INTERNATIONAL STANDARD

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Third edition
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Road vehicles — Lateral transient response test methods — Open-loop test methods

Véhicules routiers — Méthodes d'essai de réponse transitoire latérale — Méthodes d'essai en boucle ouverte

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 7401 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

This third edition cancels and replaces the second edition (ISO 7401:2003), which has been technically revised.

Introduction

The main purpose of this International Standard 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 is each complex in itself. A complete and accurate description of the behaviour of the road vehicle must 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. Consequently, any application of this test method for regulation purposes will require proven correlation between test results and accident statistics.

Road vehicles — Lateral transient response test methods — Open-loop test methods

1 Scope

This International Standard specifies open-loop test methods for determining the transient response behaviour of road vehicles. It is applicable to passenger cars, as defined in ISO 3833, and to light trucks.

NOTE The open-loop manoeuvres specified in this International Standard are not representative of normal driving conditions, but are nevertheless useful for obtaining measures of vehicle transient behaviour in response to several specific types of steering input under closely controlled test conditions. For measurements of steady-state properties, see ISO 4138.

2 Normative references

The following referenced documents are indispensable for the application 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 1176:1990, *Road vehicles — Masses — Vocabulary and codes*

ISO 2416:1992, *Passenger cars — Mass distribution*

ISO/TR 8725:1988, *Road vehicles — Transient open-loop response test method with one period of sinusoidal input*

ISO/TR 8726:1988, *Road vehicles — Transient open-loop response test method with pseudo-random steering input*

ISO 8855[1)], *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*

ISO 15037-1:2006, *Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars*

3 Terms and definitions

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

4 General conditions

The general conditions specified in ISO 15037-1 shall apply.

1) To be published.

5 Principle

5.1 General

IMPORTANT — The method of data analysis in the frequency domain assumes that the vehicle has a linear response; this is unlikely to be the case over the whole range of lateral accelerations of interest. The standard method of dealing with such a situation is to restrict the input to a sufficiently small range such that linear behaviour can be assumed. If necessary, testing can be performed with several ranges of inputs that, together, cover the entire range of interest.

The primary object of these tests is to determine the transient response behaviour of a vehicle. Characteristic values and functions in the time and frequency domains are considered necessary for characterizing vehicle transient response.

Important characteristics in the time domain are:

a) time lags between steering-wheel angle, lateral acceleration and yaw velocity;

b) response times of lateral acceleration and yaw velocity (see 10.2.1 and 10.2.2);

c) lateral acceleration gain (lateral acceleration divided by steering-wheel angle);

d) yaw velocity gain (yaw velocity divided by steering-wheel angle); and

e) overshoot values (see 10.2.3).

These characteristics show correlation with subjective evaluation during road driving.

Important characteristics in the frequency domain are the frequency responses, i.e. amplitudes and phases of:

— lateral acceleration related to steering-wheel angle; and

— yaw velocity related to steering-wheel angle.

5.2 Test methods

There are several test methods for obtaining these characteristics in the domains of time and frequency, the applicability of which depends in part on the size of the test track available.

a) Time domain:

   1) step input; and

   2) sinusoidal input (one period).

b) Frequency domain:

   1) random input;

   2) pulse input; and

   3) continuous sinusoidal input.

These test methods are optional, but at least one of each domain type should be performed. The methods chosen shall be indicated in the general data specified in Annex A and in the presentation of test results specified in Annex B.

It is possible that the characteristic values of lateral acceleration gain and yaw velocity gain, obtained by the different test methods, may not be comparable, owing to one or more of the following circumstances:

— linear versus non-linear vehicle behaviour;

— periodic versus non-periodic steady-state condition;

— steady state versus dynamic vehicle behaviour.

6 Reference system

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

The location of the origin of the vehicle axis system (X_V, Y_V, Z_V) is the reference point and therefore should be independent of the loading condition. It is fixed in the longitudinal plane of symmetry at half-wheelbase and at the same height above the ground as the centre of gravity of the vehicle at complete vehicle kerb mass (see ISO 1176).

7 Variables

The following variables shall be determined:

a) steering-wheel angle, δ_H;

b) lateral acceleration, a_Y;

c) yaw velocity, $\dot{\psi}$;

d) longitudinal velocity, v_X.

The following variables may be determined:

— roll angle, ϕ;

— sideslip angle, β;

— lateral velocity, v_Y;

— steering-wheel torque, M_H.

These variables, defined in ISO 8855, are not intended to comprise a complete list.

8 Measuring equipment

8.1 Description

Subclause 4.1 of ISO 15037-1:2006 shall apply as well as the following additions shown in Table 1.

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

Variable	Range	Recommended maximum error of the combined transducer/ recorder system
Steering-wheel angle	−180° to +180°[a]	±1°
Yaw velocity	−50 °/s to +50 °/s	±0,5 °/s
Lateral velocity	−10 m/s to +10 m/s	±0,1 m/s
Sideslip angle	−15° to +15°	±0,3°
[a] Assuming a conventional steering system.		

The use of a programmable steer robot may help to increase the accuracy and repeatability of steer inputs for the described transient response manoeuvres.

8.2 Transducer installation

Subclause 4.2 of ISO 15037-1:2006 shall apply.

8.3 Data processing

The recording system and data processing requirements contained in 4.3 of ISO 15037-1:2006 shall apply.

9 Test conditions

9.1 General

The test conditions specified in Clause 5 of ISO 15037-1:2006 shall apply.

9.2 Vehicle loading conditions

9.2.1 General

Tests shall be carried out at the minimum loading condition and at the maximum loading condition defined below, and at other loading conditions of interest.

In accordance with ISO 1176:1990, 4.8 and 4.13, the maximum authorized total mass (Code: ISO-M08) and the maximum authorized axle load (Code: ISO-M13) shall not be exceeded.

Care shall be taken to minimize the difference of both the location of the centre of gravity and the moments of inertia as compared to the loading conditions of the vehicle in normal use (see ISO 2416:1992, Clause 4). The resulting static wheel loads shall be determined and recorded in the test report (see Annex A).

9.2.2 Minimum loading condition

For the minimum loading condition, the total vehicle mass shall consist of the complete vehicle kerb mass (Code: ISO-M06) in accordance with ISO 1176:1990, 4.6, plus the masses of the driver and the instrumentation. The mass of the driver and the instrumentation should not exceed 150 kg. The load distribution shall be equivalent to that of two occupants in the front seats, in accordance with ISO 2416.

9.2.3 Maximum loading condition

For the maximum loading condition, the total mass shall be equal to the maximum authorized total mass.

For the maximum loading condition, the total mass shall be equivalent to the complete vehicle kerb mass, plus 68 kg for each seat in the passenger compartment and with the remaining maximum mass of transportable goods equally distributed over the luggage compartment in accordance with ISO 2416. Loading of the passenger compartment shall be such that the actual wheel loads are equal to those obtained by loading each seat with 68 kg according to ISO 2416.

The transient lateral response is strongly influenced by the moments of inertia and by the height of the centre of gravity. Wheel loads define only one of several factors contributing to the dynamic properties of vehicles. Care shall be taken to keep test conditions between test runs as constant as possible. Therefore, it is recommended to limit weight changes caused by fuel consumption.

9.3 Warm-up

The warm-up procedures specified in 6.1 of ISO 15037-1:2006 shall apply.

9.4 Test speed

The test speed is defined as the nominal value of the longitudinal velocity. The standard test speed is 100 km/h. Other test speeds of interest may be used (preferably in 20 km/h steps).

10 Step input

10.1 Test procedure

Drive the vehicle at the test speed (see 9.4) in a straight line. The initial speed shall not deviate by more than 2 km/h from the test speed. Starting from a 0 °/s ± 0,5 °/s yaw velocity equilibrium condition, apply a steering input as rapidly as possible to a preselected value and maintain at that value for several seconds after the measured vehicle motion variables have reached a steady state. In order to keep the steering input short relative to the vehicle response time, the time between 10 % and 90 % of the steering input should not be greater than 0,15 s. No change in throttle position shall be made, although speed may decrease. A steering-wheel stop may be used for selecting the input angle.

Take data for both left and right turns. All data shall be taken in one direction followed by all data in the other direction. Alternatively, take data successively in each direction for each acceleration level, from the lowest to the highest level, this being preferable with respect to tyre wear and symmetrical vehicle stress. Record the method chosen in the test report (see Annex A).

Data shall be taken throughout the desired range of steering inputs and response variable outputs.

Determine the steering-wheel angle amplitude by steady-state driving on a circle the radius of which gives the preselected steady-state lateral acceleration at the required test speed. The standard steady-state lateral acceleration level is 4 m/s^2. Additional levels of 2 m/s^2 and 6 m/s^2 may be used.

