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Passenger cars — Braking in a turn — Open-loop test method

Voitures particulières — Freinage en virage — Méthode d'essai en boucle ouverte

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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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 of 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 www.iso.org/iso/foreword.html.

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

This fourth edition cancels and replaces the third edition (ISO 7975:2006), which has been technically revised. The main changes compared to the previous edition are as follows:

— recognizing regenerative braking and active control systems.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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 will necessarily involve 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. If this test method is used for regulation purposes, the correlation between test results and accident statistics should be checked.

Passenger cars — Braking in a turn — Open-loop test method

1 Scope

This document specifies an open-loop test procedure to examine the effect of braking on course holding and directional behaviour of a vehicle. Specifically, the method determines how the steady-state circular response of a vehicle is altered by a braking action only. This document is applicable to passenger cars as defined in ISO 3833 and to light trucks.

The open-loop manoeuvre specified in this test method is not representative of real driving conditions but is useful to obtain measures of vehicle braking behaviour resulting from control inputs under closely controlled test conditions.

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 4138, *Passenger cars — Steady-state circular driving behaviour — Open-loop test methods*

ISO 15037-1:2019, *Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8855 and ISO 15037-1 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 https://www.iso.org/obp

4 Principle

The purpose of this test is to examine the effect of braking on course holding and directional behaviour of a vehicle. Specifically, the method determines how the steady-state circular response of a vehicle is altered by braking action only.

The initial conditions are defined by constant longitudinal velocity and by a circle with a given radius, as specified by the constant-radius test method of ISO 4138. The steering-wheel angle required for the steady-state circular run shall be constantly maintained during the entire test. During the test, the driver input and the vehicle response are measured and recorded. From the recorded signals, characteristic values are calculated.

5 Variables

5.1 Reference system

The reference system specified in ISO 15037-1 shall apply.

5.2 Variables to be measured

The following variables shall be determined:

— moment of brake application (t_0);

— steering-wheel angle (δ_H);

— lateral acceleration (a_Y);

— longitudinal acceleration (a_X);

— longitudinal velocity (v_X);

— yaw velocity ($d\psi/dt$); and

— sideslip angle (β and/or lateral velocity (v_Y).

Strictly speaking, test results based on lateral acceleration should not be used for comparison of the performance of different vehicles. This is because lateral acceleration is measured at right angles to the intermediate X-axis and not perpendicular to the vehicle path. To overcome this difficulty, lateral acceleration can be corrected for vehicle sideslip angle, which gives the centripetal acceleration. However, the extent of this correction is not likely to exceed a few percent and may generally be neglected.

It is recommended that the following variables be determined:

— pressure at master cylinder output or in the brake circuit which activates at least one of the front wheel brakes p_B); and

— wheel rotation speed ($\omega_1 - \omega_4$).

The variables are defined in ISO 8855 except for stopping distance and the moment of brake application, t_0, which is the instant at which the brake pedal is operated. The actuation of the brake pedal may be determined by the use of a contact switch mounted directly on the brake pedal or a sensor for the brake pedal force which set a trigger signal when the brake pedal force exceeds 10 N.

6 Measuring equipment

6.1 Description

ISO 15037-1:2019, Table 1 shall apply with the following additions from Table 1:

Table 1 — Variables, typical operating ranges and recommended maximum errors

Variable	Typical operating range	Recommended maximum error of the combined transducer/recorder system
Moment of brake application	—	0,05 s
Pressure of braking system	30 MPa[a]	±0,3 MPa
Wheel rotation speed	0 s^{-1} to 200 s^{-1}	±2 s^{-1}
[a] 1 MPa = 10 bar = 10^6 N/m^2.		

6.2 Transducers and their installation

ISO 15037-1:2019, 5.2 shall apply.

6.3 Data processing

The recording system and data processing requirements contained in ISO 15037-1:2019, 5.3 shall apply.

7 Test conditions

The test conditions specified in ISO 15037-1:2019, Clause 6 shall apply.

General data on the test vehicle shall be recorded as specified in ISO 15037-1:2019, 6.4.1, with the following additions:

The tyre type, tyre brand, any special equipment on the test vehicle, any deviation in type or operating condition of components from the manufacturer's specification, the odometer reading at the beginning and end of the test, and any other condition that may affect test results shall also be recorded on the test report for general data (see ISO 15037-1:2019, Annex A).

8 Test methods

8.1 Run-in program for newly installed brakes (pads/shoes)

The brake linings (pads/shoes) shall be conditioned following the recommendations of the vehicle manufacturer. If manufacturer's recommendations are not available, the brake linings shall be conditioned using one of the following procedures:

For vehicles with disc/disc braking systems, a total of 60 brake applications shall be performed. From an initial vehicle speed of 100 km/h, the vehicle shall be decelerated to approximately 20 km/h at the following approximate deceleration rates:

— 2 m/s^2 for the first 15 brake applications;

— 3 m/s^2 for the next 15 brake applications; and

— 5 m/s^2 for the final 30 brake applications.

