INTERNATIONAL STANDARD

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Road vehicles — Vehicle dynamics test methods —

Part 1:
General conditions for passenger cars

Véhicules routiers — Méthodes d'essai de la dynamique des véhicules —

Partie 1: Conditions générales pour voitures particulières

Reference number
ISO 15037-1:1998(E)

Foreword

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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.

International Standard ISO 15037-1 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

ISO 15037 consists of the following parts, under the general title *Road vehicles — Vehicle dynamics test methods*:

— *Part 1: General conditions for passenger cars*

— *Part 2: General conditions for heavy commercial vehicles*

Annexes A and B form and integral part of this part of ISO 15037. Annex C is for information only.

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Introduction

The dynamic behaviour of a road vehicle is a most important part of active vehicle safety. Any given vehicle, together with its driver and the prevailing environment, constitutes a closed-loop system which is unique. The task of evaluating the dynamic behaviour of the vehicle is therefore very difficult since there is significant interaction between these driver-vehicle-environment elements, and each of these elements is individually complex in itself.

The test conditions exert large influence on the test results. Only vehicle dynamic properties obtained at identical test conditions are comparable.

Road vehicles — Vehicle dynamics test methods —

Part 1:
General conditions for passenger cars

1 Scope

This part of ISO 15037 specifies the general conditions that apply when vehicle dynamics properties are determined according to ISO test methods (see annex C).

In particular, it specifies general conditions for

— variables,

— measuring equipment and data processing,

— environment (test track and wind velocity),

— test vehicle preparation (tuning and loading),

— initial driving,

— test report (general data and test conditions),

which are of general significance, independent of the specific vehicle dynamics test method. They apply when vehicle dynamics properties are determined, unless other conditions are required by the standard which is actually used for the test method.

This part of ISO 15037 is applicable to passenger cars as defined in ISO 3833.

NOTE The general conditions defined in existing vehicle dynamics standards are valid until a reference to this part of ISO 15037 is included.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 15037. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 15037 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1176:1990, *Road vehicles — Masses — Vocabulary and codes.*

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

ISO 3833:1977, *Road vehicles — Types — Terms and definitions.*

ISO 8855:1991, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary.*

3 Variables

3.1 Reference system

The variables of motion used to describe vehicle behaviour in a test-specific driving situation relate to the intermediate axis system (X, Y, Z) (see ISO 8855).

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. The origin is therefore fixed in the longitudinal plane of symmetry at half-wheel base and at the same height above the ground as the centre of gravity of the vehicle at complete vehicle kerb mass (see ISO 1176).

3.2 Variables to be measured

To describe the horizontal dynamics of a vehicle, the following variables are relevant:

— longitudinal velocity (v_X);

— sideslip angle (β) or lateral velocity (v_Y);

— longitudinal acceleration (a_X);

— lateral acceleration (a_Y);

— yaw velocity ($\mathrm{d}\psi/\mathrm{d}t$);

— roll angle (φ);

— pitch angle (θ).

To describe the input of the driver, it is necessary to measure the variable

— steering wheel angle (δ_H).

These variables are defined in ISO 8855. All standards that make reference to this part of ISO 15037 shall specify which variables apply.

4 Measuring equipment

4.1 Description

All variables shall be measured by means of appropriate transducers and their time histories shall be recorded by a multi-channel recording system. Typical operating ranges and recommended maximum errors of the transducer and recording system are shown in Table 1.

4.2 Transducer installations

The transducers shall be installed according to the manufacturer's instructions when such instructions exist, so that the variables corresponding to the terms and definitions of ISO 8855 can be determined.

If a transducer does not measure a variable directly, appropriate transformations into the reference system shall be carried out.

4.3 Data processing

4.3.1 General

The frequency range relevant for tests on horizontal dynamics of passenger cars is between 0 Hz and the maximum utilized frequency f_{max} = 5 Hz. According to the chosen data processing method, analogue or digital data processing, the requirements given in 4.3.2 or 4.3.3 apply.

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

Variables range system	Typical operating of the combined transducer	Recommended maximum errors and recording
Longitudinal velocity	0 m/s to + 50 m/s	± 0,5 m/s
Lateral velocity	–10 m/s to + 10 m/s	± 0,4 m/s
Sideslip angle	–15° to +15°	± 0,5°
Longitudinal acceleration	–15 m/s² to + 15 m/s²	± 0,15 m/s²
Lateral acceleration	–15 m/s² to + 15 m/s²	± 0,15 m/s²
Yaw velocity	– 50°/s to + 50°/s	± 0,5°/s
Roll angle	–15° to +15°	± 0,15°
Pitch angle	–15° to +15°	± 0,15°
Steering wheel angle	–360° to + 360°	± 2° for angles ⩽ 180° ± 4° for angles > 180°
NOTE Transducers for measuring some of the listed variables are not widely available and are not in general use. Many such instruments are developed by users. If any system error exceeds the recommended maximum value, this and the actual maximum error shall be stated in the test report (see annex A).		