Perform all test runs at least three times.

10.2 Data analysis

10.2.1 Response time

The transient-response data reduction shall be carried out such that the origin for each response is the time at which the steering-wheel angle change is 50 % complete. This is the reference point from which all response times are measured. Response time is thus defined as the time, measured from this reference, for the vehicle transient response to first reach 90 % of its new steady-state value (see Figure 1).

10.2.2 Peak response time

The peak response time is the time, measured from the reference point, for a vehicle transient response to reach its peak value (see Figure 1).

In some instances, system damping can be so high that a peak value cannot be determined. If this occurs, data sheets should be marked accordingly.

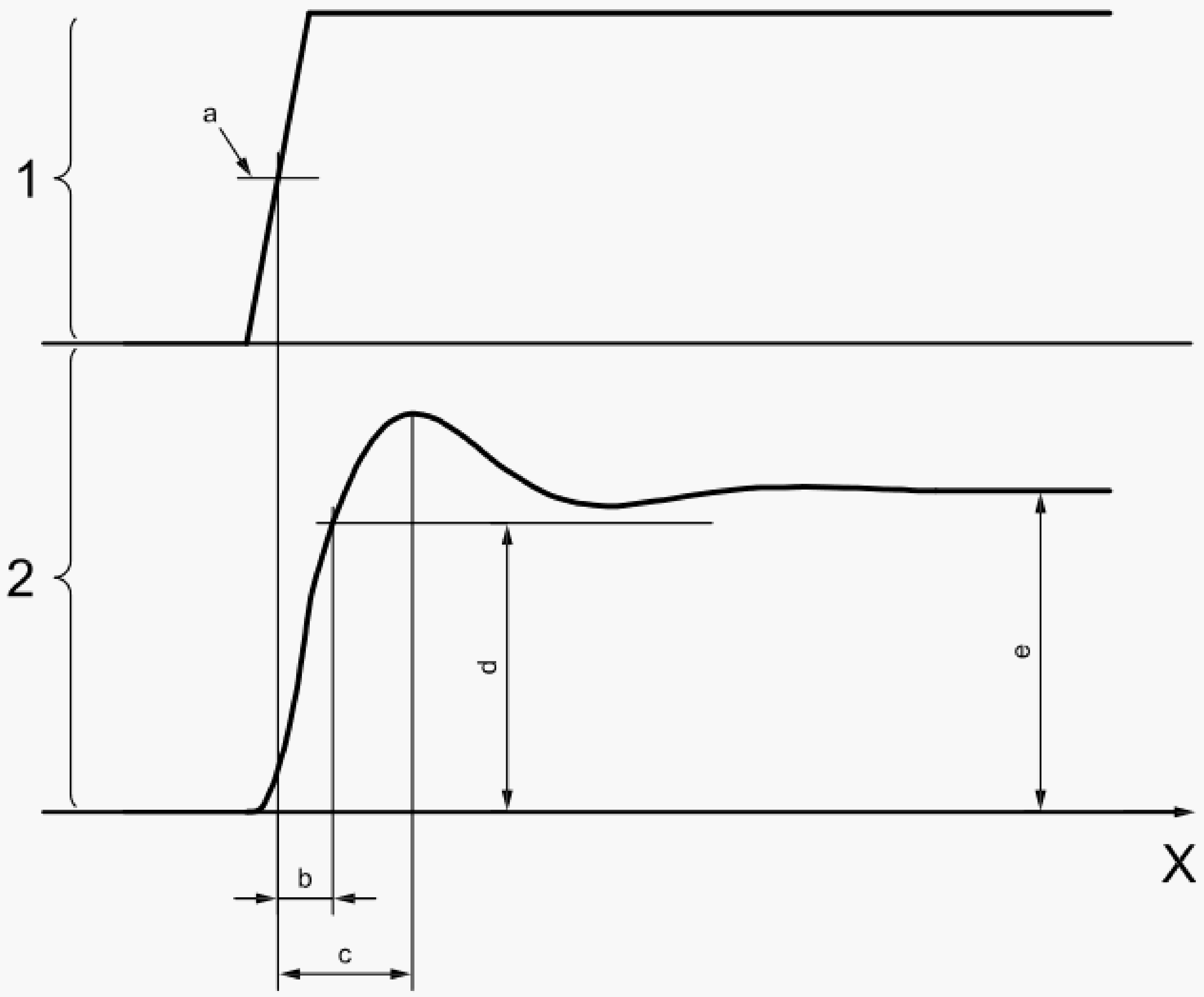
10.2.3 Overshoot values

The overshoot values are calculated as a ratio: the difference of peak value and steady-state value divided by steady-state value.