For vehicles with disc/drum or drum/drum braking systems, a total of 200 brake applications shall be performed. From an initial vehicle speed of 100 km/h, the vehicle shall be decelerated to approximately 20 km/h at the following approximate deceleration rates:

— 2 m/s^2 for the first 50 brake applications;

— 3 m/s^2 for the next 50 brake applications; and

— 5 m/s^2 for the final 100 brake applications.

During these brake applications, brake disc and/or brake drum temperatures must not exceed 200 °C. The tyres used for running in the brakes must not be used for subsequent braking distance measurements.

8.2 Warm-up

The procedure specified in ISO 15037-1:2019, 7.1 shall be followed to warm up the tyres and other vehicle components prior to the test.

In addition to warming up the braking system, five full stops should be performed from an initial speed of about 100 km/h. In each of these stops, brake actuation should be sufficient to cause the anti-lock

braking system to be active throughout the majority of the stop. To avoid excessive strain on the brakes, the temperature of the brake discs (drums) should be below 120 °C at the beginning of each single stop.

8.3 Brake temperature

The temperature of the front brake discs (drums) shall be between 80 °C and 120 °C, and the rear brake discs (drums) shall be less than 120 °C before each test run. If necessary, the brakes shall be cooled between runs. The installation of reliable temperature sensors is recommended to monitor the brake temperatures.

8.4 Initial driving condition

The initial driving conditions for a steady-state circular run, as specified in ISO 15037-1:2019, 7.2.1 and 7.2.3, shall apply with the initial conditions according to the combinations of radii and lateral acceleration given in Table 2. As it is known that the significance of the results and the discrimination between different vehicles increase with increasing test speed, the standard radius of this path shall be 100 m. Additional radii ranging from 30 m to 200 m may be used and shall be noted in the figures of Annex A. Because of the importance of the initial driving conditions, especially for brake tests, the throttle position and/or accelerator pedal shall be observed. For the time interval from t_1 to t_2 (see ISO 15037-1:2019, Figure 2) the standard deviation of the throttle position shall not exceed 10 % of its mean value.

NOTE Results of different radii are not comparable.

Table 2 — Initial test conditions

Condition	Radius	Lateral acceleration		Corresponding longitudinal velocity	
	m	m/s^2	tolerance %	km/h	tolerance %
Standard	100	5	±10	81	±5
Optional	30 to 200	5	±10	44 to 114	±5

The initial combination of one radius and one lateral acceleration given in Table 2 could be widened by additional test runs with lateral accelerations other than 5 m/s^2, mainly by steps of 1 m/s^2.

8.5 Performance of the braking procedure

When the initial steady-state driving condition has been reached, the steering wheel is fixed by a mechanical device or, alternatively, is firmly held by the driver. The accelerator pedal shall be released, and brakes applied as quickly as possible.

For vehicles with manual transmission, the test shall be performed in the highest gear compatible with the conditions of the test speed given in Table 2. The clutch may be disengaged immediately or at the end of the test run. The option chosen (gear position and clutch disengagement) shall be indicated in the test report (see Annex A).

For vehicles with automatic transmission, the standard drive mode shall be used. The position of the transmission lever and the selected driving programme shall be recorded in the test report (see Annex A).

Cars with adaptive gear selection or Continuously Variable Transmission (CVT) may use different gears or ratios at a given speed. For such cars, engine speed shall be recorded for the purpose of determining gear ratio. It shall be recorded in the test report.

For vehicles with regenerative braking capabilities the specific vehicle configuration may alter the dynamic vehicle behaviour while releasing the accelerator pedal and/or while pressing the brake pedal. Also, the different dynamic vehicle behaviour with or without active regenerative braking shall be

considered while performing the tests. The selected level of regenerative braking capability and the transmission lever position shall be documented in the test report as defined in ISO 15037-1.

The charging status of the energy storage could influence the results which should be reflected. The test should be run with a status equal or less of 50 % to reach the maximum of recuperation unless the effect on performance with a fully charged battery is meant to be measured.

The actuation of the brake-pedal or the brake light switch is considered as the moment of brake application, t_0. During braking, the pressure in the braking system or the brake-pedal force or the brake-pedal travel shall be kept as constant as possible (an adjustable stop under the brake-pedal may serve) and the steering wheel shall be fixed until the test run is finished.

The test runs for a combination of radius and lateral acceleration defined in Table 2 shall be made at increasing levels of longitudinal acceleration, until on vehicles with conventional braking system, lock up of at least one of the front wheels occurs (if possible). The test may be continued beyond this point resulting in further wheels locking until lock up of all wheels has occurred but testing under these conditions may result in rapid and large changes of tyre characteristics, which may cause wide variations in test results. On vehicles equipped with an antilock braking system, the test shall be continued until the peak value of mean longitudinal acceleration at time t_n (see Figure 2) is detected.