4.3.2 Analogue data processing

The bandwidth of the entire, combined transducer/recording system shall be no less than 8 Hz.

In order to execute the necessary filtering of signals, low-pass filters with order 4 or higher shall be employed. The width of the passband (from 0 Hz to frequency f_0 at –3 dB) shall not be less than 9 Hz. Amplitude errors shall be less than ± 0,5 % in the relevant frequency range of 0 Hz to 5 Hz. All analogue signals shall be processed with filters having sufficiently similar phase characteristics to ensure that time delay differences due to filtering lie within the required accuracy for time measurement.

NOTE During analogue filtering of signals with different frequency contents, phase shifts can occur. Therefore, a data processing method, as described in 4.3.3, is preferable.

4.3.3 Digital data processing

4.3.3.1 General considerations

Preparation of analogue signals includes consideration of filter amplitude attenuation and sampling rate to avoid aliasing errors, and filter phase lags and time delays. Sampling and digitizing considerations include pre-sampling amplification of signals to minimize digitizing errors; number of bits per sample; number of samples per cycle; sample and hold amplifiers; and timewise spacing of samples. Considerations for additional phaseless digital filtering includes selection of passbands and stopbands and the attenuation and allowable ripple in each; and correction of filter phase lags. Each of these factors shall be considered in order to achieve a relative overall data acquisition accuracy of ± 0,5 %.

4.3.3.2 Aliasing errors

In order to avoid uncorrectable aliasing errors, the analogue signals shall be appropriately filtered before sampling and digitizing. The order of the filters used and their passband shall be chosen according to both the required flatness in the relevant frequency range and the sampling rate.

The minimum filter characteristics and sampling rate shall be such that

a) within the relevant frequency range of 0 Hz to f_{max} = 5 Hz the attenuation is less than the resolution of the data acquisition system; and

b) at one-half the sampling rate (i.e. the Nyquist or "folding" frequency) the magnitudes of all frequency components of signal and noise are reduced to less than the system resolution.

For 0,05 % resolution the filter attenuation shall be less than 0,05 % to 5 Hz, and the attenuation shall be greater than 99,95 % at all frequencies greater than one-half the sampling frequency.

NOTE For a Butterworth filter the attenuation is given by

$$A^2 = \frac{1}{1+\left(f_{max}/f_0\right)^{2n}} \quad \text{and} \quad A^2 = \frac{1}{1+\left(f_N/f_0\right)^{2n}}$$

where

n is the order to filter;

f_{max} is the relevant frequency range (5 Hz);

f_0 is the filter cut-off frequency;

f_N is the Nyquist or "folding" frequency.

For a fourth order filter

for A = 0,999 5: $f_0 = 2{,}37 \times f_{max}$ = 11,86 Hz;

for A = 0,000 5: $f_s = 2 \times (6{,}69 \times f_0)$ = 158 Hz, where f_s is the sampling frequency = $2 \times f_N$.

4.3.3.3 Filter phase shifts and time delays for anti-aliasing filtering

Excessive analogue filtering shall be avoided, and all filters shall have sufficiently similar phase characteristics to ensure that time delay differences lie within the required accuracy for the time measurement.

Phase shifts are especially significant when measured variables are multiplied together to form new variables, because while amplitudes multiply, phase shifts and associated time delays add. Phase shifts and time delays are reduced by increasing f_0. Whenever equations describing the pre-sampling filters are known, it is practical to remove their phase shifts and time delays by simple algorithms performed in the frequency domain.

NOTE In the frequency range in which the filter amplitude characteristics remain flat, the phase shift Φ of a Butterworth filter can be approximated by

$\Phi = 81 \times (f/f_0)$ degrees for second order;

$\Phi = 150 \times (f/f_0)$ degrees for fourth order;

$\Phi = 294 \times (f/f_0)$ degrees for eighth order.

The time delay for all filter orders is: $t = (\Phi/360°) \times (1/f_0)$.

4.3.3.4 Data sampling and digitizing

At 5 Hz the signal amplitude changes by up to 3 % per millisecond. To limit dynamic errors caused by changing analogue inputs to 0,1 %, sampling or digitizing time shall be less than 32 µs. All pairs or sets of data samples to be compared shall be taken simultaneously or over a sufficiently short time period.

4.3.3.5 System requirements

The data system shall have a resolution of 12 bits (± 0,05 %) or more and an accuracy of 2 LSB (± 0,1 %). Anti-aliasing filters shall be of order 4 or higher and the relevant data range f_{max} shall be 0 Hz to 5 Hz.

For fourth order filters the passband frequency f_0 (from 0 Hz to frequency f_0) shall be greater than 2,37 $\times f_{max}$ if phase errors are subsequently adjusted in digital data processing, and greater than 5 $\times f_{max}$ otherwise. For fourth order filters the data sampling frequency f_s shall be greater than 13,4 $\times f_0$.

For filters having orders different from fourth order, f_0 and f_s shall be selected for adequate flatness and alias error prevention.

Amplification of the signal before digitizing shall be such that in the digitizing process the additional error is less than 0,2 %.

Sampling or digitizing time for each data channel sampled shall be less than 32 µs.

4.3.3.6 Digital filtering

For filtering of sampled data in data evaluation, phaseless (zero phase shift) digital filters shall be used incorporating the following characteristics (see Figure 1):

— passband shall range from 0 Hz to 5 Hz;

— stopband shall begin between 10 Hz and 15 Hz;

— the filter gain in the passband shall be 1 ± 0,005 (100 ± 0,5 %);

— the filter gain in the stopband shall be ≤ 0,01 (≤ 1%).

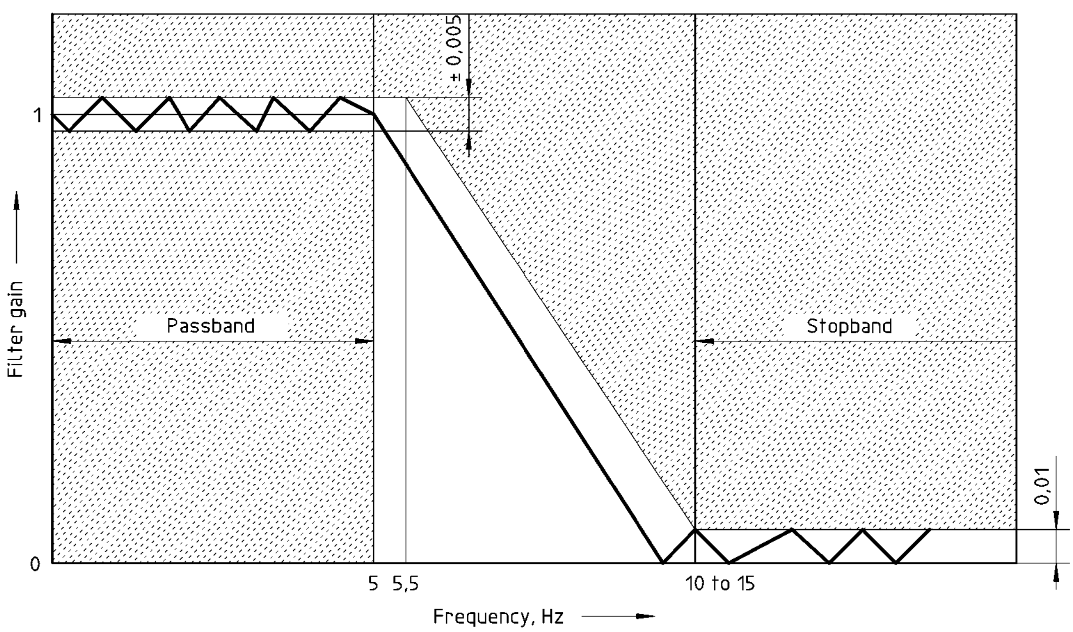


Figure 1 — Required characteristics of phaseless digital filters

5 Test conditions

5.1 General

Limits and specifications for the ambient conditions and vehicle test conditions are established below, these shall be maintained during the specific test. Any deviations shall be shown in the test report (see annexes A and B) including the individual diagrams of the presentation of results. For each test method, the test specific conditions and those which may not be kept constant (e.g. tread depths) shall be recorded in a separate test report in accordance with annex B.

5.2 Test track

All tests shall be carried out on a smooth, clean, dry and uniform paved road surface. The gradient of the paved test surface to be used shall not exceed 2,5 % in any direction when measured over any distance interval between that corresponding to the vehicle track and 25 m. For each test the road surface conditions and paving material shall be recorded in the test report (see annex B).

5.3 Wind velocity

The ambient wind velocity shall not exceed 5 m/s during a test. For each test method the climatic conditions shall be recorded in the test report (see annex B).

5.4 Test vehicle

5.4.1 General data

General data of the test vehicle shall be presented in the test report shown in annex A. For any change of vehicle specification (e.g. load), the general data shall be documented again.

NOTE Since in certain cases the ambient temperature has a significant influence on test results, it should be taken into account when making comparisons between vehicles.

5.4.2 Tyres

For a general tyre condition, new tyres shall be fitted on the test vehicle according to the manufacturer's specifications. If not specified otherwise by the tyre manufacturer, they shall be run in for at least 150 km on the test vehicle or an equivalent vehicle without excessively harsh use, for example braking, acceleration, cornering, hitting the kerb, etc. After run in the tyres shall be maintained at the same vehicle locations for the tests.

Tyres shall have a tread depth of at least 90 % of the original value across the whole breadth of the tread and around the whole circumference of the tyre.

Tyres shall be manufactured not more than one year before the test. The date of manufacturing shall be noted in the presentation of test conditions (see annex B).

Tyres shall be inflated to the pressure as specified by the vehicle manufacturer for the test vehicle configuration. The tolerance for setting the cold inflation pressure is ± 5 kPa[1)] for pressures up to 250 kPa and ± 2 % for pressure above 250 kPa.

Inflation pressure and tread depth of the tyres determined before tyre warm-up and after the test runs shall be recorded in the test report (see annex B).

Tests may also be performed under conditions other than general tyre conditions. The details shall be noted in the test report (see annex B).

1) 1 kPa = 10^{-2} bar = 10^{3} N/m^{2}

NOTES

1 Tread breadth is the width of that part of the tread which, with the tyre correctly inflated, contacts the road in normal straight-line driving.

2 As the tread depth or uneven tread wear may have a significant influence on test results, it is recommended that they be taken into account when making comparisons between vehicles or between tyres.

5.4.3 Operating components

For the standard test conditions all operating components likely to influence the results of a test (for example condition, setting and temperature of shock absorbers, springs and other suspension components and suspension geometry) shall be as specified by the manufacturer. Any deviations from manufacturer's specification shall be noted in the presentation of general data (see annex A).

5.4.4 Loading conditions of the vehicle

The test mass shall be between the complete vehicle kerb mass (ISO 1176, code ISO-M06) plus driver and test equipment (combined mass should not exceed 150 kg) and the maximum authorized total mass (ISO 1176, code ISO-M08).

The maximum authorized axle loads (ISO 1176, code ISO-M13) shall not be exceeded.

Care shall be taken to generate a minimum deviation in the location of the centre of gravity and in the moments of inertia as compared to the loading conditions of the vehicle in normal use (refer to ISO 2416). The resulting wheel loads shall be determined and recorded in the test report (see annex A).

6 Test method

6.1 Warm-up

All relevant vehicle components shall be warmed up prior to the tests in order to achieve temperature representative of normal driving conditions. Tyres shall be warmed up prior to the tests to achieve an equilibrium temperature and pressure representative of normal driving conditions.

A procedure equivalent to driving at the test speed for a distance of 10 km or driving 500 m at a lateral acceleration of 3 m/s^2 (both left and right turn each) may be appropriate for warming up the tyres.

6.2 Initial driving condition

6.2.1 General

The initial driving condition is specified in most of the vehicle dynamics test methods. It can either be a steady-state straight ahead run or a steady-state circular run.

If there is no specific requirement defined in a test method standard the tests shall be performed in the highest suitable gear for vehicles with manual transmission and for vehicles with automatic transmission in drive D. The position of the transmission lever and the selected driving programme shall be recorded in the test report (see annex B).

The position of the steering wheel and the accelerator pedal shall be kept as constant as possible during the initial driving condition. The moment of observation t_{ss} to evaluate steady state conditions is defined as the point in time which usually is between 0,5 s and 0,8 s (see note below) before the reference point in time t_0 of the specific test method. The initial condition is considered to be sufficiently constant if for the moment of observation t_{ss} the requirements of 6.2.2 and 6.2.3 are fulfilled (see Figure 2).

NOTE For test method which are used to determine only steady state values (e.g. ISO 4138) the moment of observation t_{ss} and the reference point t_0 will be identical.

