INTERNATIONAL STANDARD

ISO 7975

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

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

Reference number
ISO 7975:1996(E)

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.

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 7975 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

This second edition cancels and replaces the first edition (ISO 7975:1985), which has been technically revised.

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 braking in a turn 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.

Moreover, insufficient knowledge is available concerning the relationship between overall vehicle dynamic properties and accident avoidance. A large 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 this test in particular. Therefore, it is not possible to use this procedure for regulation purposes.

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

1 Scope

This International Standard specifies an open-loop test procedure to determine the effect of braking on course holding and directional behaviour of a vehicle whose steady-state circular motion is altered by a braking action only.

It applies to passenger cars as defined in ISO 3833.

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 4138:1996, *Passenger cars — Steady-state circular driving behaviour — Open-loop 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 effect of braking on course holding and directional behaviour of a vehicle, whose steady-state circular motion is disturbed by a braking action only.

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 effect of braking on course holding and directional behaviour of the vehicle relate to the intermediate axis system X, Y, Z (see ISO 8855).

The location of the origin of the intermediate axis system, being the reference point, is independent from 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).

4 Variables

The following variables shall be measured:

- 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, $\dot{\Psi}$.

It is recommended to measure the following variables as well:

- pressure at master cylinder output or in the brake circuit which activates at least one of the front wheel brakes, p_B;
- roll angle, φ;
- pitch angle, θ;
- sideslip angle, β;

  or lateral velocity, v_Y;
- stopping distance, s_B;
- wheel rotation speed, $\omega_1 - \omega_4$.

The variables are defined in ISO 8855 except the stopping distance, the brake pressure and the moment of brake application t_0, which is the instant at which the brake pedal is operated. Alternatively the actuation of the brake light switch may be used to specify the moment of brake application t_0.

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 shall be recorded by a multi-channel recorder. This does not obligatorily apply to stopping distance, which can be measured directly after the test has been completed. 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 tentative and provisional until more experience is 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.

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 brake application	—	0,05 s
Steering-wheel angle	– 180° to + 180°	± 2°
Lateral acceleration	– 15 m/s^2 to + 15 m/s^2	± 0,15 m/s^2
Longidutinal acceleration	– 15 m/s^2 to + 15 m/s^2	± 0,15 m/s^2
Longitudinal velocity	0 m/s to 50 m/s	± 0,5 m/s
Yaw velocity	– 50°/s to + 50°/s	± 0,5°/s
Pressure of braking system	30 MPa[1)]	± 0,3 MPa[1)]
Roll angle	– 15° to + 15°	± 0,15°
Pitch angle	– 15° to + 15°	± 0,15°
Sideslip angle	– 20° to + 20°	± 0,5°
Lateral velocity	– 10 m/s to + 10 m/s	± 0,1 m/s
Stopping distance	300 m	± 0,5 m
Wheel rotation speed	0 s^{-1} to 200 s^{-1}	± 2 s^{-1}

1) 1 Mpa = 10 bar = 10^6 N/m^2

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 values, this and the actual maximum error shall be stated in the test report (see annex A).

5.3 Data processing

The frequency range relevant for this test is between 0 Hz and the maximum utilized frequency of 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.

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 — Phase shifts may occur during analog filtering of signals with different frequency contents. 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 f_0 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 utilized frequency range from zero to f_{max}. 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 signals 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 f_s shall be appropriate to the order of the filters being used and shall under no circumstances be less than $2f_0$.

NOTE — In common practice anti-aliasing filters of Butterworth type are used. For this type of filter the following specifications are recommended:

four pole filter: $f_s \geqslant 5f_0$

eight pole filter: $f_s \geqslant 3{,}6f_0$

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):

— passband range, ⩾ 0 Hz to ⩾ 5 Hz;

— start of stopband, ⩾ 10 Hz and ⩽ 15 Hz;

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

— filter gain in the stopband, ⩽ 0,01 (⩽ 1 %).

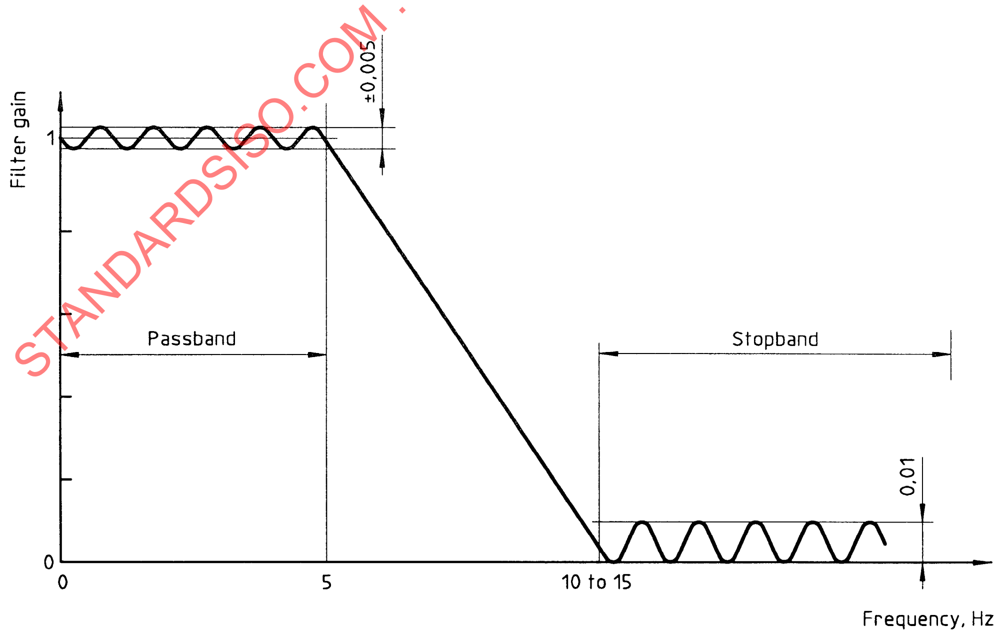

Figure 1 — Required characteristics of phaseless digital filters

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).

NOTE — The ambient temperature may influence both the road friction and the tyre characteristics. Therefore the tests should be carried out without the ambient temperature varying too much.

6.1 Test track

All tests shall be carried out on a level, clean and uniform hard road surface, which must not exceed a gradient of 2,5 % at any place. For standard test conditions, a smooth dry road pavement of asphalt or concrete or a high friction test surface is recommended.

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 on the test vehicle according to the manufacturer's specifications. 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 at the ambient temperature. The tolerance for setting the cold pressure is ± 5 kPa[1)] for pressures up to 250 kPa and ± 2 % for pressure above 250 kPa.

They shall be run in for at least 150 km without excessively harsh use, for example braking, acceleration, cornering, hitting the kerb, etc. After the tyres have been run in, they should remain in the same position on the vehicle for the test.

The test may also be performed with tyres in any state of wear as long as the end of the test they are in such a condition that a minimum of 1,6 mm of tread depth remains across the whole breadth of the tread (see note) and around the whole circumference of tyre.

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 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.

6.3.2 Operating components

For standard test conditions, 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 as specified by the manufacturer. Any deviations from manufacturer's specification shall be noted in the test report (see the annex A).

The brakes shall be bedded fully and correctly according to procedures specified by the vehicle manufacturer or to other available specifications. The procedure used shall be indicated in the test report (see annex A).

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

6.3.3 Engine and drivetrain

For standard test conditions, the adjustment and condition of the engine and the drivetrain (especially the differentials, clutches, locks and free wheel shifts) 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 instrumentation plus driver should preferably not exceed 150 kg.

The maximum authorized total mass and the maximum authorized axle loads (code: ISO-M13) shall not be exceeded.

Care shall be taken to generate the minimum deviation in the location of the centre of gravity and in the values of 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 in order to achieve a tyre temperature and pressure representative of normal driving conditions. This should be done by driving at a speed of 100 km/h over a distance of at least 10 km. However, if this is not practicable, it may be done by driving 500 m at a lateral acceleration of 3 m/s^2 on the radius to be used for the tests. The tyre pressures after warm-up should be recorded.

7.2 Brake temperature

At the beginning of the test, the braking system shall be warmed up to its operating temperature by performing some consecutive stops.

Prior to each test run the temperature of the brake discs and drums shall be measured to ensure an initial brake temperature of less than 100 °C.

7.3 Initial driving condition

The initial driving condition is that of the steady-state circular test (see ISO 4138) with the initial conditions relating to the combinations of radii and lateral acceleration given in table 2. During this procedure the vehicle shall be steered in such a manner that the reference point of the vehicle moves on the desired circular path. 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. Smaller radii ranging from 30 m to 50 m with 40 m as the recommended lower value may be used. Additional tests using a radius of 200 m are recommended.

