INTERNATIONAL STANDARD

ISO 19377

First edition
2017-11

Heavy commercial vehicles and buses — Emergency braking on a defined path — Test method for trajectory measurement

Véhicules utilitaires lourds et autobus — Freinage d'urgence sur un passage défini — Méthodes d'essai pour la mesure de trajectoire

Reference number
ISO 19377:2017(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics and chassis components*.

Introduction

The main purpose of this document is to provide repeatable and discriminatory test results.

The dynamic behaviour of a road vehicle is a very important aspect of active vehicle safety. Any given vehicle, together with its driver and the prevailing environment, constitutes a closed-loop system that is unique. The task of evaluating the dynamic behaviour is, therefore, very difficult since the significant interaction of these driver-vehicle-environment elements are each complex in themselves. A complete and accurate description of the behaviour of the road vehicle requires information obtained from a number of different tests.

Since this test method quantifies only one small part of the complete vehicle handling characteristics, the results of these tests can only be considered significant for a correspondingly small part of the overall dynamic behaviour.

Moreover, insufficient knowledge is available concerning the relationship between overall vehicle dynamic properties and accident avoidance. A substantial amount of work is necessary to acquire sufficient and reliable data on the correlation between accident avoidance and vehicle dynamic properties in general and the results of these tests in particular. Consequently, any application of this test method for regulation purposes will require proven correlation between test results and accident statistics.

Heavy commercial vehicles and buses — Emergency braking on a defined path — Test method for trajectory measurement

1 Scope

This document describes test methods for determining the deviation of the path travelled by a vehicle during a braking manoeuvre induced by an emergency braking system from a pre-defined desired path. The purpose of this document is the evaluation of the vehicle path during and following the system intervention. The corrective steering actions for keeping the vehicle on the desired path can be applied either by the driver or by a steering machine or by a driver assistance system. By making this document open for either open-loop or closed-loop testing, it is possible to apply the test method for evaluating how well the vehicle can be kept within user-defined lane markings after the system intervention, and also for evaluating the precision of the interaction between the emergency braking system and an active lane keeping system.

This document applies to heavy vehicles equipped with an advanced emergency braking system (AEBS), including commercial vehicles, commercial vehicle combinations, buses and articulated buses as defined in ISO 3833 (trucks and trailers with maximum weight above 3,5 tonnes and buses and articulated buses with maximum weight above 5 tonnes, according to ECE and EC vehicle classification, categories M3, N_2, N3, O3 and O4).

NOTE The test method is intended to evaluate the entire vehicle behaviour, not for defining system requirements for the AEBS, which is done in the respective standards created by ISO/TC 204.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8855:2011, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*

ISO 15037-2:2002, *Road vehicles — Vehicle dynamics test methods — Part 2: General conditions for heavy vehicles and buses*

ISO 16552:2015, *Heavy commercial vehicles and buses — Stopping distance at straight-line braking with ABS — Open-loop and closed-loop test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8855 and ISO 15037-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
vehicle reference point
point fixed in the vehicle

Note 1 to entry: For use with this document, the vehicle reference point of the first vehicle unit shall be set to the following:

— $X_V = 0$ at the wheel centre of the first axle;

— $Y_V = 0$ at the centre of the connection line between the tyre contact centres of the first axle;

— $Z_V = 0$ on ground level.

3.2
activation time
t_0
point in time of intervention of the AEBS, given by a trigger signal

3.3
vehicle reference position
X_0, Y_0
lateral and longitudinal position of the reference point of the first vehicle unit at the *activation time* (3.2)

3.4
path deviation
D_{Pn}
shortest distance between the desired vehicle path and the position of the reference point of vehicle unit, n, at a certain point in time, t

4 Principle

This document specifies a method to determine the deviation of the vehicle from a defined path. The driving situation represents an intervention of an advanced emergency braking system during straight-ahead driving or in a curve on an even road surface with a uniform coefficient of friction as specified in ISO 15037-2. It is necessary that the emergency braking system of the test vehicle allows an external input for triggering the system intervention. After the triggering, the AEBS shall remain active until vehicle standstill. The test may be conducted as open-loop or as a closed-loop test. In case of an open-loop test, the steering wheel angle is kept to its initial value. In case of a closed-loop test, the driver (or a steering robot) or a lane keeping assistance system or both attempt to keep the vehicle on the desired path.

If the test is conducted with corrective steering actions by the driver, the results will strongly depend on the driver activities. This should be considered when comparing closed-loop test results. For excluding the driver influence during a closed-loop test, it is recommended to conduct the test with a steering robot which has the capability to be programmed for a desired path via GPS feedback.

NOTE By leaving the test method open for interventions of driver assistance systems other than the emergency braking system, the interactions of the systems can be investigated, e.g. the steering interventions of an active lane keeping assistance system acting during the emergency braking can be compared with the steering actions of a steering robot or a driver.

5 Variables

The variables of motion used to describe the behaviour of the vehicle shall be related to the *reference axis system* (*X, Y, Z)* of the first vehicle unit (see ISO 8855) with the *reference point* as described in 3.1. The variables that shall be determined for compliance with this document are the following:

— longitudinal velocity, v_x;

— steering-wheel angle, δ_H;

— activation time (t_0);

— longitudinal and lateral distance travelled by the vehicle reference point of the first unit (X_{V1}, Y_{V1});

— longitudinal and lateral distance travelled by the centre of the last axle i of the first unit (X_{V1Ai}, Y_{V1Ai});

— longitudinal and lateral distance travelled by the centre of the last axle (i = i_{max}) of the vehicle combination (X_{VnAi}, Y_{VnAi});

— longitudinal and lateral acceleration at the vehicle reference point, a_x and a_y.

It is recommended that the following variables are also determined:

— yaw velocity of the first vehicle unit, $\dot{\psi}$;

— yaw angle of the first vehicle unit, ψ ;

— articulation angles between the vehicle units, $\psi_{Vn-Vn+1}$;

— sideslip angle of the first vehicle unit, β_{V1} ;

— wheel brake pressures.

6 Measuring equipment

The measuring equipment, transducer installation and data processing shall be in accordance with ISO 15037-2. Typical operating ranges of the variables to be determined for this document are shown in Table 1 and in ISO 15037-2.

It is recommended to use a position measurement system (e.g. a differential GPS device) to measure the path travelled by the vehicle before and after the activation time. Only the relative position between the desired path and the path travelled by the vehicle shall be determined, see Table 1 for the accuracy. Furthermore, it is recommended to use a photoelectric barrier for triggering the system intervention at the same place on the test track for each measurement.

Table 1 — Variables, typical operating ranges and recommended maximum errors of variables not listed in ISO 15037-2

Variable	Typical operating range	Recommended maximum errors of the combined transducer and recorder system
Longitudinal and lateral distance (for position measurement systems)	0 m to 200 m	±0,05 m
Yaw angle	±360°	±1°

7 Test conditions

7.1 General

The test conditions described in ISO 15037-2 shall apply to this document. General data of the test vehicle shall be recorded as specified in ISO 15037-2. See Annex A.

7.2 Test track and ambient conditions

All tests shall be carried out on an even road surface with a uniform coefficient of friction. An estimation of the friction level shall be reported.

NOTE The test method can be used for investigation of the differences in vehicle behaviour on different road friction conditions.

7.3 Test vehicle

7.3.1 General vehicle condition

The reference condition of the test vehicle shall be in accordance with the vehicle manufacturer's specifications, particularly with respect to the brake system, the suspension, power train configuration (e.g. differentials and locks) and shall be in accordance with ISO 15037-2. Deviations from this reference condition shall be reported in the test results.

The brake system shall be in a well-maintained condition. Any newly installed wheel brakes shall be burnished in accordance with vehicle manufacturer specifications. If the vehicle is equipped with additional drive train braking devices (e.g. retarder) or functions other than ABS that influence braking performance (e.g. cross-axle braking difference compensation), the actual condition shall be reported.

7.3.2 Loading condition

The loading condition of the vehicle shall be in accordance with ISO 15037-2 and shall be reported in the test results.

7.3.3 Number of test runs

One test sequence consists of at least three valid test runs, i.e. test runs performed while observing all conditions specified.

8 Test methods

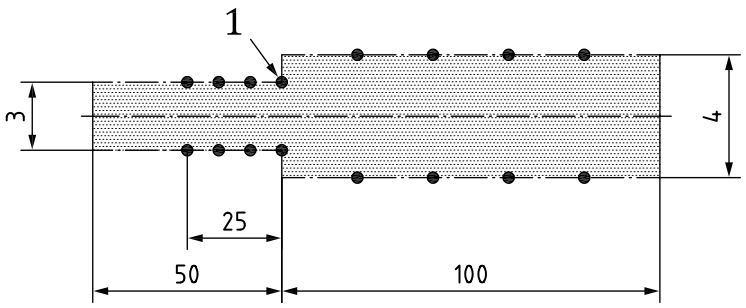
8.1 Test method for braking straight ahead

8.1.1 Initial driving condition

The initial driving condition for the test shall be driving straight ahead as specified in ISO 15037-2. The standard nominal initial vehicle velocity at the beginning of braking is 80 km/h. Other initial velocities may be used, especially for tests conducted on road surfaces with a low coefficient of friction.

8.1.2 Definition of the desired path and track

The desired path for braking straight ahead is a straight line in the lane centre with a length of at least 50 m before the trigger point and at least 100 m after this point. The track shall be marked with pylons as shown in Figure 1. An entrance lane with a recommended width of 3,0 m and a recommended length of 25 m is set up to help ensure precise straight-ahead driving before the intervention of the emergency braking system. The following lane width may also be marked by pylons for an indication if the vehicle is leaving a desired lane width during the system intervention. For this purpose, a standard lane width of 4,0 m and a longitudinal distance of 10 m between the pylons are recommended. Alternatively, especially when the vehicle is equipped with an active lane keeping system, existing lane markings may be used.



Key

1 photoelectric trigger

Figure 1 — Test track for braking straight ahead

8.1.3 System intervention

After reaching the initial driving conditions in the entrance lane, an intervention by the emergency braking system is initiated by the photoelectric barrier at the end of the entrance lane. After the activation time, given by the point in time marked by the trigger signal, the emergency braking system shall be active until vehicle standstill.

In case of performing the test as an open-loop test, the steering wheel angle shall be kept at its initial value at the activation time until standstill. In case of performing the test as a closed-loop test, the driver or a steering machine shall try to keep the vehicle on the desired straight-ahead path by corrective steering actions. In both cases, no additional control shall be applied by the driver. When using a steering robot or (in case of simulation) a driver model to perform the corrective steering actions as a driver surrogate, the steering wheel velocity shall be limited to 360°/s.

For manual transmissions, it is recommended to disengage the clutch before standstill. For automatic transmissions, the transmission should remain in drive condition.

8.2 Test method for braking in a constant radius curve

8.2.1 Initial driving condition

For performing the test on a constant radius track, the initial driving condition for the test shall be steady-state cornering as specified in ISO 15037-2. The recommended values for the initial lateral acceleration and the initial vehicle velocity at the activation time, t_0, are 2 m/s^2 and 72 km/h, respectively. Other values may be used, especially for tests conducted on road surfaces with a low coefficient of friction.

8.2.2 Definition of the desired path and track

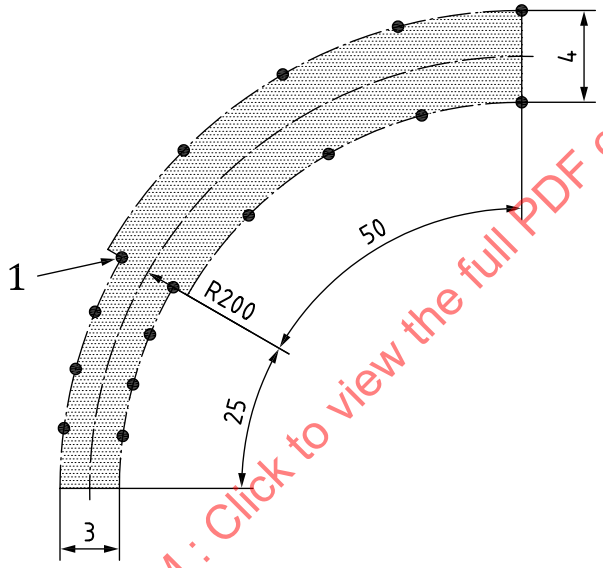
Based on the recommendation for the initial driving conditions, the desired path for this test method is a curve segment with a constant radius of 200 m, a length of at least 25 m before the intervention point and at least 50 m after this point. The desired path is the lane centre of this track. The radius of the track may vary according to the chosen initial values of lateral acceleration and vehicle velocity. The track shall be marked with pylons as shown in Figure 2. An entrance lane with a recommended width of 3,0 m and a recommended length of 20 m is set up to help ensure precise steady-state circular driving before intervention of the emergency braking system. The following lane width may also be marked by pylons for an indication if the vehicle is leaving a desired lane width during the system intervention. For this purpose, a standard lane width of 4,0 m is recommended, using at least 5 pylons for marking the inside and outside lane. Alternatively, especially when the vehicle is equipped with an active lane keeping system, existing lane markings may be used.

8.2.3 System intervention

After reaching the initial driving conditions in the entrance lane, an intervention by the emergency braking system is initiated, e.g. by the photoelectric barrier at the end of the entrance lane. After the activation time, given by the point in time marked by the trigger signal, the emergency braking system shall be active until vehicle standstill.

In case of performing the test as an open-loop test, the steering wheel angle shall be kept at its initial value at the activation time until standstill. In case of performing the test as a closed-loop test, the driver or a steering machine shall try to keep the vehicle on the desired constant radius path by corrective steering actions. In both cases, no additional control shall be applied by the driver. When using a steering robot or (in case of simulation) a driver model to perform the corrective steering actions as a driver surrogate, the steering wheel velocity shall be limited to 360°/s.

For manual transmissions, it is recommended to disengage the clutch before standstill. For automatic transmissions, the transmission should remain in drive condition.



Key

1 photoelectric trigger

Figure 2 — Test track for braking in a constant radius curve

9 Data evaluation and presentation of results

9.1 General

In the test report, test conditions shall be presented as shown in ISO 15037-2. Each change in vehicle equipment (e.g. different loading conditions) shall be documented. Annex A shall be consulted for an example of result reporting.

For every test run, time histories of the variables listed in Clause 5 and the following characteristic values shall be presented. Apart from their evaluation purposes, the time histories serve to monitor correct test performance and functioning of the transducers.

9.2 Characteristic values

9.2.1 Maximum path deviation, $D_{P,max}$

A graph of the vehicle path (lateral position of the vehicle reference point of the first vehicle unit versus the longitudinal position of the vehicle reference point of the first vehicle unit) shall be plotted, the *vehicle reference position* serving as zero position for the coordinate system. The graph shall also contain the predefined path (see Figure 3).

The path deviation, D_P, at a certain point in time after the activation time is derived from the shortest distance between the present position of the vehicle reference point to the predefined path (see Figure 3). A time history of D_P and its maximum value, $D_{P,max}$, shall be presented in the test report.

For vehicle combinations, it is recommended to plot additionally a corresponding graph of the trajectory of the trailer.

Key

D_p path deviation at time, t
1 position of vehicle reference point at time, t
2 path of vehicle reference point
3 predefined path

Figure 3 — Predefined path, path travelled by the vehicle reference point and path deviation, D_P

9.2.2 Maximum rear axle path deviation, $D_{PR,max}$

For gaining information of the yaw stability of the first vehicle unit during braking, a graph of the lateral position of the centre of the last axle of the first vehicle unit versus its longitudinal position shall be plotted.

The rear axle path deviation, D_{PR}, at a certain point in time after the *activation time* is derived from the shortest distance between the present position of this point to the predefined path, with the same method as for the path deviation, D_P. A time history of D_{PR} and its maximum value, $D_{PR,max}$, with comparison to the respective values of the first vehicle unit, D_P and $D_{P,max}$ shall be presented in the test report.

9.2.3 Maximum trailer path deviation, $D_{PT,max}$

For vehicle combinations, a graph of the vehicle path of the trailer (lateral position of the centre of the last axle of the vehicle combination versus its longitudinal position) shall be plotted.

The trailer path deviation, D_{PT}, at a certain point in time after the *activation time* is derived from the shortest distance between the present position of this point to the predefined path, with the same method as for the path deviation, D_P. A time history of D_{PT} and its maximum value, $D_{PT,max}$, with comparison to the respective values of the first vehicle unit, D_P and $D_{P,max}$ shall be presented in the test report.

9.2.4 Deceleration at full braking

For indication of the deceleration reached by the vehicle after the intervention of the emergency braking system, a time history and the value of the deceleration at full braking of the first vehicle unit according to ISO 16552 shall be reported.

9.2.5 Maximum articulation angle(s) (optional)

For vehicle combinations, the maximum value of the articulation angle(s) between *activation time* and vehicle standstill may be reported.

9.2.6 Corrective steering action, $\delta_{H,C}$ (for closed-loop test)

When using one of the closed-loop test methods, a mean integral value of the steering wheel angle within the time interval between the activation time and the standstill may serve as a measure for the necessary corrective steering action. The value of $\delta_{H,C}$ is derived from:

$$\delta_{H,C} = \frac{1}{t_{end} - t_0} \int_{t_0}^{t_{end}} \left| \delta_H(t) - \delta_{H,ref} \right| \; dt \tag{1}$$

For t_{end}, the time of vehicle standstill (e.g. point in time when the vehicle velocity has reached less than 1 m/s) shall be used. For $\delta_{H,ref}$, the initial steering wheel angle at t_0 shall be used as a constant value.

Alternatively or additionally, the root mean square of the deviation of the steering wheel angle values with respect to the reference steering wheel angle may be derived from:

$$\delta_{RMS} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (\delta_{H,i} - \delta_{H,ref})^2} \tag{2}$$

9.2.7 Indication of leaving the desired track (optional)

If pylons are used for marking the lane width after the vehicle reference position, they may be used as an indication of the vehicle leaving a user-defined lane. The position of the first pylon hit by the vehicle shall then be reported.

Annex A
(normative)

Test report — General data and test conditions

A.1 General data

The test report for general data shall be as given in ISO 15037-2:2002, Annex A.

A.2 Test conditions

The test report for test conditions shall be as given in ISO 15037-2:2002, Annex B.

Annex B
(informative)

Example of test reports

Table B.1 — Example for reporting the characteristic values (Simulation results, 40 t tractor/semitrailer combination, fully laden, dry road surface)

V_0, [km/h] a_{y0} (m/s²)	**S/ = straight C/ = curve /O = open-loop /C = closed-loop**	**Maximum path dev** $D_{P,max}$ (m)	**Maximum path dev rear axle** $D_{PR,max}$ (m)	**Maximum path dev trailer** $D_{PT,max}$ (m)	**Deceleration during full braking** (m/s²)	**Maximum articul. angle** (°)	**Mean steering correction** $\delta_{H,C}$ (°)	**Pylon hit after *x* metres**
70 km/h, 2 m/s²	C/O	2,905	2,98	2,85	6,67	[a]	—	[a]
70 km/h, 2 m/s²	C/C	1,377	1,46	1,32	6,67	[a]	11,8	[a]

[a] Not recorded.