6.2.2 Steady-state straight ahead run

For the time interval from t_1 to t_2 the mean value of the longitudinal velocity shall not vary from the nominal value by more than ± 3 % and the mean value of lateral acceleration shall be within a range from – 0,3 m/s^2 to + 0,3 m/s^2. As an alternative to the limits of lateral acceleration the mean value of the yaw velocity shall be within a range from – 0,5 °/s to + 0,5 °/s.

For the time interval from t_1 to t_2 the standard deviation of the lateral acceleration shall not exceed 0,3 m/s^2 and the standard deviation of the longitudinal velocity shall not exceed 3 % of its mean value. As an alternative to the limits of lateral acceleration the standard deviation of the yaw velocity shall not exceed 0,5 °/s.

The difference between the mean values of the longitudinal velocity during the time intervals t_1 to t_{ss} and t_{ss} to t_2 shall not exceed 3 % of the nominal value.

6.2.3 Steady-state circular run

The initial radius R_0 may be observed or calculated as follows:

$$R_0 = v_{X,0} / (\mathrm{d}\psi_0/\mathrm{d}t)$$

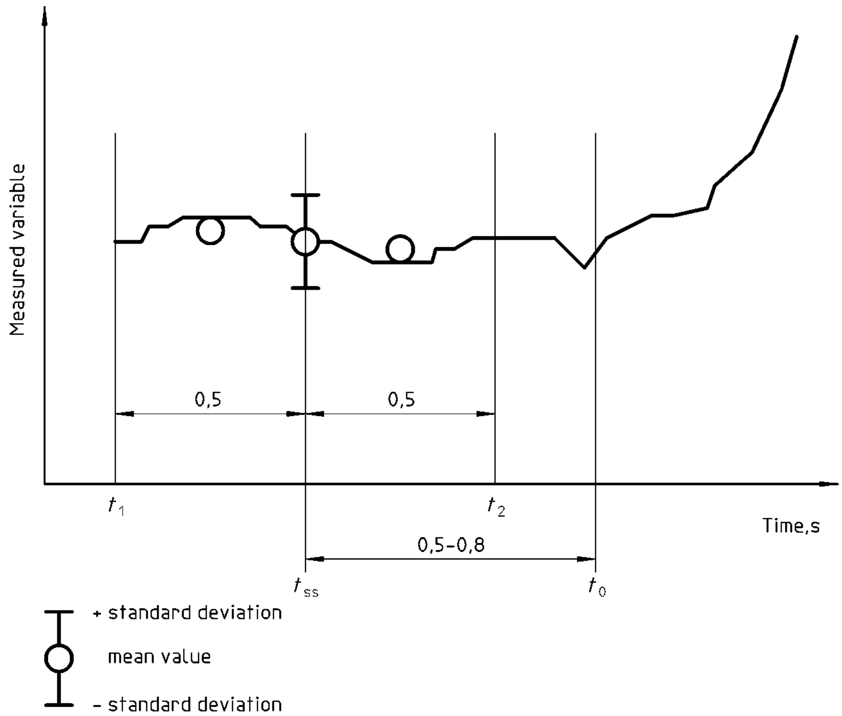
$$R_0 = v_{X,0}^2 / a_{Y,0}$$

The initial radius in the initial driving condition shall not deviate by more than ± 0,5 m from the nominal value during the time interval from t_1 to t_2.

For the time interval from t_1 to t_2 the standard deviation of the lateral acceleration shall not exceed 5 % of its mean value and the standard deviation of the longitudinal velocity shall not exceed 3 % of its mean value.

The difference between the mean values during the time intervals t_1 to t_{ss} and t_{ss} to t_2 shall not exceed the nominal value for the lateral acceleration by more than 5 % and the longitudinal velocity by more than 3 %.

For the time interval from t_1 to t_2 the mean value of the lateral acceleration shall not deviate from the nominal value by more than ± 3 %.



t_{ss}: moment of observation to evaluate steady state conditions

t_0: reference point in time of the specific test method

Figure 2 — Definition of times

Annex A
(normative)

Test report — General data

Vehicle identification	Vehicle identification number:	....
	Type of vehicle:	....
	Manufacturer:	....
	Model:	....
	Model year/first registration date:	....
Drive train	Driven axle:	❑ front axle ❑ rear axle
	Type of 4WD:	....
	Special features:	....
Engine	Identification code:	....
	Type of engine:	❑ spark ignition ❑ diesel
	Air/fuel mixture control:	❑ carburettor ❑ injection
	Charging system:	❑ turbo charger ❑ super-charger
	Ignition point control:	❑ mechanical ❑ electronic
	Fuel cut-off:	❑ yes ❑ no
	Displacement/number of cylinders:	.... cm^3 .... cylinders
	Maximum power/engine speed:	.... kW 1/min
	Maximum torque/engine speed:	.... Nm 1/min
Transmission	Identification code:	
	Type/number of forward gears:	❑ manual .... gears
		❑ automatic .... gears
		❑ continuously variable (e.g. CVT)
	Gear ratios:	1st gear: .... : 1 2nd gear: .... : 1
		3rd gear: .... : 1 4th gear: .... : 1
		5th gear: .... : 1 6th gear: .... : 1
	Final drive ratio:	.... : 1
Rear axle	Type of rear axle:	....
	Suspension/damping:	....
	Stabilizer/Anti-roll bar:	❑ yes ❑ no
Front axle	Type of front axle:	....
	Suspension/damping:	....
	Stabilizer/Anti-roll bar:	❑ yes ❑ no

Steering	Steered axle:	❒ front axle	❒ rear axle
	Power assisted:	❒ yes	❒ no
	Overall steering ratio on front axle:	....	
	Steering wheel diameter:	.... mm	
Braking system	Power assisted:	❒ yes	❒ no
	Anti-lock braking system:	❒ yes	❒ no
	Type:	....	
	Wheel brakes on front axle:	❒ drums	❒ discs
	Wheel brakes on rear axle:	❒ drums	❒ discs
Wheels	Rim size:	front:	rear: ....
Tyres	Size:	front:	rear: ....
	Tread depth (new):	front: .... mm	rear: .... mm
	Inflation pressure, according to the vehicle manufacturer's specifications		
	— at complete vehicle kerb mass (ISO–M06):	front: .... kPa	rear: .... kPa
	— at maximum authorized total mass (ISO–M08):	front: .... kPa	rear .... kPa
Masses	Complete vehicle kerb mass (ISO-M06):	.... kg	
	Maximum authorized total mass (ISO-M08):	.... kg	
	Maximum authorized axle load (ISO-M13):	front: .... kg	rear: .... kg
	Measured wheel loads of test vehicle, including driver and instrumentation:	FL: .... kg	FR: .... kg
		RL: .... kg	RR: .... kg
Vehicle dimensions	Overall length:	.... mm	
	Overall width:	.... mm	
	Overall height at test mass:	.... mm	
	Wheelbase:	.... mm	
	Track:	front: .... mm	rear: .... mm
	Height of centre of gravity at complete vehicle kerb mass (ISO-M06):	.... mm	

General comments and/ or other relevant details

....

....

....

....

....

Annex B
(normative)

Test report — Test conditions

Test method	ISO	....	
Proving ground	Location:	....	
	Path radius:	....	
Ambient conditions	Road surface:	Type:	
		Condition:	
		Skid number:	
	Climate:	Air temperature: .... °C	
		Relative humidity: .... %	
		Wind speed: .... m/s	
		Wind direction:	
Tyres	Date of manufacture:	front:	rear: ....
	Tread depth:		
	— before warm-up:	FL: .... mm	FR: .... mm
		RL: .... mm	RR: .... mm
	— after test runs:	FL: .... mm	FR: .... mm
		RL: .... mm	RR: .... mm
	Tyre pressure:		
	— before warm-up:	FL: .... kPa	FR: .... kPa
		RL: .... kPa	RR: .... kPa
	— after test runs:	FL: .... kPa	FR: .... kPa
		RL: .... kPa	RR: .... kPa
Driving conditions	Manual transmission:	Engaged gear: .... gear	
	Automatic transmission:	Transmission program:	
		Gear selector position:	
Staff	Driver:	....	
	Observer:	....	
	Data analyst:	....	
Test method specific data	....		
	....		
	....		
	....		

Annex C
(informative)

Bibliography

[1] ISO 4138:1996, *Road vehicles — Steady-state circular driving behaviour — Open-loop test procedure.*

[2] ISO 7401:1988, *Road vehicles — Lateral transient response test methods.*

[3] ISO 7975:1996, *Passenger cars — Braking in a turn — Open-loop test procedure.*

[4] ISO 9815:1992, *Passenger-car/trailer combination — Lateral stability test.*

[5] ISO 9816:1993, *Passenger cars — Power-off reactions of a vehicle in a turn — Open-loop test method.*

[6] ISO 12021-1:1996, *Road vehicles — Sensitivity to lateral wind — Part 1: Open-loop test method using wind generator input.*

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