For vehicles with manual transmission the test shall be performed in the highest gear compatible with the conditions of the test given in table 2. For vehicles with automatic transmission the position of the transmission lever and the selected driving program shall be recorded in the test report (see 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 brake application the standard deviation of the lateral acceleration shall not exceed 5 % of the mean value and the standard deviation of the longitudinal 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 brake application shall not exceed the last mentioned mean value for the lateral acceleration by 5 % and for the longidudinal velocity by 3 %.

The radius in the initial driving condition may not deviate by more than ± 0,5 m of the desired value during the time interval of 1,3 s to 0,3 s before brake application. The initial radius R_0 is calculated as follows:

$$R_0 = \frac{v_{X,0}}{\dot{\Psi}_0} \quad \text{or} \quad R_0 = \frac{v_{X,0}^2}{a_{Y,0}}$$

Table 2 — Initial test conditions

Condition	Radius	Lateral acceleration		Corresponding longitudinal velocity	
	m	m/s²	tol., %	km/h	tol., %
Standard	100	5	± 10	81	± 5
Option	200	5	± 10	114	± 5
	30 to 50	5	± 10	44 to 57	± 5

7.4 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. On vehicles with manual transmission, the clutch may be disengaged immediately or at the end of the test run; the option chosen shall be indicated in the test report (see annex A). On vehicles with automatic transmission the shift lever remains in the initial position.

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 each 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 8.3.4) is detected.

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

Tests shall be carried out for both left- and right-hand turns.

The transducer signals shall be recorded from 1,3 s before brake application until the vehicle comes to a standstill. This recording period shall be extended by the setting 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. To increase accuracy it is recommended that the series of tests should be performed at least three times.

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 therefore represent 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 Braking action

8.3.1 Reference point in time t_0

The reference point in time t_0 for the following characteristic values is the moment of brake pedal actuation or the actuation of the brake light switch.

8.3.2 Definition of times and requirements

Figure 2 shows the pattern of longitudinal acceleration during braking versus time.

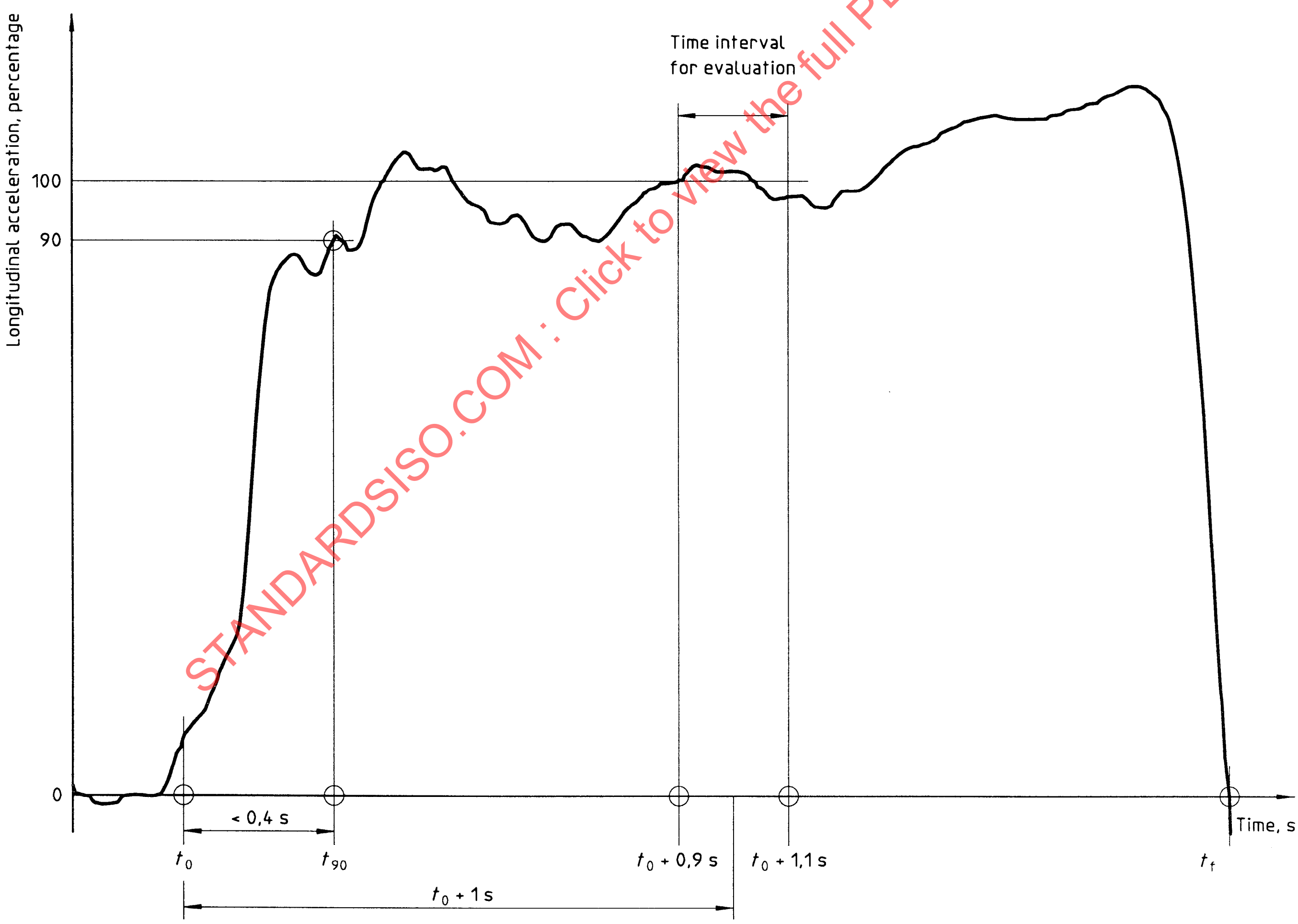

Figure 2 — Definition of times

For the correct performance of a test run, the rise time of the longitudinal acceleration shall not exceed 0,4 s. The rise time is defined as the difference between the reference point in time t_0 and the time t_{90}. Time t_{90} is the time when the longitudinal acceleration reaches 90 % of the value at 1 s after the time t_0. The longitudinal acceleration at 1 s after the time t_0 is evaluated by taking the mean value during the time interval 0,9 s and 1,1 s and after 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.

8.3.3 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:

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

$$-\bar{a}_X = \frac{v_{\text{eff}}^2}{2 \times s_{\text{eff}}}$$

where

s_{eff} is the actual stopping distance, in metres;

v_{eff} is the actual initial velocity, in metres per second;

b) taking the mean value during the time interval t_0 to t_f of the longitudinal acceleration (see figure 3).