The minimum braking action shall correspond to a mean longitudinal acceleration of 2 m/s^2 and shall be increased by increments of not more than 1 m/s^2. If the results vary rapidly with the longitudinal acceleration, smaller increments should be selected.

Depending on the conditions of load, there could be a certain risk of rollover. If necessary, some safety device is recommended.

8.6 General test description

All necessary variables shall be recorded throughout the manoeuvre from time t_1 (see ISO 15037-1:2019, Figure 2) before brake application until the vehicle comes to a standstill. Data shall be taken for both left and right turns. It is recommended that the test be repeated at least three times so that the results can be examined for repeatability and averaged.

9 Data evaluation and presentation of results

9.1 General

General data on the test vehicle shall be presented on a summary form using the general data test report contained in ISO 15037-1:2019, Annex A. The general test conditions shall be presented using the test conditions test report contained in ISO 15037-1:2019, Annex B.

9.2 Time histories

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

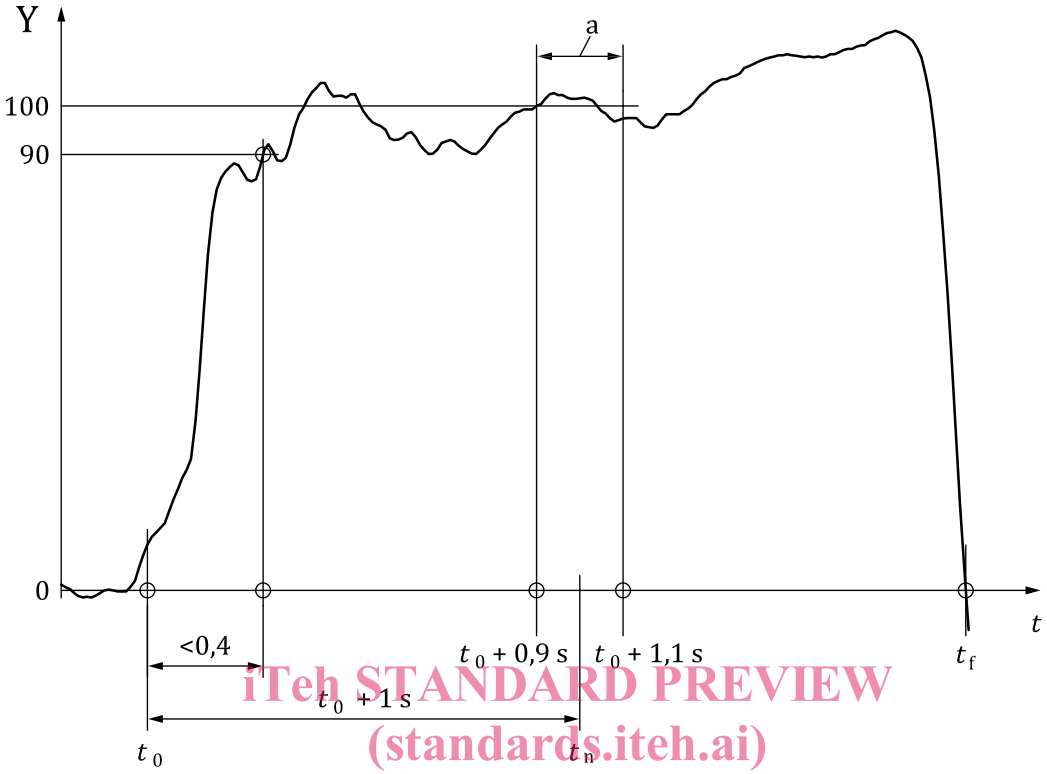
9.3 Braking action

9.3.1 Reference point in time, t_0

The reference point in time, t_0, for the following characteristic values is the moment of the brake-pedal actuation.

9.3.2 Definition of times and requirements for standard evaluation

Figure 1 shows the pattern of longitudinal acceleration during braking versus time.



Key

t time (s)

Y longitudinal acceleration (%)

a Time interval for evaluation (see 9.4.1).

Figure 1 — Definition of times

For the correct performance of a test run, the rise time of the longitudinal acceleration shall not exceed 0,4 s.

The longitudinal acceleration at 1 s after time t_0 is evaluated by taking the mean value during the time interval 0,9 s to 1,1 s after t_0.

The rise time is defined as the difference between the reference point in time t_0 and time t_{90}.

Time t_{90} is the time when the longitudinal acceleration reaches 90 % of the value at 1 s after time t_0.

The time t_f is defined as the time when the longitudinal acceleration reaches the value zero at the end of the braking actuation.

9.3.3 Mean longitudinal acceleration, $-\bar{a}_X$

The mean longitudinal acceleration is the average value of longitudinal acceleration measured during each brake application.

This average value may be obtained by either of the following methods:

a) measuring the distance needed by the vehicle to stop from instant t_0, in which case the mean longitudinal acceleration is given by:

