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Heavy commercial vehicles and buses — Straight-ahead braking on surfaces with split coefficient of friction — Open-loop test method

Véhicules utilitaires lourds — Freinage en ligne droite sur surfaces à adhérence mixte — Méthode d'essai en boucle ouverte

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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 16234 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

Introduction

The dynamic behaviour of a road vehicle is a most important aspect of active vehicle safety. Any given vehicle, together with its driver and the prevailing environment, constitutes a unique closed-loop system. The task of evaluating the dynamic behaviour is therefore very difficult, since significant interactions 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 this test method quantifies only a 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, sufficient knowledge is not available to correlate overall vehicle dynamic properties with accident prevention. A large amount of work is necessary to acquire sufficient and reliable data on the correlation between accident prevention and vehicle dynamic properties in general, and the results of this test in particular. Therefore, it is not possible to use this method and test results for regulation purposes.

Heavy commercial vehicles and buses — Straight-ahead braking on surfaces with split coefficient of friction — Open-loop test method

1 Scope

This international Standard describes an open-loop test method for determining vehicle reactions during a straight-line braking manoeuvre on a surface having a split coefficient of friction.

It applies to heavy vehicles, i.e. commercial vehicles, commercial vehicle combinations, buses and articulated buses as defined in ISO 3833 (trucks and trailers with maximum weight above 3,5 tonnes and buses and articulated buses with maximum weight above 5 tonnes, according to ECE and EC vehicle classification, categories M3, N2, N3, O3 and O4).

The method is limited to vehicles in which at least the first unit is equipped with an anti-lock braking system. It is valid for braking with service-brake systems only or in combination with retarders and/or engine brakes.

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 611, *Road vehicles — Braking of automotive vehicles and their trailers — Vocabulary*

ISO 3833, *Road vehicles — Types — Terms and definitions*

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

ISO 15037-2:2002, *Road vehicles — Vehicle dynamics test methods — Part 2: General conditions for heavy vehicles and buses*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this International Standard, the terms and definitions in ISO 611, ISO 15037-2:2002 and ISO 8855 apply.

3.2 Symbols

For the purposes of this International Standard, the symbols in ISO 15037-2:2002 and ISO 8855 apply.

4 Principle

The objective of this test method is to determine the effects on the yaw reaction and the longitudinal acceleration of a vehicle produced by a braking manoeuvre on a straight roadway having a low coefficient of friction on one side and a high coefficient of friction on the other side.

Test results are strongly influenced by friction coefficients as well as the difference in friction between the left and right side of the course. A large difference between the left- and right-side friction conditions is desirable. Surface properties other than friction coefficient (e.g. roughness, ice or synthetic materials, etc.) that are not quantified by the friction coefficient alone exert an important influence on the test results. For this reason, it is difficult to establish the surface conditions in a reproducible way. Therefore, comparison of results should only be made for tests done on a given track within a short time period. It may also be useful to include tests of a reference vehicle.

The initial condition for the test is driving in a straight line at constant velocity. The steering wheel is held fixed after the braking manoeuvre is initiated. During the test, the operating functions and vehicle responses are measured and recorded. Characteristic values are determined from the measured signals.

5 Measuring equipment

The measuring equipment, transducer installation and data processing shall be in accordance with ISO 15037-2:2002.

6 Variables

The variables of motion used to describe the behaviour of the vehicle shall be related to the intermediate axis system (X, Y, Z) of the individual vehicle units (See ISO 8855 and ISO 15037-2:2002).

The variables that shall be determined for compliance with this International Standard are:

— longitudinal velocity, v_X,

— yaw velocity of each unit of the test vehicle, $\dot{\psi}_{i, i=1,n \quad n=\text{number of units}}$,

— brake pedal position (for vehicles with air brake systems),

— brake pedal force (for vehicles with hydraulic brake systems),

— steering-wheel angle, δ_H,

— yaw articulation angles, Γ_i^J,

— longitudinal acceleration, a_X,

— initial brake temperatures, $T_{B,0}$.

It is also recommended that the following variables be determined:

— supply pressure and brake pressures of interest, p_B,

— rotational velocity of wheels, $\omega_{i,\ i=1,\dots n}$ or equivalent wheel speeds from electronic systems,

— sideslip angle of the first unit, β_1,

— lateral acceleration, a_y.

Typical operating ranges of the variables to be determined for this International Standard are shown in Table 1 and in ISO 15037-2:2002.