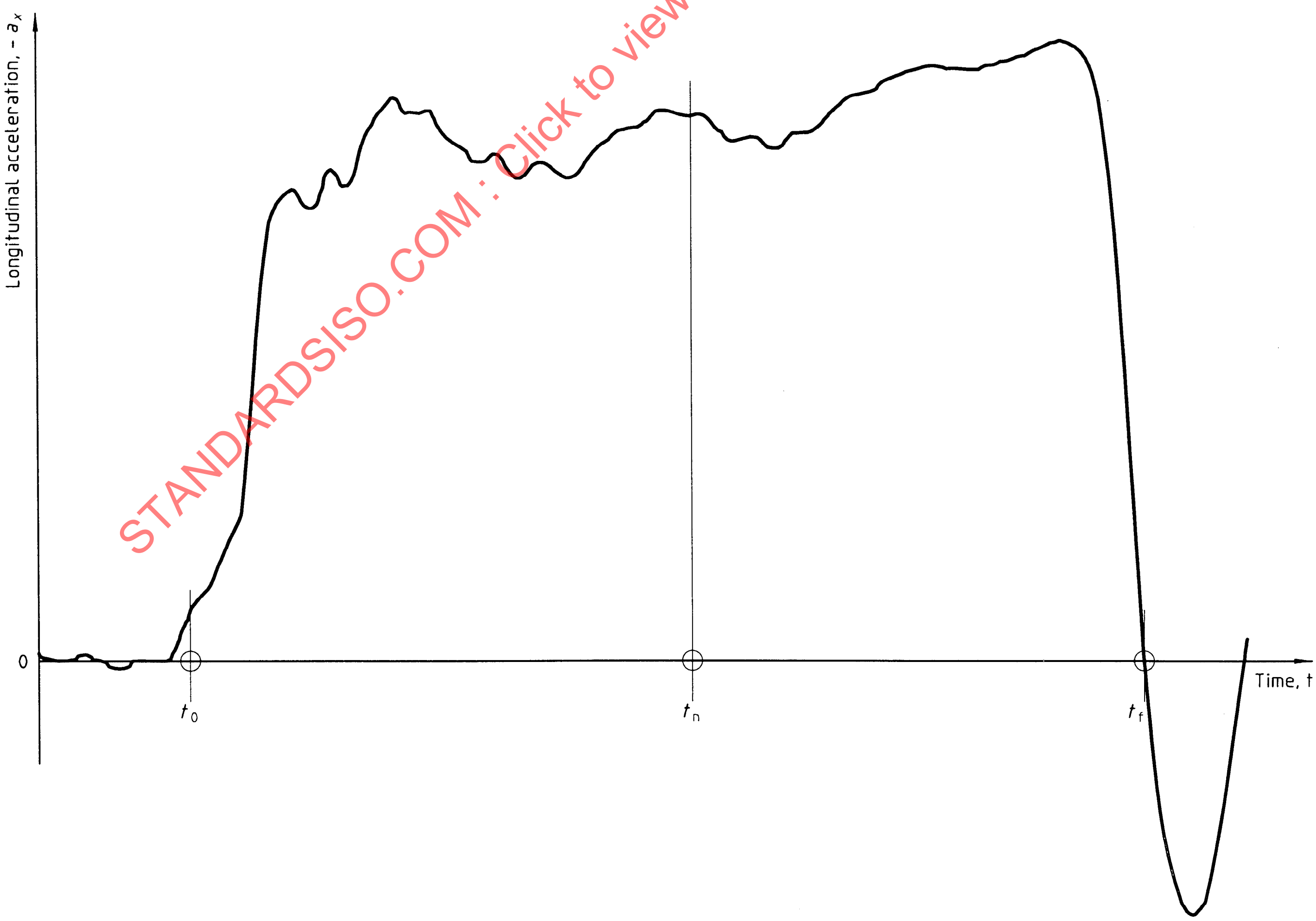

Figure 3 — Longitudinal acceleration $-a_X$ versus time

8.3.4 Mean longitudinal acceleration $-\bar{a}_{X,t_n}$ until time t_n

The mean longitudinal acceleration at any time t_n after brake application is defined as the mean value during the time interval t_0 to t_n of the longitudinal acceleration (see figure 3).

8.4 Characteristic values

The characteristic values shall be determined and presented as a function of the mean longitudinal acceleration or the mean longitudinal acceleration at time t_n (see 8.3.3 and 8.3.4). The characteristic values in the steady-state condition are defined as mean values during the time interval 1,3 to 0,3 s before brake application. The other characteristic values are determined during an observation period beginning at t_0 and ending with the standstill of the vehicle. The instantaneous values at t_n shall be calculated by taking the mean value during the time interval t_n from −0,1 s to +0,1 s. For standard evaluation the actual time is $t_n = t_0 + 1$ s, but t_n may also assume additional values.

For each set of initial conditions, calculate and plot the characteristic values listed below. The reference values of yaw velocity and lateral acceleration used in some of the formulas are those values which would be obtained at actual time t and actual longitudinal velocity $v_{X,t}$, if the initial radius were maintained by the vehicle. They are defined as follows:

Reference yaw velocity: $\dot{\Psi}_{\text{Ref},t} = \dfrac{v_{X,t}}{R_0}$

Reference lateral acceleration: $a_{Y,\text{Ref},t} = \dfrac{v_{X,t}^2}{R_0}$

8.4.1 The ratio of the maximum value attained by the yaw velocity during braking to the initial steady-state value of the yaw velocity (see figure B.1):

$$\frac{\dot{\Psi}_{\max}}{\dot{\Psi}_0} = f_1(-\bar{a}_X)$$

8.4.2 The ratio of the maximum value attained by the lateral acceleration during braking to the initial steady-state value of the lateral acceleration (see figure B.2):

$$\frac{a_{Y,\max}}{a_{Y,0}} = f_2(-\bar{a}_X)$$

8.4.3 The ratio of the maximum value attained by the sideslip angle during braking to the initial steady-state value of the sideslip angle (see figure B.3):

$$\frac{\beta_{\max}}{\beta_0} = f_3(-\bar{a}_X)$$

8.4.4 The maximum value of the difference between the yaw velocity during braking and the affiliated reference yaw velocity (see figure B.4):

$$\Delta\dot{\Psi}_{\max} = \left[\dot{\Psi}_t - \dot{\Psi}_{\text{Ref},t}\right]_{\max} = \left[\dot{\Psi}_t - \frac{v_{X,t}}{R_0}\right]_{\max} = f_4(-\bar{a}_X)$$

8.4.5 The ratio of the mean values of the yaw velocity during braking to the reference yaw velocity (see figure B.5):

$$\frac{\bar{\dot{\Psi}}}{\bar{\dot{\Psi}}_{\text{Ref}}} = \frac{\bar{\dot{\Psi}}}{(\dot{\Psi}_0/2)} = f_5(-\bar{a}_X)$$

8.4.6 The difference between the values of the yaw velocity at actual time t_n and the reference yaw velocity at actual time t_n (see figure B.6):

$$\Delta\dot{\Psi}_{t_n} = \dot{\Psi}_{t_n} - \dot{\Psi}_{t_{n,\mathrm{Ref}}} = \dot{\Psi}_{t_n} - \frac{v_{X,t_n}}{R_0} = f_6(-\bar{a}_{X,t_n})$$

8.4.7 The difference between the values of the lateral acceleration at actual time t_n and the reference lateral acceleration at actual time t_n (see figure B.7):

$$\Delta a_{Y,t_n} = a_{Y,t_n} - a_{Y,t_{n,\mathrm{Ref}}} = a_{Y,t_n} - \frac{v^2_{X,t_n}}{R_0} = f_7(-\bar{a}_{X,t_n})$$

8.4.8 The difference between the values of the yaw velocity at actual time t_n and the calculated yaw velocity at actual time t_n (see figure B.8):

$$\dot{\beta}'_{t_n} = \dot{\Psi}_{t_n} - \frac{a_{Y,t_n}}{v_{X,t_n}} = f_8(-\bar{a}_{X,t_n})$$

where $\dot{\beta}'$ is the sideslip angle velocity uncorrected for the effects of the sideslip angle itself and the deceleration. It gives information on the vehicle's yaw stability.

8.4.9 The ratio of the value of the initial radius to the path radius of the vehicle's reference point at actual time t_n (see figure B.9):

$$\frac{R_0}{R_{t_n}} = f_9(-\bar{a}_{X,t_n})$$

with

$$R_{t_n} = \frac{v^2_{X,t_n}}{a_{Y,t_n}}$$

8.4.10 The ratio of the value of the yaw velocity at actual time t_n to the initial steady-state value of the yaw velocity (normalized yaw velocity at actual time) (see figure B.10):

$$\frac{\dot{\Psi}_{t_n}}{\dot{\Psi}_0} = f_{10}(-\bar{a}_{X,t_n})$$

8.4.11 The ratio of the value of the lateral acceleration at actual time t_n to the initial steady-state value of the lateral acceleration (normalized lateral acceleration at actual time) (see figure B.11):

$$\frac{a_{Y,t_n}}{a_{Y,0}} = f_{11}(-\bar{a}_{X,t_n})$$

8.4.12 The difference between the values of the sideslip angle at actual time t_n and the initial steady-state value of the sideslip angle (see figure B.12):

$$\beta_{t_n} - \beta_0 = f_{12}(-\bar{a}_{X,t_n})$$

8.4.13 The difference between the values of the yaw angle at actual time t_n and the value of the reference yaw angle at actual time t_n (see figure B.13).

Approximation:

$$\Delta\Psi_{t_n} = \Psi_{t_n} - \left(\Psi_0 + (t_n - t_0) \times \frac{\dot{\Psi}_0 + \dot{\Psi}_{t_n,\mathrm{Ref}}}{2}\right) = f_{13}(-\bar{a}_{X,t_n})$$

Exact solution:

$$\Delta\Psi_{t_n} = \int_{t=t_0}^{t=t_n} \left[\dot{\Psi}_t - \dot{\Psi}_{\mathrm{Ref},t}\right] \mathrm{d}t$$

8.4.14 The path deviation at actual time t_n defined as the radial distance of the reference point and its initial circular path (see figure B.14):

$$\Delta s_{Y,t_n} = f_{14}(-\bar{a}_{X,t_n})$$

The path deviation is calculated by the path of the reference point in the earth fixed axis system (see figure 4). The coordinates of the reference point can be determined for example by transforming the vehicle fixed velocity vectors $\vec{v}_X$ and $\vec{v}_Y$ into the earth fixed axis system and subsequent integration.

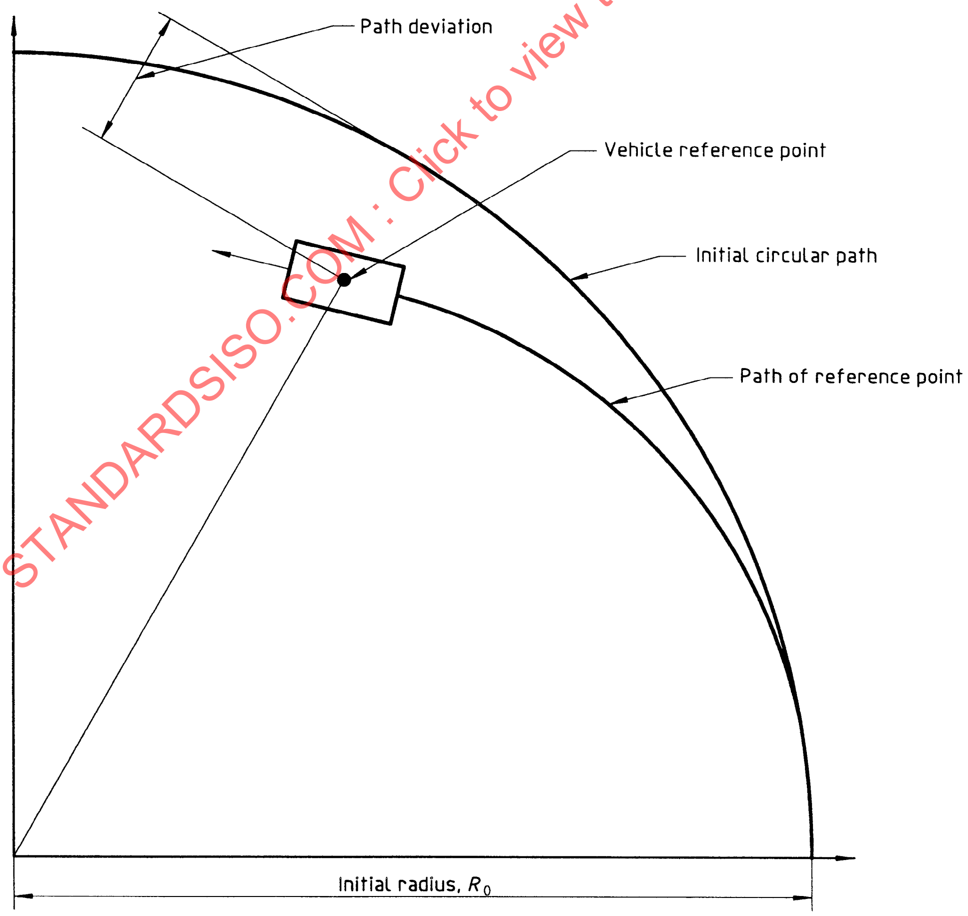

Figure 4 — Definition of path deviation

8.5 Criteria for vehicle behaviour

The behaviour of the vehicle in this test can be described under the headings steerability and yaw behaviour as a function of the braking characteristics.

8.5.1 Steerability

Criteria which may be used amongst others to describe steerability are:

a) the value of mean longitudinal acceleration $-\bar{a}_{X,t_n}$ at actual time t_n at which the normalized lateral acceleration at actual time (see 8.4.11) reaches the value zero;

NOTE — This criteria is not applicable to ABS systems.

b) the value of mean longitudinal acceleration $-\bar{a}_{X,t_n}$ at actual time t_n at which the normalized lateral acceleration at actual time reaches the normalized reference value (see figure 5). The normalized reference value can be approximately defined according to the equation

$$\frac{a_{Y,t_{n,\mathrm{Ref}}}}{a_{Y,0}} = \frac{\left\{v_{X,0} - \left[-\bar{a}_{X,t_n} \times (t_n - t_0)\right]\right\}^2}{R_0 \times a_{Y,0}}$$

NOTE — The criteria listed above assume a vehicle equipped with a conventional braking system. For vehicles supplied with an antilock braking system it may be impossible to determine these values by direct measurements. Because of the high possibility of inaccuracy, the values should not be calculated by extrapolation.

8.5.2 Yaw behaviour

Criteria which may be used amongst others to describe yaw behaviour are:

a) the maximum value of the difference between the values of the yaw velocity at actual time t_n and the reference yaw velocity at actual time t_n (see 8.4.6):

$$\left(\Delta\dot{\Psi}_{t_n}\right)_{\max}$$

b) the maximum value of the ratio between the value of the initial path radius and the path radius of the vehicle's reference point at actual time t_n (see 8.4.9):

$$\left(\frac{R_0}{R_{t_n}}\right)_{\max}$$

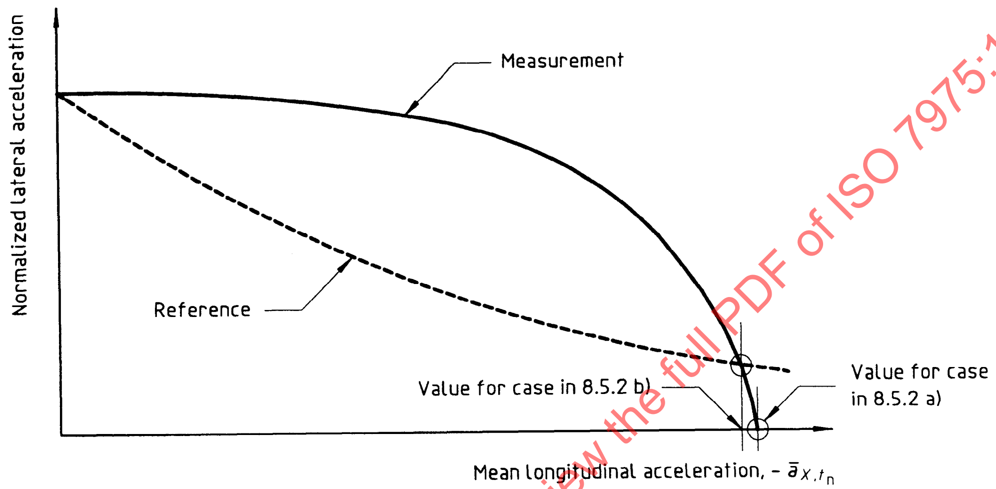

Figure 5 — Criteria for steerability

Annex A
(normative)

Test report — General data

Vehicle identification:	Vehicle identification number (VIN):	....	
	Type of vehicle:	....	
	Manufacturer:	....	
	Model:	....	
	Model year/1st registration date:	....	
Drive configuration:	Front-wheel drive:	☐	
	Rear-wheel drive:	☐	
	Four-wheel drive; type of 4WD:	....	
	Special features:	....	
Engine:	Identification code:	....	
Transmission:	Identification code:	....	
Steering:	Conventional (front-wheel) steering:	☐	
	Four-wheel steering:	☐	
	Power-assisted steering:	☐	
	Steering ratio overall on front axle:	........................:1	
	Steering-wheel diameter:	.... mm	
Braking system:	Conventional braking system:	☐	
	Power-assisted braking system:	☐	
	Antilock braking system:	☐	
	— Type:	....	
	Wheel brakes on front axle:	☐ disc	☐ drum
	Wheel brakes on rear axle:	☐ disc	☐ drum
	Brake force distribution:	....	
	Special features:	....	
	Procedure applied for bedding the brakes:	....	
		Front	**Rear**
Tyres:	Size:	....	....
	Make and type:	....	
	Date of manufacture:	....	
	Tread depth: Right:	.... mm	.... mm
	Tread depth: Left:	.... mm	.... mm
	Original tread depth:	.... mm	.... mm
	Inflation pressure:	....	
	— according to vehicle manufacturer at complete vehicle kerb mass (ISO-M06):	.... kPa	.... kPa
	at maximum authorized total mass (ISO-M08):	.... kPa	.... kPa
	— on vehicle test weight:	.... kPa	.... kPa
	Rim size:	.... mm	.... mm

		Front	Rear
Masses:	Complete vehicle kerb mass (ISO-M06):	....kg	
	Maximum authorized total mass (ISO-M08):	....kg	
	Maximum authorized axle load (ISO-M13)	..................kg	..................kg
	Measured wheel loads of test vehicle including driver and instrumentation: Right:	..................kg	..................kg
	Left:	..................kg	..................kg
Vehicle specifications:	Length overall:	.... mm	
	Width overall:	.... mm	
	Height overall at test mass:	.... mm	
	Wheelbase:	.... mm	
	Track width:	.... mm	.... mm
	Height of centre of gravity at complete vehicle kerb mass (ISO-M06):	.... mm	
Wheel suspension:	Front		
	— Type:	....	
	— stabilizer	☐	
	— anti-roll bar	☐	
	Rear		
	— Type:	....	
	— stabilizer	☐	
	— anti-roll bar	☐	
	Suspension/damping	....	
		....	
Test conditions:	Engaged gear:	....	
	Time of clutch disengagement:	....	
	Gear selector position:	....	
	Transmission programme:	....	
	Radius of circle:	.... m	
	Reference point for sideslip angle and lateral velocity:	....	
	Road surface condition (e.g. skid number, wet, dry):	....	
	Ambient climate conditions:		
	— temperature:	....°C	
	— wind speed:	....m/s	
	Method for verifying the uniformity of initial conditions:	....	
	standard deviation	☐	
	mean value difference	☐	
Staff:	Driver:	....	
	Observer:	....	
	Data analyst:	....	

General comments and/or other relevant details:

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Annex B
(normative)

Test report — Presentation of results

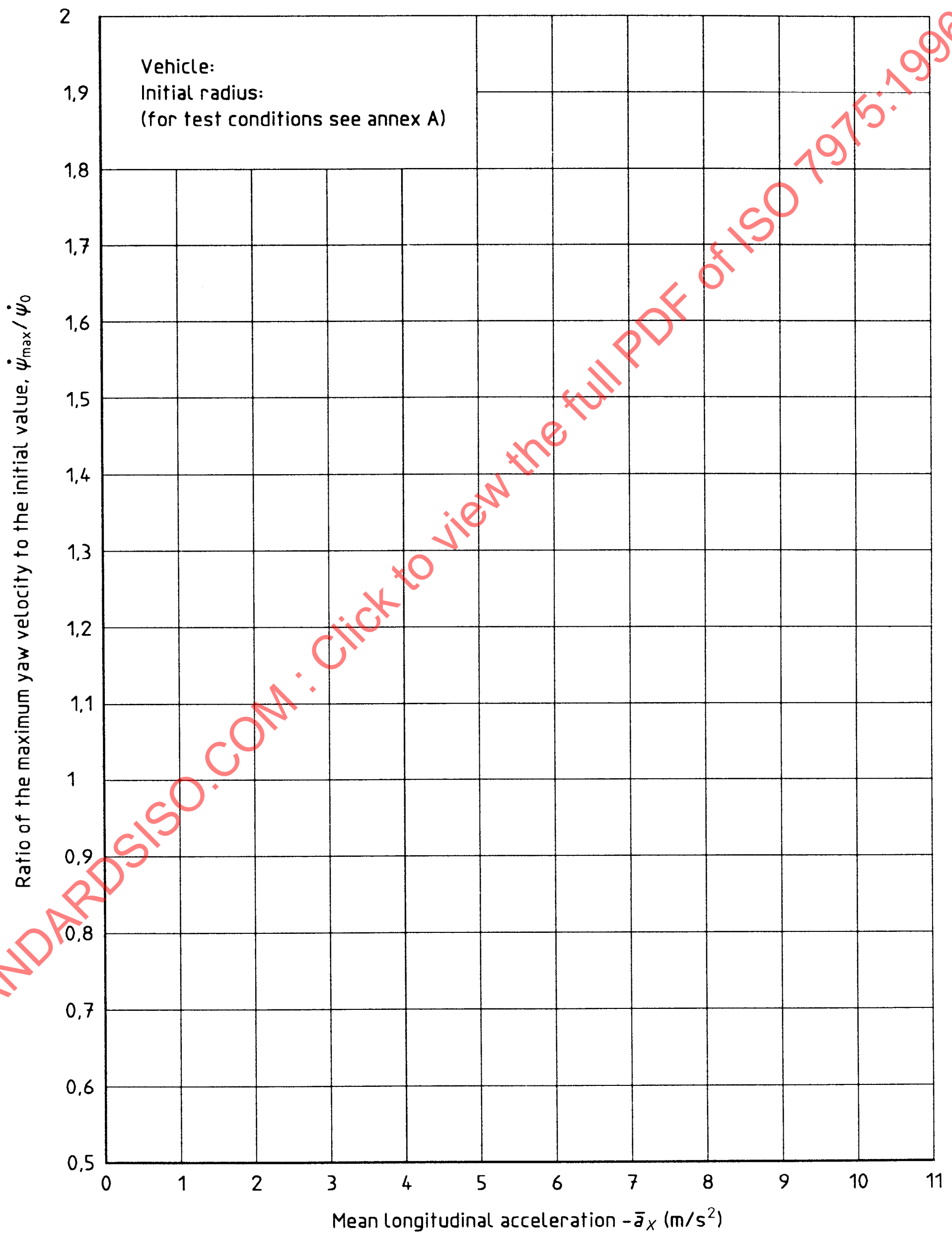

Figure B.1 — Ratio of the maximum value of yaw velocity during braking $\dot{\Psi}_{max}$ to the initial steady-state value $\dot{\Psi}_0$ as a function of the mean longitudinal acceleration $-\bar{a}_X$

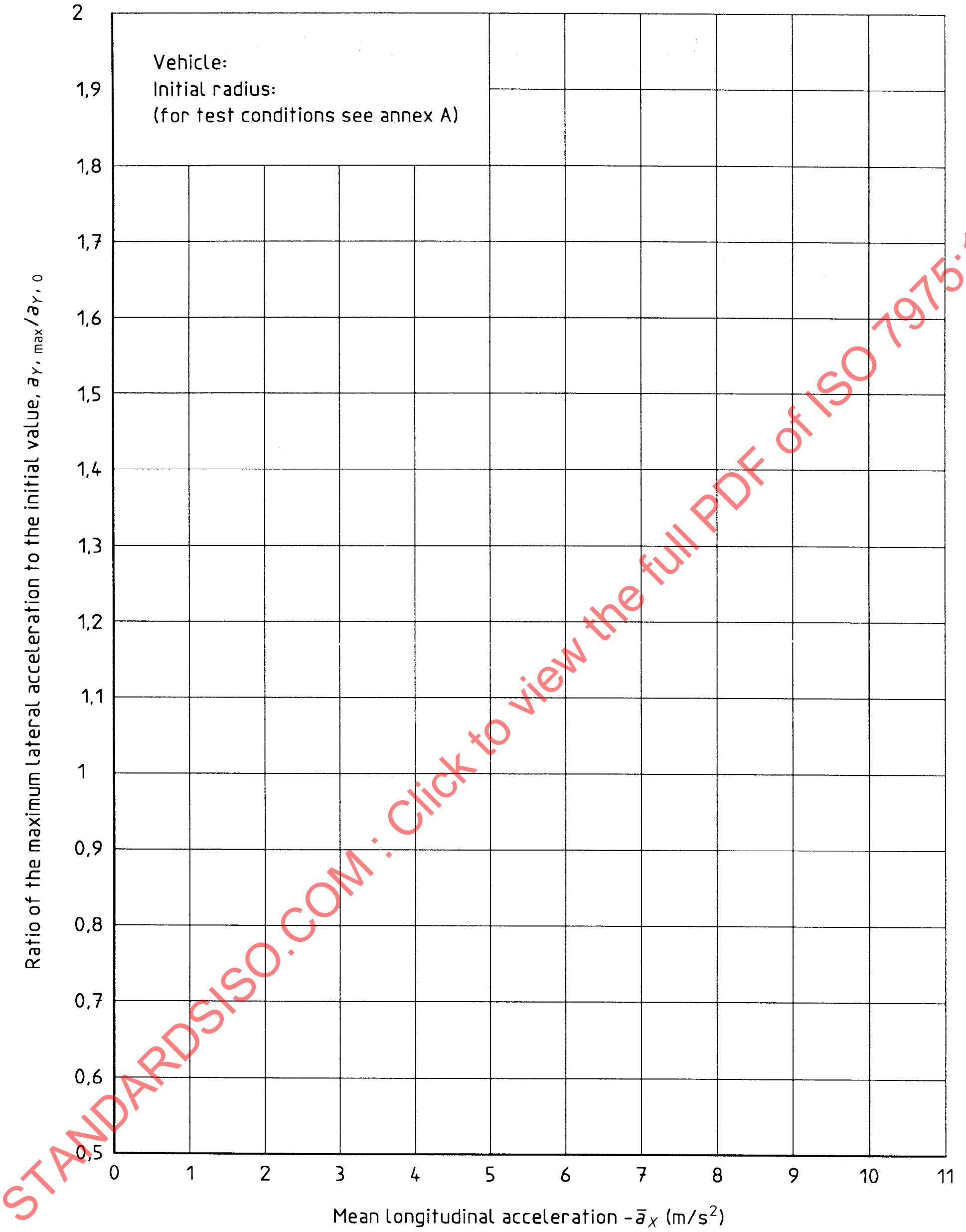

Figure B.2 — Ratio of the maximum value of lateral acceleration $a_{Y,max}$ during braking to the initial steady-state value $a_{Y,0}$ as a function of the mean longitudinal acceleration $-\bar{a}_X$

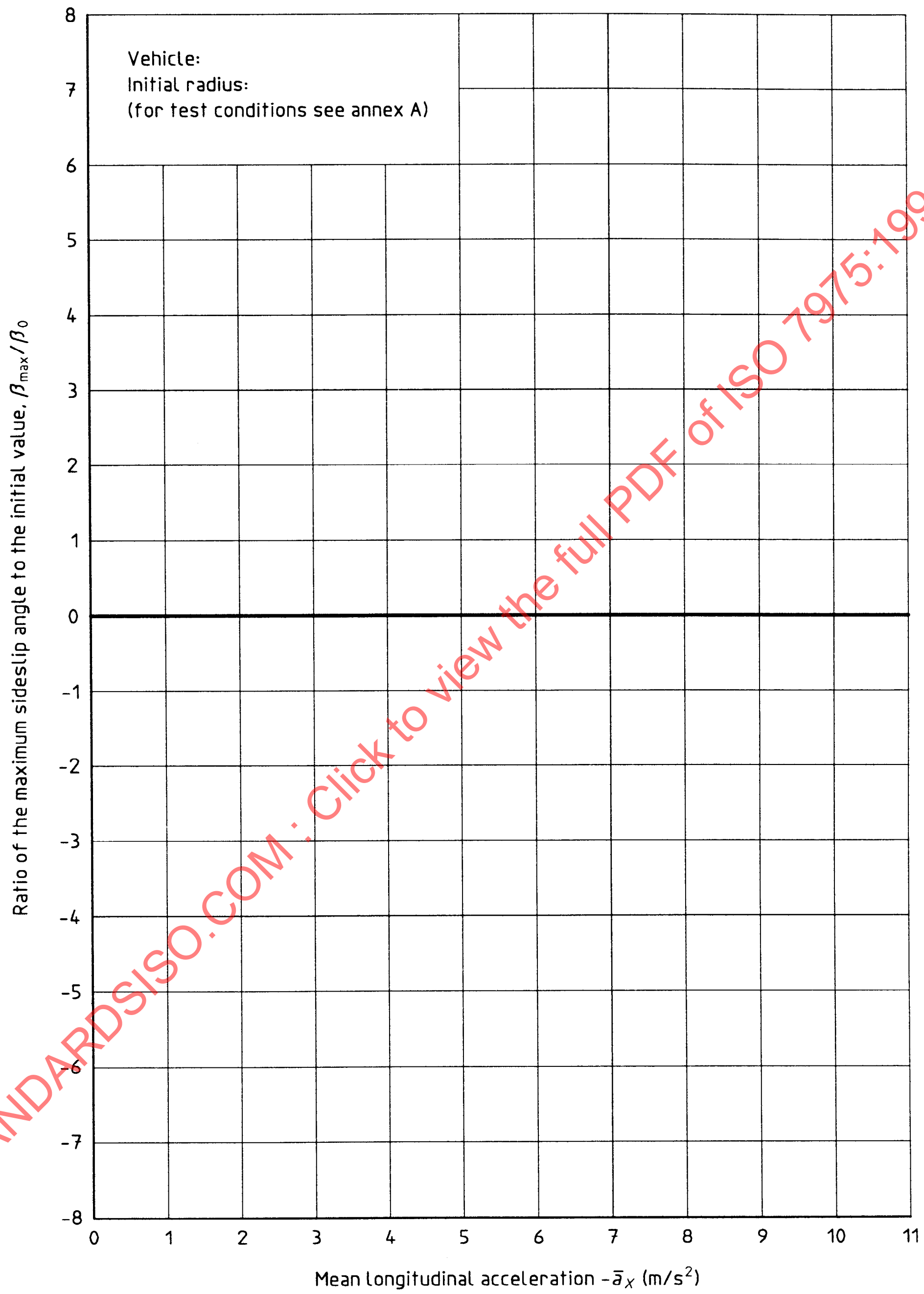

Figure B.3 — Ratio of the maximum value of sideslip angle β_{max} during braking to the initial steady-state value β_0 as a function of the mean longitudinal acceleration $-\bar{a}_X$

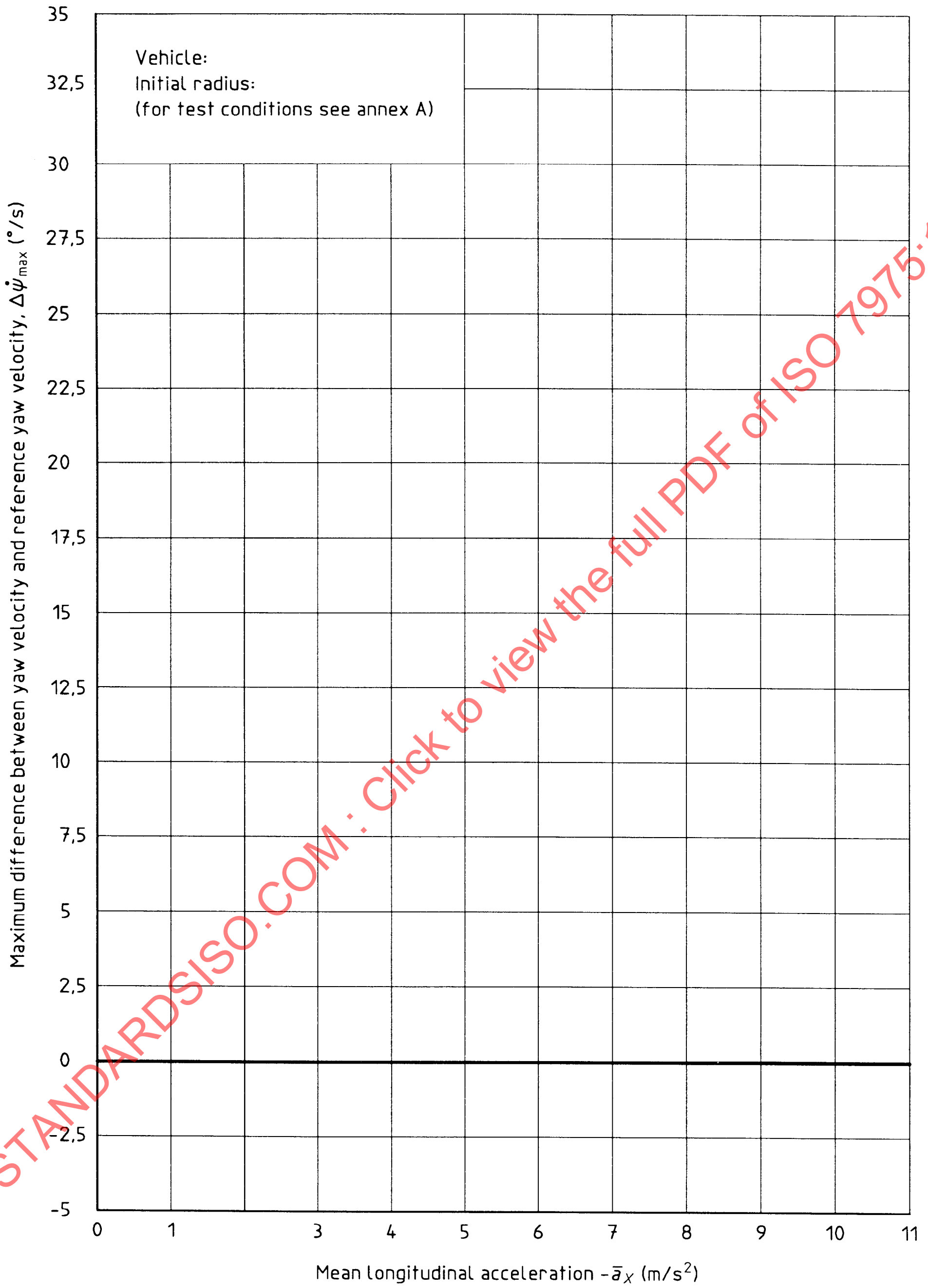

Figure B.4 — Maximum difference between yaw velocity $\dot{\Psi}$ during braking and the affiliated reference yaw velocity $\dot{\Psi}_{Ref}$ as a function of the mean longitudinal acceleration $-\bar{a}_X$

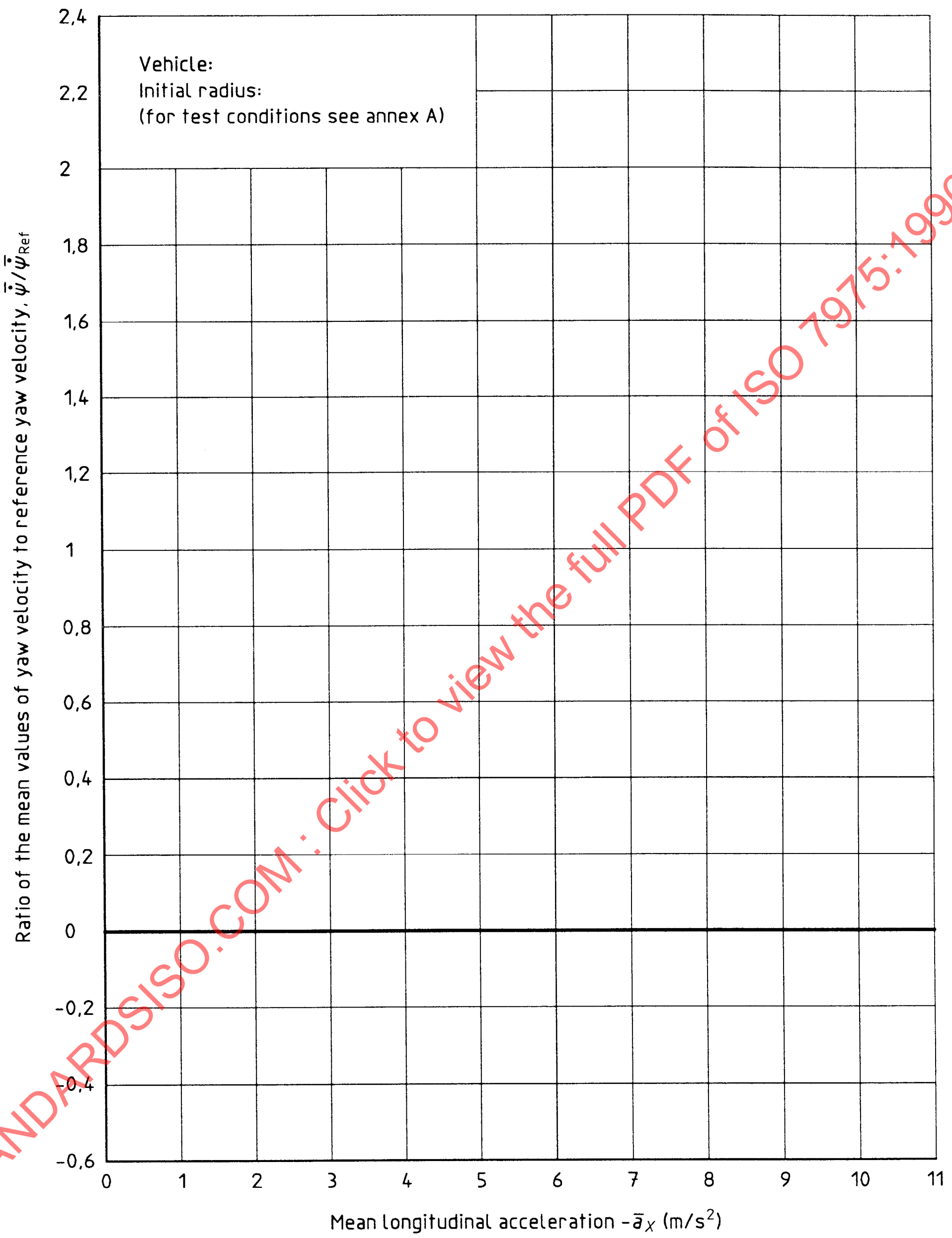

Figure B.5 — Ratio of the mean values of the yaw velocity $\bar{\dot{\Psi}}$ during braking to the reference yaw velocity $\bar{\dot{\Psi}}_{Ref}$ as a function of the mean acceleration $-\bar{a}_X$

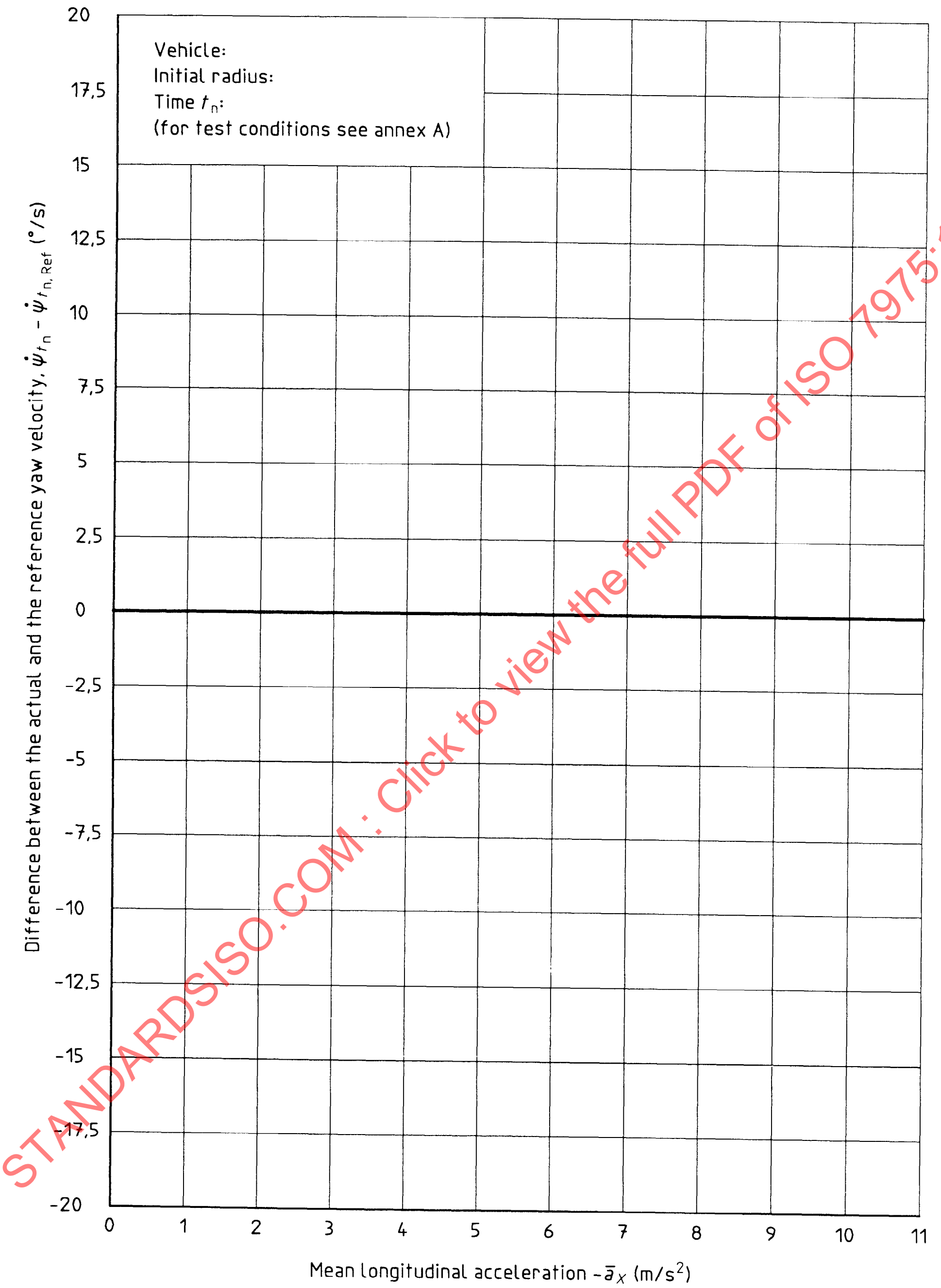

Figure B.6 — At actual time t_n the difference between the value of the yaw velocity $\dot{\Psi}_{t_n}$ and the reference yaw velocity $\dot{\Psi}_{t_{n,Ref}}$ as a function of the mean longitudinal acceleration $-\bar{a}_{X,t_n}$