10.3 Data presentation

10.3.1 General

General data shall be presented in accordance with Annex A.



Key

1 steering-wheel input
2 vehicle response time
X time

a 50 % level.
b Response time; T.
c Peak response time; Tmax.
d 90 % steady state.
e Steady state.

Figure 1 — Response time and peak response time

10.3.2 Time histories

The time histories of variables used for data evaluation shall be plotted. If a curve is fitted to any set of data, the method of curve fitting shall be described in the presentation of results in Annex B.

Plot the time histories of steering-wheel angle, lateral acceleration and yaw velocity for each measured lateral acceleration level in the form, as shown in Figure B.1.

10.3.3 Time response data summary

Record the following values in accordance with Table B.1 for each combination of test speed and lateral acceleration:

a) steady-state yaw velocity response gain, $\left(\frac{\dot{\psi}}{\delta_{\text{H}}}\right)_{\text{ss}}$;

b) lateral acceleration response time, T_{aY};

c) yaw velocity response time, $T_{\dot{\psi}}$;

d) lateral acceleration peak response time, $T_{aY,\text{max}}$;

e) yaw velocity peak response time, $T_{\dot{\psi},\text{max}}$;

f) overshoot value of lateral acceleration, U_{aY};

g) overshoot value of yaw velocity, $U_{\dot{\psi}}$.

11 Sinusoidal input — one period (see ISO/TR 8725)

11.1 Test procedure

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Take data while the steering-wheel is rotated, initially both to the left and to the right. All data shall be taken in one direction followed by all data in the other direction. Alternatively, take data successively in each direction for each acceleration level, from the lowest to the highest level. Record the method chosen in the test report (see Annex A).

Increase the steering-wheel input stepwise up to a magnitude sufficient to produce the desired lateral acceleration in accordance with 11.2.2. The standard lateral acceleration level is 4 m/s^2. Additional acceleration levels of 2 m/s^2 and 6 m/s^2 and up to the adhesion limit (see ISO/TR 8725) may be used.

Perform at least three test runs for each combination of speed and steering.

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Record the following values in accordance with Table B.1 for each combination of test speed and lateral acceleration:

a) steady-state yaw velocity response gain, $\left(\frac{\dot{\psi}}{\delta_{\mathrm{H}}}\right)_{\mathrm{ss}}$;

b) lateral acceleration response time, T_{aY};

c) yaw velocity response time, $T_{\dot{\psi}}$;

d) lateral acceleration peak response time, $T_{aY,\mathrm{max}}$;

e) yaw velocity peak response time, $T_{\dot{\psi},\mathrm{max}}$;

f) overshoot value of lateral acceleration, U_{aY};

g) overshoot value of yaw velocity, $U_{\dot{\psi}}$.

11 Sinusoidal input — one period (see ISO/TR 8725)

11.1 Test procedure

Drive the vehicle at the test speed (see 9.4) in a straight line. The initial speed shall not deviate by more than 2 km/h from the test speed. Starting from a 0 °/s ± 0,5 °/s yaw velocity equilibrium condition, apply one full period sinusoidal steering-wheel input with a frequency of 0,5 Hz. An additional frequency of 1 Hz should also be used. The amplitude error of the actual waveform compared to the true sine wave shall be less than 5 % of the first peak value. No change in throttle position shall be made, although speed may decrease.

Take data while the steering-wheel is rotated, initially both to the left and to the right. All data shall be taken in one direction followed by all data in the other direction. Alternatively, take data successively in each direction for each acceleration level, from the lowest to the highest level. Record the method chosen in the test report (see Annex A).

Increase the steering-wheel input stepwise up to a magnitude sufficient to produce the desired lateral acceleration in accordance with 11.2.2. The standard lateral acceleration level is 4 m/s^2. Additional acceleration levels of 2 m/s^2 and 6 m/s^2 and up to the adhesion limit (see ISO/TR 8725) may be used.

Perform at least three test runs for each combination of speed and steering.

10.3.2 Time histories

The time histories of variables used for data evaluation shall be plotted. If a curve is fitted to any set of data, the method of curve fitting shall be described in the presentation of results in Annex B.

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