Table 1 — Variables, typical operating ranges and recommended maximum errors of variables not listed in ISO 15037-2:2002

Variable	Typical operating range	Recommended maximum errors of the combined transducer and recorder system
Brake pedal position	0 mm to 100 mm	± 1 %
Brake pedal force	0 N to 1 000 N	± 2 %
Brake pressure in air systems	0 kPa to 1 500 kPa	± 15 kPa
Brake pressure in hydraulic systems	0 mPa to 30 MPa	± 0,3 MPa
Rotational velocity of wheels	0 °/s to 6 000 °/s	± 5 °/s
Yaw velocity	± 20 °/s	± 0,2 °/s
Initial brake temperature	50 °C to 200 °C	± 10 °C

7 Test conditions

7.1 General

The test conditions described in ISO 15037-2:2002, along with the following additions and exceptions, shall apply to this International Standard. Any deviations shall be shown in the test report.

NOTE Large yaw angles and/or large articulation angles may develop during the test. Loss of control is a realistic risk in these tests. For safety, sufficient open space should be provided adjacent to the test surface in case of loss of control.

7.2 Test track

The test surface shall have a high coefficient of friction on one side and a low coefficient of friction on the other side. The difference between the coefficients of friction of the high-friction and low-friction surfaces shall be at least 0,4. This difference and the value of the low-friction coefficient shall be determined at least once before and once after the test and shall be recorded in the report.

Either natural ice or an artificial surface may be used for the low-friction surface. If a lubricated, artificial surface is used, the lubricant shall be evenly distributed prior to each test run. The high-friction surface shall be as described in ISO 15037-2:2002 except that it may be wet.

The following shall be taken into account:

1) that substitute materials may have slip characteristics which differ significantly from that of natural ice; and

2) that the friction of natural ice may change rapidly during a test series.

The split-coefficient track shall be long enough to accommodate the entire period of observation (see 8.4). Both the low- and high-friction portions of the path should also be wide enough to allow testing to determine a reference coefficient of friction for the surface.

NOTE There are two methods to determine friction coefficients: The first method is according to ISO 8349 [1]. In the second method, a reference friction coefficient is determined from ABS-braking tests conducted with all wheels of the test vehicle on the surface being measured [2]. A reference coefficient of friction determined in this manner only approximates the actual coefficient of friction and is dependent on the performance of the ABS.

7.3 Test vehicle

7.3.1 Tyres

The tyre conditions shall be in accordance with ISO 15037-2:2002.

7.3.2 Safety equipment

An anti-jack-knife device should be used when executing tests with heavy vehicle combinations. For vehicles with a risk of rollover, outriggers should be used and reported in Annex A.

7.3.3 Loading conditions

Tests may be performed at the minimum, maximum or other loading conditions as specified in ISO 15037-2:2002.

7.3.4 Condition of the brakes

Prior to testing, the brakes of the test vehicle shall be burnished. The method of burnishing the brakes shall be reported in Annex A.

The brakes of the test vehicle shall not be contaminated with foreign material.

NOTE If brake burnishing or testing are conducted on roads that have been treated with salt or other materials for melting ice, dust from the dried material may be present in the brakes and may change their friction properties.

8 Test method

8.1 Condition and temperature of the brakes

The user shall identify an acceptable range for initial brake temperature. Prior to each individual run, the brakes shall be warmed up or allowed to cool as required such that the initial brake temperatures are within this range. The initial temperature of the brakes shall be reported in the General Data (Annex A).

NOTE Typical initial temperatures of disc brakes are from 50 °C to 200 °C and for drum brakes from 50 °C to 150 °C.

8.2 Initial driving conditions

The initial driving conditions for the test shall be driving straight ahead as specified in ISO 15037-2:2002 with the addition that the steering wheel be held fixed within ± 3° during the time interval from t_1 to t_2.

For safety reasons, the first test runs should be conducted with an initial longitudinal velocity of 30 km/h. The initial longitudinal velocity, v_{x0}, of subsequent tests should be increased in increments of 10 km/h up to the maximum velocity of interest.

8.3 Performance of the braking procedure

The test track should be approached in such a way that the border between high- and low-friction surfaces is located in the X-Z plane of symmetry of the vehicle.

After reaching the initial driving conditions, the steering wheel shall be held fixed by the test driver or by a mechanical device, and the accelerator pedal shall be released and the brakes applied as quickly as possible to 100 % of full braking and maintained during the period of evaluation defined in 8.4.4. For air brake systems, full braking corresponds to 100 % of the full stroke of the brake pedal, and for hydraulic brake systems full braking corresponds to 100 % of the brake-pedal force, i.e. no less than 500 N.

The position of the steering wheel during the period of observation shall not vary more than ± 3° from the mean value of the initial state.