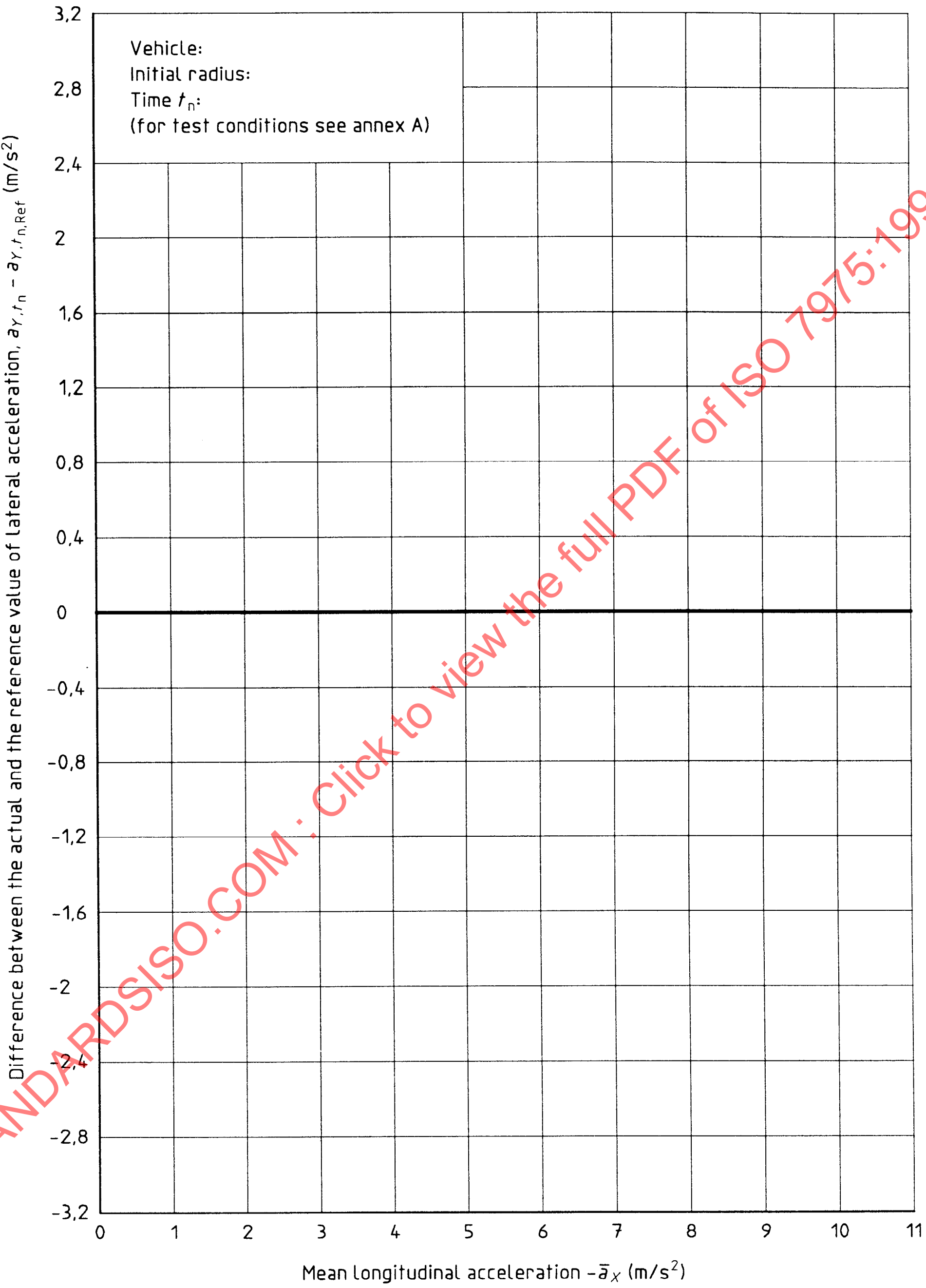

Figure B.7 — At actual time t_n the difference between the value of the lateral acceleration a_{Y,t_n} and the reference lateral acceleration $a_{Y,t_{n,Ref}}$ as a function of the mean longitudinal acceleration $-\bar{a}_{X,t_n}$

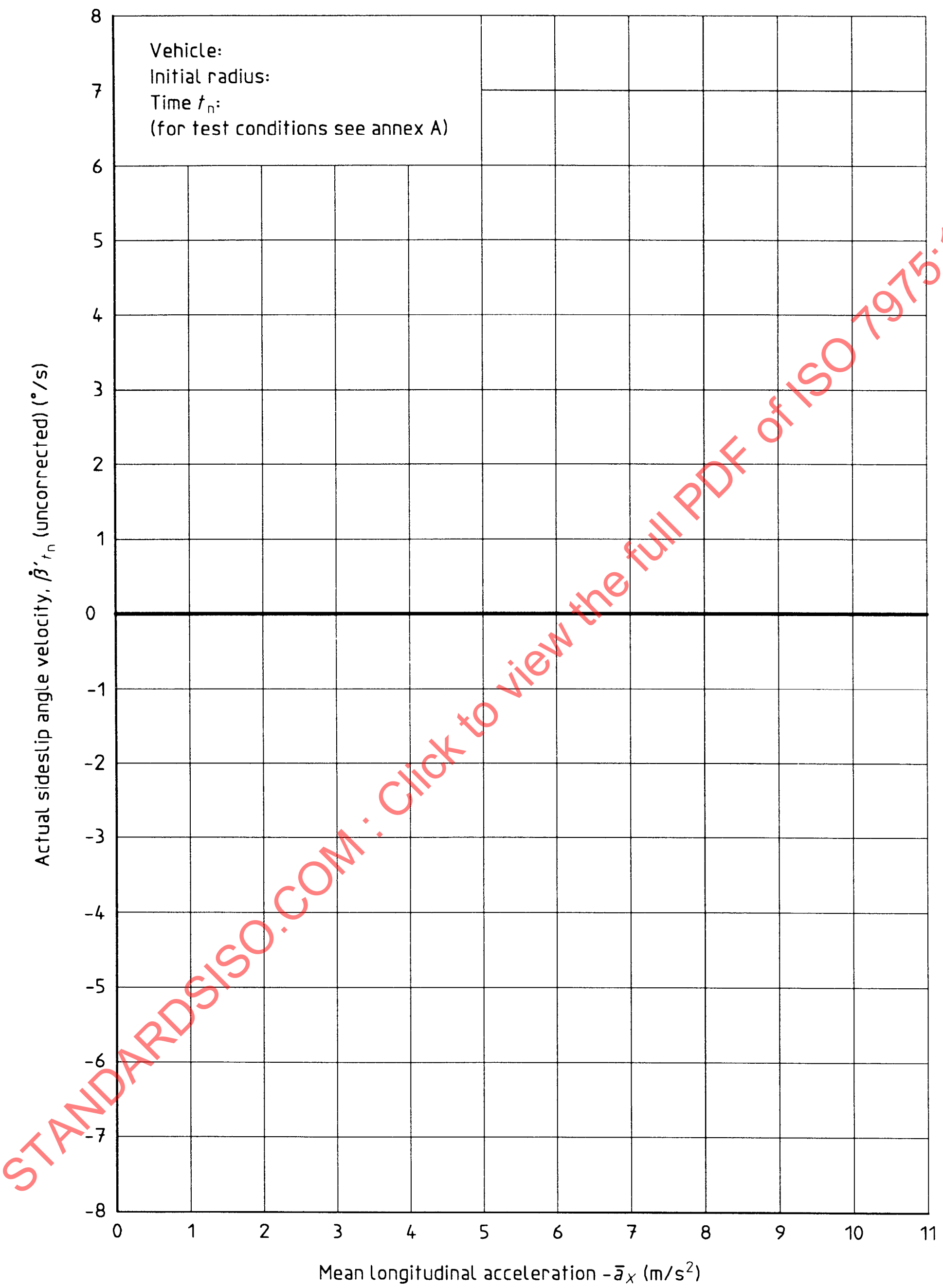

Figure B.8 — At actual time t_n the difference between the value of the yaw velocity $\dot{\Psi}_{t_n}$ and the calculated yaw velocity as a function of the mean longitudinal acceleration $-\bar{a}_{X,t_n}$ (uncorrected sideslip velocity)