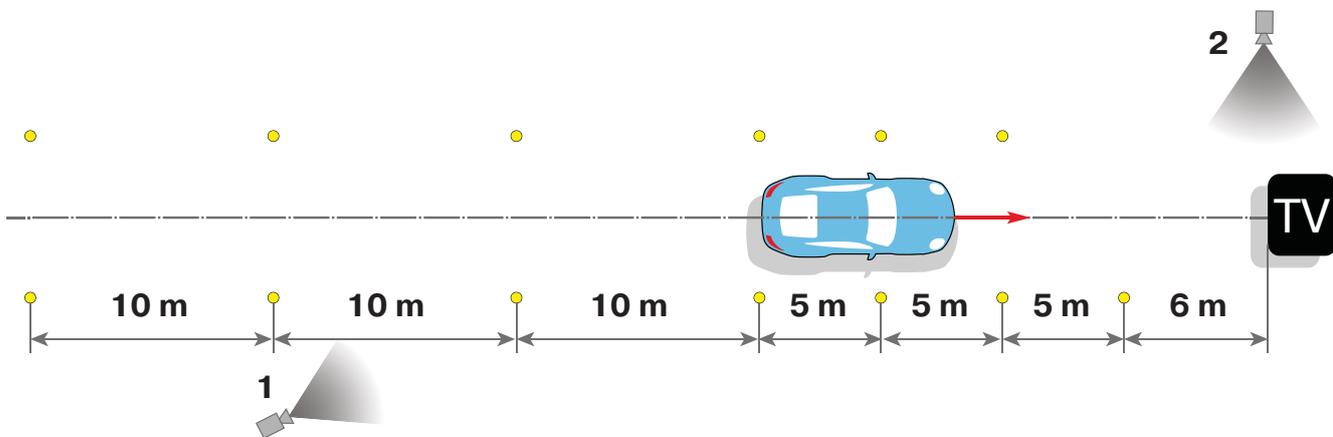


Fig. 4. Arrangement of the external video cameras

In case of absence of video cameras, or absence of opportunity for due synchronization of the records with the main parametric record of the movement of OT with accuracy 0.1 s, it is necessary to ensure another possibility of determining of the moments of sending the acoustic and/or visual collision warning signal and the moment of switching on the stop lamps with the same accuracy.

## 7. Test equipment

### 7.1. Test site

- The tests shall be conducted on a level horizontal site with asphalt-concrete surface. The width of one traffic lane shall be  $3.5 \text{ m} \pm 0.25 \text{ m}$ . The traffic lanes shall be divided with the help of signal cones.
- The test site shall be marked with signal cones limiting the width of the corridor of movement depending on the overall width of the OT at the wheels at height of 150 mm from the road surface. The width of the corridor shall be determined as overall width of the OT + 0.5 m.
- It is not permitted to conduct the test runs under bridges or platforms crossing the trajectory of movement of OT.
- It is not permitted to change the test site within the testing of a given OT.

Before the start of the tests, it is necessary to evaluate the adhesion coefficient of the surface of the test site by the value of maximum deceleration of the OT. A series of three stops with initial speed 60 km/h shall be performed. The effort at the brake pedal shall cause the ABS operating in continuous cycling mode. The maximum possible deceleration is defined as the mean value of established deceleration in three test runs, in the range of speed decreasing from 45 km/h to 15 km/h.

### 7.2. Target vehicle (TV)

The Target Vehicle used for testing of the AEBS shall conform to standard ISO 19206-1.

## 8. Preparation of the object of testing

- The OT shall be in a technically good condition; it shall be equipped and run-in according to the Operating Manual.
- Before the start of the test runs, the mass of the vehicle with installed test equipment shall be determined. In addition, the mass of the test driver shall be indicated in the test report.
- The aggregates of transmission and chassis of the vehicle must be warmed up by means of continuous driving for not less than 20 minutes at speed equal  $0.8-0.9 V_{\max}$ , but not exceeding 100 km/h.
- Directly before the start of the tests, three stops shall be performed from initial speed 60 km/h with mean deceleration from 5 to 6 m/s<sup>2</sup>. The same procedure shall be repeated in case when the intervals between the test runs exceed 15 minutes.
- Before the start of the tests, the AEBS shall be brought into operating condition in accordance with the manufacturer's instructions. Signals of AEBS malfunction shall be absent. If the AEBS has different operating modes, then the mode corresponding to the earliest warning about possible collision shall be chosen.

## 9. Test conditions

- The tests shall be conducted at ambient air temperature from -20 °C to +40 °C.
- It is not permitted to perform the tests during precipitations and at wind speed exceeding 4 m/s.
- The direction of the test runs shall be chosen in such way as to exclude situations when the sun rays are directed towards the moving OT.
- Meteorological conditions shall be registered directly before the start of testing. The following parameters shall be measured and registered in the test report:
  - ambient air temperature, °C;
  - temperature of the road surface, °C;
  - wind speed in m/s and its direction;
  - illumination, lux.
- The object of testing shall be in running order and it shall be equipped with necessary measuring and registering equipment. It is permitted that an assistant is present in the front passenger seat in addition to the test driver.