For vehicles with manual transmissions, the test run shall be conducted with the driveline disengaged. Additional tests with the driveline engaged may be performed. For vehicles with automatic transmissions or automatic shifted gearboxes, the selected shift-lever position and driving programme shall remain unchanged during the test run and shall be reported. For vehicles with retarders and/or engine brakes, the settings shall be reported.

The test should be repeated several times so that the results can be examined for repeatability and averaged.

8.4 Time references

8.4.1 Period of observation

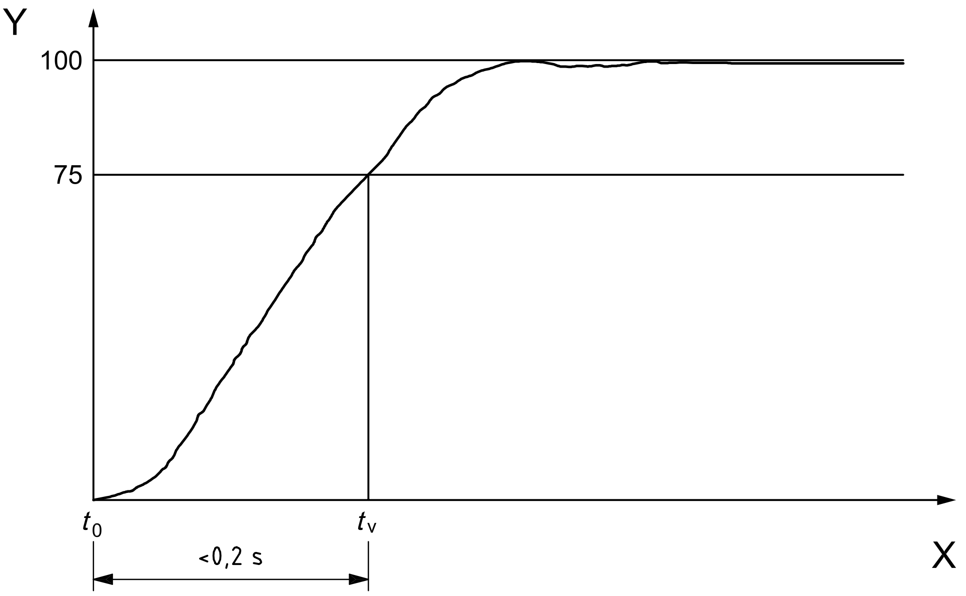
The period of observation is the time interval over which measurements are to be made. The period of observation begins at least 2 s before the beginning of braking (t_0) and ends no earlier than 2 s after the period of evaluation (see 8.4.4).

8.4.2 Time of brake pedal actuation, t_0

The point in time of brake pedal actuation is designated as t_0 (see Figure 1).

8.4.3 Time when brake pedal reaches value of validity, t_v

Figure 1 shows the time history of the brake pedal position and the definition of t_v, the point in time at which the brake pedal position first reaches 75 % of full application (see Figure 1).



