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Passenger cars — Power-off reactions of a vehicle in a turn — Open-loop test method

Voitures particulières — Réponse d'un véhicule à un lever de pied en virage — Méthode d'essai en boucle ouverte

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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 9816 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

Annexes A and B form an integral part of this International Standard.

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Introduction

The dynamic behaviour of a road vehicle is a most important part of the 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 is therefore very difficult, since the significant interaction of these driver-vehicle-road elements are each complex in themselves. A description of the behaviour of the road vehicle must inevitably involve information obtained from a number of tests of different types.

Since the power-off test procedure quantifies only one small part of the complete handling characteristics, the results of this test can only be considered significant for a correspondingly small part of the overall dynamic behaviour.

In addition, no significant correlation has been found between dynamic characteristics as a result of this test and accident avoidance. A substantial amount of effort is necessary to obtain sufficient and reliable data on the correlation between dynamic characteristics in general and accident avoidance.

Moreover, insufficient knowledge is available concerning the relationship between overall vehicle dynamic properties and accident avoidance. A large amount of work is still necessary to acquire sufficient and reliable data on the correlation between accident avoidance and vehicle dynamic properties in general and the results of this test in particular. Therefore, it is not possible to use this procedure and test results for regulation purposes.

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Passenger cars — Power-off reactions of a vehicle in a turn — Open-loop test method

1 Scope

This International Standard defines an open-loop test method for determining the power-off reactions of a vehicle in a turn. It applies to passenger cars as defined in ISO 3833.

It is not possible at present to use this procedure and test results for regulation purposes.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard 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 3833:1977, *Road vehicles — Types — Terms and definitions.*

ISO 4138:1982, *Road vehicles — Steady-state circular test procedure.*

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

3 Principle

The purpose of this test procedure is to determine the power-off effect on course holding and directional behaviour of a vehicle, whose steady-state circular motion is disturbed by power-off only. The sudden release of the accelerator pedal causes this effect.

The initial conditions are defined by constant longitudinal velocity and by a circle with a given radius. 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.

The variables of motion used to describe the power-off reaction of the vehicle relate to the intermediate axis system X, Y, Z.

The location of the origin of the intermediate axis system, being the reference point, is indepedent from loading conditions. It is 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).

4 Variables

The following variables shall be measured:

— moment of power-off initiation, t_0;

— steering-wheel angle, δ_H;

— yaw angle, ψ, or yaw velocity, $\dot{\psi}$;

— longitudinal velocity, v_X;

— lateral acceleration, a_Y.

It is recommended to measure the following variables as well:

— longitudinal acceleration, a_X;

— sideslip angle, β, or lateral velocity, v_Y;

— steering-wheel torque, M_H;

— pitch angle, θ;

— roll angle, φ.

The variables are defined in ISO 8855, except the moment of power-off initiation t_0, which is the instant at which the accelerator pedal is released.

5 Measuring equipment

5.1 Description

The variables selected from those listed in clause 4 shall be measured by means of appropriate transducers and their time histories recorded by a multichannel recorder. The typical operating ranges and recommended maximum errors of the transducer and recording system are shown in table 1. The values in table 1 are provisional until more experience and data are available.

5.2 Transducer installation

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

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

5.3 Data processing

The frequency range relevant for this test is between 0 Hz and the maximum utilized frequency f_{max} = 5 Hz. According to the chosen data processing method, analog or digital, the stipulations given in 5.3.1 or 5.3.2 shall be observed.

5.3.1 Analog data processing

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

Table 1 — Measured variables, their typical operating ranges and recommended maximum errors

Variable	Typical operating range	Recommended maximum error of the combined transducer and recorder system
Moment of power-off initiation	—	0,05 s
Steering-wheel angle	– 360° to + 360°	± 2° for angles ⩽ 180° ± 4° for angles > 180°
Yaw angle	– 180° to + 180°	± 2°
Yaw velocity	– 50°/s to + 50°/s	± 0,5°/s
Sideslip angle	– 15° to + 15°	± 0,5°
Lateral velocity	– 10 m/s to + 10 m/s	± 0,1 m/s
Longitudinal velocity	0 to 50 m/s	± 0,5 m/s
Lateral acceleration	– 15 m/s^2 to + 15 m/s^2	± 0,15 m/s^2
Longitudinal acceleration	– 15 m/s^2 to + 15 m/s^2	± 0,15 m/s^2
Steering-wheel torque	– 30 N·m to + 30 N·m	± 0,3 N·m
Pitch angle	– 15° to + 15°	± 0,15°
Roll angle	– 15° to + 15°	± 0,15°

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.

In order to execute the necessary filtering of signals, low-pass filters with order four or higher shall be employed. The width of the passband frequency f_0 at − 3 dB shall not be less than 8 Hz. Amplitude errors shall be less than ± 0,5 % in the relevant frequency range of 0 Hz to 5 Hz. All analog signals shall be processed with filters having sufficiently similar phase characteristics in order to ensure that time delay differences due to filtering lie within the required accuracy for time measurement.

NOTE 1 During analog filtering of signals with different frequency contents, phase shifts may occur. Therefore a data processing method, as described in 5.3.2, is preferable.

5.3.2 Digital data processing

5.3.2.1 Preparation of analog signals

In order to avoid aliasing, the analog signals shall correspondingly be filtered before digitizing. In this case, low-pass filters with order four or higher shall be employed. The width of the passband (frequency at − 3 dB) shall amount to roughly

$$f_0 \geqslant 5 f_{max}$$

The amplitude error of the anti-aliasing filter should not exceed ± 0,5 % in the usable frequency range. All analog signals shall be processed with anti-aliasing filters having sufficiently similar phase characteristics in order to ensure that time delay differences lie within the required accuracy for time measurement.

Additional filters shall be avoided in the data acquisition string.

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

5.3.2.2 Digitizing

The sampling rate shall be higher than the frequency at − 3 dB of the anti-aliasing filter and appropriate to the order of the filters used.

5.3.2.3 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):

— pass range 0 Hz to 5 Hz;

— stopband begins 10 Hz to 15 Hz;

— maximum amplitude error in passband ⩽ 0,005 (0,5 %);

— maximum amplitude error in stopband ⩽ 0,01 (1 %).

6 Test conditions

Limits and specifications for the ambient and vehicle test conditions are established in 6.1 to 6.3, and shall be maintained during the test. Any deviations shall be shown in the test report (see annex A), including the individual diagrams of the presentation of results (see annex B).

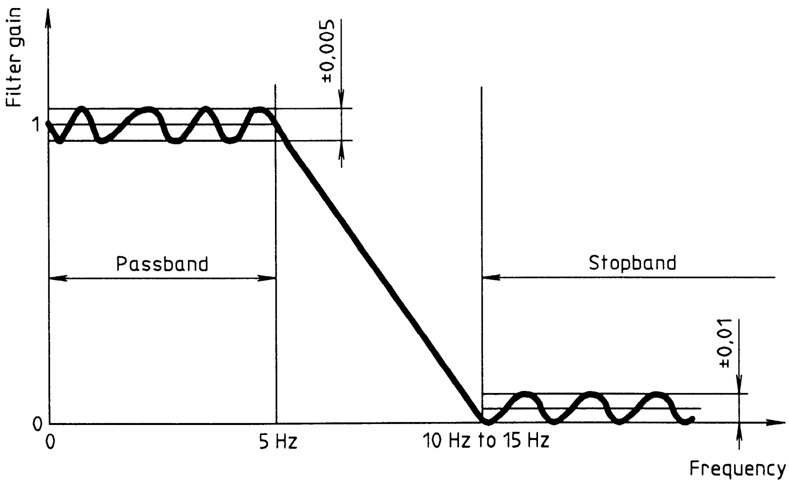

Figure 1 — Required characteristics of phaseless digital filters

6.1 Test track

All tests shall be carried out on a level, clean, dry and uniform hard road surface, which must not exceed a gradient of 2,5 % at any place.

6.2 Wind velocity

The wind velocity shall not exceed 5 m/s and shall be recorded in the test report (annex A).

6.3 Test vehicle

6.3.1 Tyres

For standard tyre condition, new tyres shall be fitted in the appropriate position on the test car. They shall be run in for at least 150 km without excessively harsh use, for example braking, acceleration, cornering, hitting the kerb, etc. They shall have a tread depth of at least 90 % of the original value and shall be manufactured not more than one year before the test.

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

The test may also be performed with tyres in any state of wear as long as at the end of the test they retain a minimum of 1,5 mm of tread depth in the whole contact width across the whole breadth of the tread (see note 2) and around the whole circumference of tyre.

NOTE 2 As in certain cases the tread depth has a significant influence on test results, it is recommended that it should be taken into account when making comparisons between vehicles or between tyres.

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.

6.3.2 Operating components

All operating components likely to influence the results of this test (for example condition, setting and temperature of shock absorbers, springs and other suspension components and suspension geometry) shall be inspected. The results of these inspections and measurements shall be recorded and in particular any deviations from manufacturer's specification shall be noted in the test report if appropriate (see annex A).

For the standard test conditions, new suspension components shall be used.

6.3.3 Engine and drivetrain

For the standard test conditions, the adjustment and condition of the engine and drivetrain (especially the differentials, clutches, locks, free wheel shifts, engine idle calibration etc.) shall correspond to the vehicle manufacturer's specifications.

6.3.4 Loading conditions of the vehicle

The test mass shall be between complete vehicle kerb mass (code: ISO-M06) plus driver's mass and maximum authorized total mass (code: ISO-M08). The minimum mass of the vehicle is defined by ISO 1176:1990, item 4.6. The mass of instrumentation plus driver shall preferably not exceed 150 kg.

The maximum authorized total mass and the maximum design axle loads, both defined by ISO 1176:1990, items 4.8 and 4.11, shall not be exceeded.

Care shall be taken to generate the 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. The resulting wheel loads shall be determined and recorded in the test report (annex A).

7 Test procedure

7.1 Tyre warm-up

The tyres shall be warmed up prior to each test as specified in ISO 4138.

7.2 Initial driving condition

The initial driving condition is the steady-state circular test (ISO 4138). During this procedure the vehicle shall be steered in such a manner that the reference point of the vehicle moves on a circular path. The standard radius of this path shall be 100 m, but smaller radii are admissible, with 40 m as the recommended lower value and 30 m as the minimum. It should be noted that the significance of the results decreases with the initial radius.

The initial driving speeds shall be chosen in such manner as to obtain lateral accelerations starting at

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

about 4 m/s^2 up to the maximum value, in increments of not more than 1 m/s^2.

For vehicles with manual transmission the test shall be performed with the lowest gear possible, yet not in the first gear. If the increase in the vehicle speed requires a gear change, the previous speed shall be run in both gears.

For vehicles with automatic transmission, the position of the transmission lever and the selected driving programme shall be recorded in the test report (annex A).

The position of the steering wheel and the accelerator pedal shall be kept as constant as possible during the initial driving condition. The initial condition is considered to be sufficiently constant, if one of the following conditions is fulfilled:

a) For the time interval from 1,3 s to 0,3 s before power-off initiation, the standard deviation of the lateral acceleration shall not exceed 5 % of the mean value, and the standard deviation of the forward velocity shall not exceed 3 % of the mean value.

b) The difference between the mean values during the time intervals 1,3 s to 0,8 s and 0,8 s to 0,3 s before power-off initiation shall not exceed the last-mentioned mean value for the lateral acceleration by 5 % and for the forward velocity by 3 %.

The radius in the initial driving condition may not deviate by more than ± 2 m of the desired value during the time interval of 1,3 s to 0,3 s before power-off initiation. The initial radius R_0 is calculated as follows:

$$R_0 = \frac{v_{X,0}}{\dot{\psi}_0}$$

or

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

7.3 Power-off procedure

After reaching the initial steady-state driving condition, the steering wheel is firmly held by the driver or fixed by a mechanical device.

The accelerator pedal is released as quickly as possible. On vehicles with manual transmission, the clutch is kept engaged. On vehicles with automatic transmission, the shift lever remains in the previously chosen position.

The release of the accelerator pedal is considered as the moment of power-off inititation.

The transducer signals shall be recorded from 1,3 s before to 3 s after the moment of power-off initiation. This recording period shall be lengthened by the settling time of all filters used during recording (0,2 s to 1 s, depending on the type of filter used).

During the recording period the steering wheel angle shall not deviate more than ± 3 % from the steady-state value. For each lateral acceleration level (see 7.2), at least three valid test runs shall be performed.

The test shall be carried out for both left and right turns.

8 Data evaluation and presentation of results

8.1 General

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

Due to the large amount of data, the use of a computer for data processing is recommended.

At the present level of knowledge, it is not yet known which variables best represent the subjective feeling of the driver and which variables, i.e. what characteristic values, best describe the dynamic reaction of vehicles. The following specified variables represent therefore only examples for the evaluation of results.

8.2 Time histories

For every test run, time histories of the variables listed in clause 4 shall be presented. Apart from their evaluation purposes, the time histories serve to monitor correct test performance and functioning of the transducers.

8.3 Reference point in time

The reference point in time for the following characteristic values is t_0, the moment of power-off initiation.

8.4 Characteristic values

The characteristic values shall be determined and presented as functions of the initial steady-state lateral acceleration (see annex B). The characteristic values in the steady-state condition are defined as the mean values during the time interval 1,3 s to 0,3 s before t_0 (power-off initiation). The other characteristic values are determined during an observation period beginning at t_0 and ending 3 s later. The instantaneous values at t_n shall be calculated by taking the mean values during the time interval t_n between − 0,1 s and + 0,1 s.

NOTE 3 The actual time t_n can also assume additional values.

8.4.1 Mean longitudinal deceleration, $-\bar{a}_{X,t_n}$, during the time interval t_0 to t_n:

$$-\bar{a}_{X,t_n} = \frac{v_{X,0} - v_{X,t_n}}{t_n - t_0}$$

where $t_n = t_0 + 1$ s

(See figure B.1.)

8.4.2 Maximum value of the sideslip angle β during the observation period:

$$\beta_{max}$$

(See figure B.2.)

8.4.3 Difference between the maximum value of the sideslip angle β_{max} during the observation period and the initial value of the sideslip angle β_0:

$$\beta_{max} - \beta_0$$

(See figure B.3.)

8.4.4 Difference between the value of the sideslip angle at actual time β_{t_n} and the initial value of the sideslip angle β_0:

$$\beta_{t_n} - \beta_0$$

where $t_n = t_0 + 1$ s

(See figure B.4.)

8.4.5 Ratio between the value of the path radius of the vehicle's reference point at actual time R_{t_n} and initial radius R_0:

$$R_{t_n}/R_0 = \frac{v_{X,t_n}\dot{\psi}_0}{v_{X,0}\left(\dot{\psi}_{t_n} + \dot{\beta}_{t_n}\right)}$$

or

$$R_{t_n}/R_0 = \frac{v_{X,t_n}^2 a_{Y,0}}{v_{X,0}^2 a_{Y,t_n}}$$

where $t_n = t_0 + 1$ s

(See figure B.5.)

8.4.6 At actual time t_n, the difference between the value of the yaw angle ψ_{t_n} and the reference value of the yaw angle $\psi_{t_n,ref}$. The reference value is that value which would be obtained at actual time t_n and actual longitudinal velocity v_{X,t_n} if the initial radius were maintained by the vehicle.

Approximation:

$$\psi_{t_n} - \psi_{t_n,ref} = \psi_{t_n} - \left[\psi_0 + t_n\left(\frac{\dot{\psi}_0 + \dot{\psi}_{t_n,ref}}{2}\right)\right]$$

Exact solution:

$$\psi_{t_n} - \psi_{t_n,ref} = \int_{t=t_0}^{t=t_n}\left[\dot{\psi}(t) - \dot{\psi}_{ref}(t)\right]dt$$

where

$$t_n = t_0 + 1 \text{ s}$$

$$\dot{\psi}_{t_n,ref} = \frac{v_{X,t_n}}{R_0}$$

$$\dot{\psi}_{ref}(t) = \frac{v_X(t)}{R_0}$$

(See figure B.6.)

8.4.7 At actual time t_n, the ratio between the value of the yaw velocity $\dot{\psi}_{t_n}$ and the reference value of the yaw velocity $\dot{\psi}_{t_n,ref}$. The reference value is that value which would be obtained at actual time t_n and actual longitudinal velocity v_{X,t_n} if the initial radius were maintained by the vehicle:

$$\dot{\psi}_{t_n}/\dot{\psi}_{t_n,ref} = \left(\dot{\psi}_{t_n}/v_{X,t_n}\right)R_0$$

where $t_n = t_0 + 1$ s

(See figure B.7.)

8.4.8 Ratio between the maximum value of the yaw velocity $\dot{\psi}_{max}$ during the observation period and the initial value of the yaw velocity $\dot{\psi}_0$:

$$\dot{\psi}_{max}/\dot{\psi}_0$$

(See figure B.8.)

8.4.9 At actual time t_n, the ratio between the value of the lateral acceleration a_{Y,t_n} and the reference value of the lateral acceleration $a_{Y,t_n,\mathrm{ref}}$. The reference value is that value which would be obtained at actual time t_n and actual longitudinal velocity v_{X,t_n} if the initial radius were maintained by the vehicle:

$$a_{Y,t_n}/a_{Y,t_n,\mathrm{ref}} = \left(a_{Y,t_n}/v_{X,t_n}^2\right)R_0$$

where $t_n = t_0 + 1$ s

(See figure B.9.)

8.4.10 Time lag, Δt_{A} between power-off initiation and the instant at which a 1 m path deviation of the reference point is obtained. This path deviation Δs_Y corresponds to the radial distance to the initial circular path (see figure 2):

$$\Delta t_{\mathrm{A}}$$

where $s_Y = 1$ m

The path deviation Δs_Y is calculated from the path of the reference point in the earth-fixed axis system. The coordinates of the reference point can be determined, for example, by transforming the vehicle-fixed velocity vectors, v_X and v_Y, into the earth-fixed axis system and subsequent integration (see figure B.10).

8.4.11 Path deviation $\Delta s_{Y,t_n}$ at actual time t_n:

$$\Delta s_{Y,t_n}$$

where $t_n = t_0 + 2$ s

The path deviation $\Delta s_{Y,t_n}$ is defined as the radial distance of the reference point and its initial circular path (see figure 2). This deviation can also be calculated as described in 8.4.10 (see figure B.11).

8.5 Projected path of the reference point

The projected path of the reference point in the $X_{\mathrm{E}}Y_{\mathrm{E}}$-plane of the earth-fixed axis system (see figure B.12) shall be given in the test report.

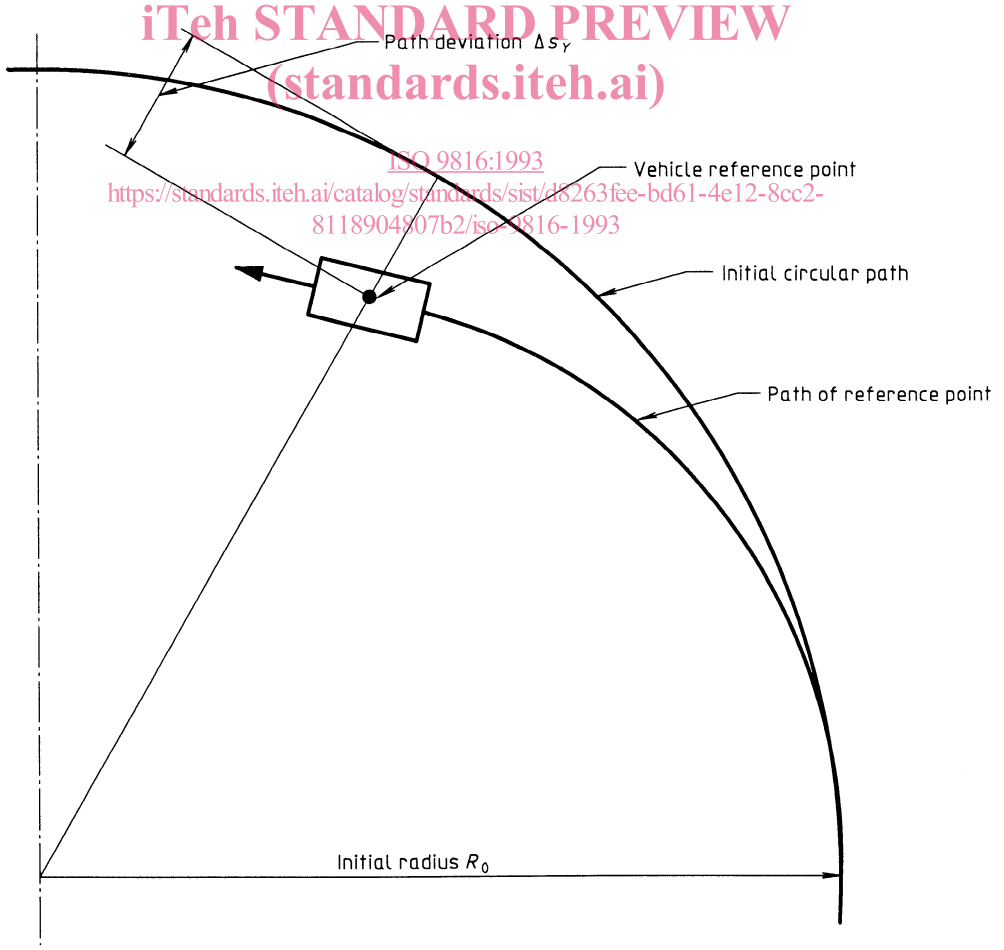

Figure 2 — Plotting of variable Δs_Y