## 10. Order of conducting the test runs

1. The OT and TV shall be at their initial positions and shall be stationary.
2. The test driver shall switch on the measuring and registration equipment installed onboard of the OT.  
The assistants shall switch on the internal and external video cameras (or the substituting registration equipment).
3. The test driver accelerates the OT until the prescribed speed and drives with this speed along the centerline of the lane towards the TV.  
Use of cruise control and other onboard devices, allowing maintaining the set speed automatically, is not permitted. The prescribed speed must be achieved not less than 120 m before the TV. After receiving warning about possible collision, the test driver shall not take any actions for reducing the speed.
4. At each speed, three test runs shall be performed. In case of OT collision with the TV at speed not exceeding 30 km/h (at the moment of contact between OT and TV), two additional test runs with the given initial speed shall be performed. In case of collision with the TV at speed exceeding 30 km/h, the tests shall be stopped.
5. Permissible deviation of the actual speed from the prescribed speed shall be  $\pm 2$  km/h.

## 11. Processing and analysis of the test results

Basing on the results of each test run, dependences of the following parameters as function of time shall be built:

- OT movement speed and speed of rotation of one of the front wheels (optional);
- effort at the brake pedal;
- longitudinal deceleration;
- steering wheel angle (optional);
- distance between the OT and TV (D).

Time counting (zero-time mark) in the chart shall start at the moment of activation of function “Warning about possible collision” (moment of activation of the acoustic and/or visual and/or the tactile warning signal about the possible collision). The zero mark of the distance axis corresponds to the moment of contact between the OT and TV.

The following events shall be marked in the charts:

- moment ( $T_2$ ) – moment of activation of the acoustic and visual signal warning about possible collision;
- longitudinal speed of the object of testing ( $V_{test.veh.2}$ ) at the moment  $T_2$ ;
- distance ( $D_2$ ) between OT and TV at the moment  $T_2$  (the distance shall be determined according to the coordinates obtained from the global positioning system);
- speed of the object of testing ( $V_{test.veh.3}$ ) at the moment of contact between OT and TV (if such contact happened). In case of absence of contact  $V_{test.veh.3}=0$ .

An example of built dependence is given in Fig. 5.

Conventional designations used in the chart:



- moment ( $T_2$ ) of activation of acoustic, visual or tactile signal warning about potential collision;



- moment of activation of the stop lamps of the OT;



— moment of contact of the OT with the TV ( $T_3$ );



— OT stop without contact with the TV.

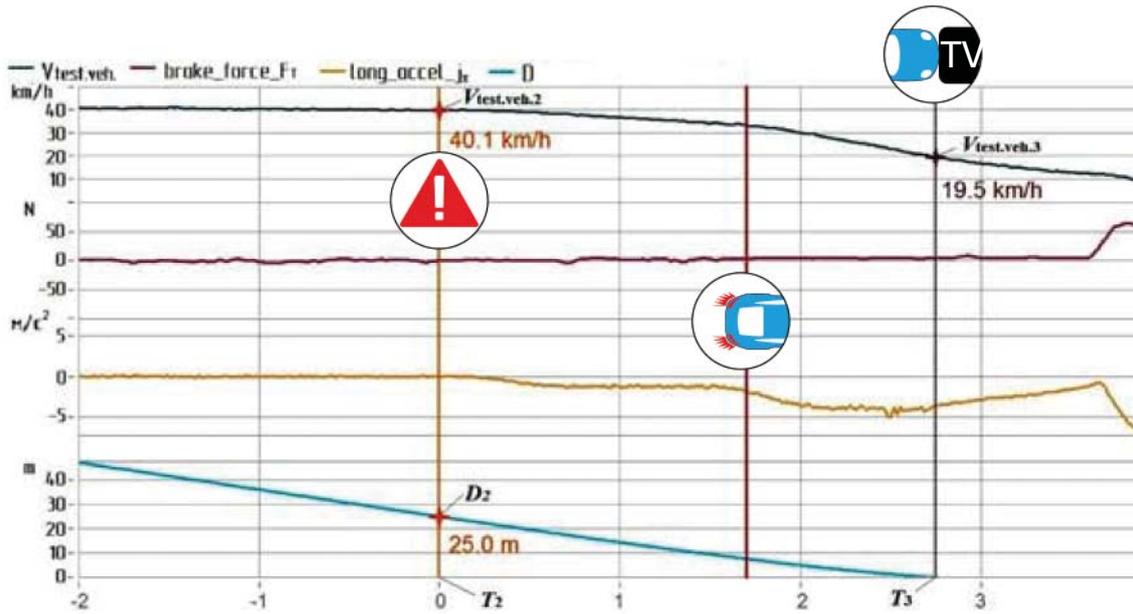


Fig. 5. Example of built dependence

## **12. Determination of the efficiency of AEBS operation**

Determination of the efficiency of AEBS operation is based on the analysis of the limit initial speed, at which there was no collision with the TV, or the collision speed did not exceed 4 km/h. The limit initial speed is the maximum initial speed of test runs, at which there was no contact of the OT with the TV in three runs of three, or if in four runs of five the speed of collision did not exceed 4 km/h.

The resulting rating of the efficiency of AEBS operation shall be defined as the sum of the limit speeds obtained as result of Test 1 and Test 2. The maximum possible number of points is 180. If during Test 1 and/or Test 2 the AEBS proved to be inefficient at any initial speed of the test run, then the number of points for this (these) Tests shall equal zero.