Key

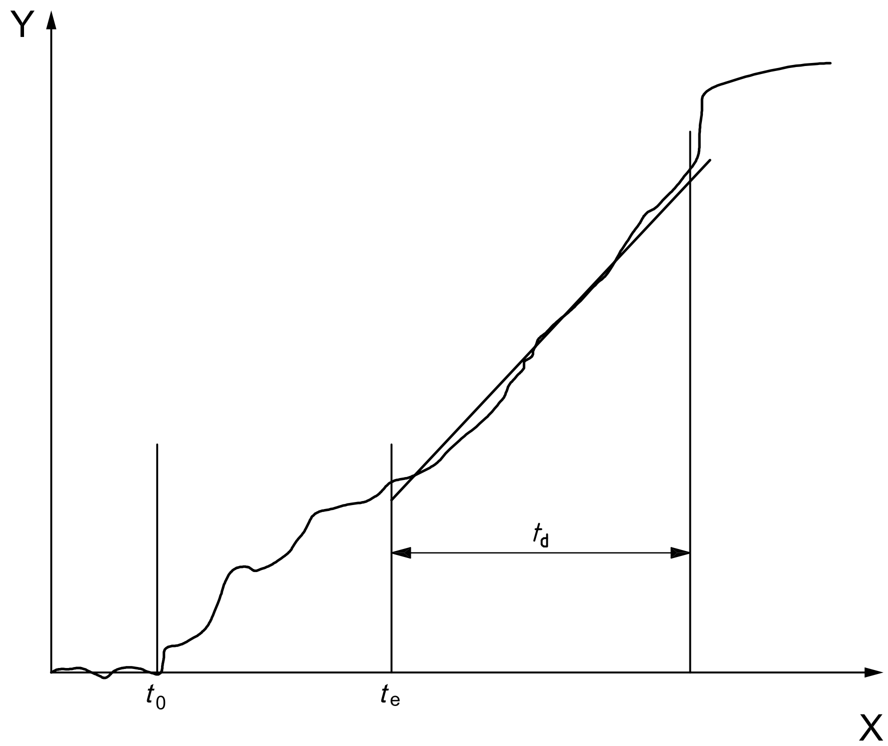
X time, t in s

Y brake pedal position/force, % of full application

Figure 1 — Definition of t_0 and t_v

8.4.4 Period of evaluation, t_d

The period of evaluation is intended to be the time, following full brake actuation, during which the vehicle's yaw acceleration is relatively constant. The period of evaluation should start at the time t_e, 0,5 s after brake actuation, although other values of t_d may be used if appropriate, given the actual yaw behaviour of the vehicle. The period of evaluation shall have a duration, t_e, of up to, but not exceeding, 2 seconds. The end of the period of evaluation shall be either the moment when the vehicle is no longer operating in the split-μ condition or when the 2-second limit is reached, whichever occurs first. The start time t_e and the duration time t_d shall be reported. The validity criteria in 9.2 shall apply during the evaluation period.



Key

X time, t in s

Y yaw velocity $\dot{\psi}$ in degrees per s

Figure 2 — Definition of t_e and t_d

9 Data evaluation

9.1 General

General data shall be presented in the test report in accordance with ISO 15037-2:2002, Annexes A and B. For every change in vehicle loading or configuration, the general data shall be documented again.

At the present level of knowledge, it is not yet known which variables from these tests best represent the subjective feeling of the driver and which variables or characteristic values most clearly describe the dynamic reaction of the vehicle. The following variables therefore represent only examples for the evaluation of results.

9.2 Validity criteria

9.2.1 Braking action

To ensure that the acceleration is achieved, the time between the time t_0 and the time t_v shall not exceed 0,2 s. Once the brake pedal has reached its maximum position, it shall be held in that position for the remainder of the manoeuvre.

9.2.2 Split-μ condition

To correctly determine the characteristic values, it is necessary that the vehicle be in split-μ condition throughout the period of evaluation. The transition of a front wheel to high-μ is revealed by a clear increase in longitudinal deceleration; the transition of a rear wheel to low-μ is revealed by a clear increase in yaw acceleration.

9.3 Time history

For every test run, time histories of the variables listed in Clause 6 shall be presented. Apart from their evaluation purposes, the time histories serve to monitor correct test performance and functioning of the transducers (see Figure B.1, Annex B).

9.4 Characteristic values

9.4.1 General

For each set of initial conditions, the characteristic values listed below shall be calculated and plotted. The mean values are obtained from linear approximations of the time histories in the period of evaluation. Three linear curve fits of these time histories shall be made. The method of curve fitting shall be reported. The correlation coefficient of each curve fit is used as a quality measure:

$f_{\dot{\psi}}(t) = k_{\dot{\psi}} \cdot t + b_{\dot{\psi}}$; with the correlation coefficient $r_{\dot{\psi}}^2$,

$f_{v_x}(t) = k_{v_x} \cdot t + b_{v_x}$; with the correlation coefficient $r_{v_x}^2$, and

$f_{\Gamma}(t) = k_{\Gamma} \cdot t + b_{\Gamma}$; with the correlation coefficient r_{Γ}^2.

9.4.2 Mean yaw acceleration during the period of evaluation (see Figure B.2)

$$\ddot{\psi}_{\text{linear}} = k_{\dot{\psi}} = f_2(\bar{v}_{x0})$$

9.4.3 Mean longitudinal acceleration during the period of evaluation (see Figure B.3)

$$a_{x,\text{linear}} = k_{v_x} = f_3(\bar{v}_{x0})$$

9.4.4 Mean articulation-angle velocity during the period of evaluation (see Figure B.4)

$$\dot{\Gamma}_{\text{linear}} = k_{\Gamma} = f_4(\bar{v}_{x0})$$

9.4.5 Yaw velocity at t_0 + 1 s (see Figure B.5)

$$\dot{\psi}_{t_0+1s} = k_{\dot{\psi}} \cdot t(t_0 + 1s) + b_{\dot{\psi}} = f_5(\bar{v}_{x0})$$

9.5 Further additional evaluation

It is assumed that the mean yaw acceleration $\ddot{\psi}_{\mathrm{linear}}$ versus the mean longitudinal acceleration $a_{x,\mathrm{linear}}$ can provide further valuable information. Also a frequency analysis for values of vehicle reactions during the period of evaluation can be an item of interest.

Annex A
(normative)

Test report — General data and test conditions

A.1 General data

The test report for general data shall be as given in ISO 15037-2:2002, Annex A.

A.2 Test conditions

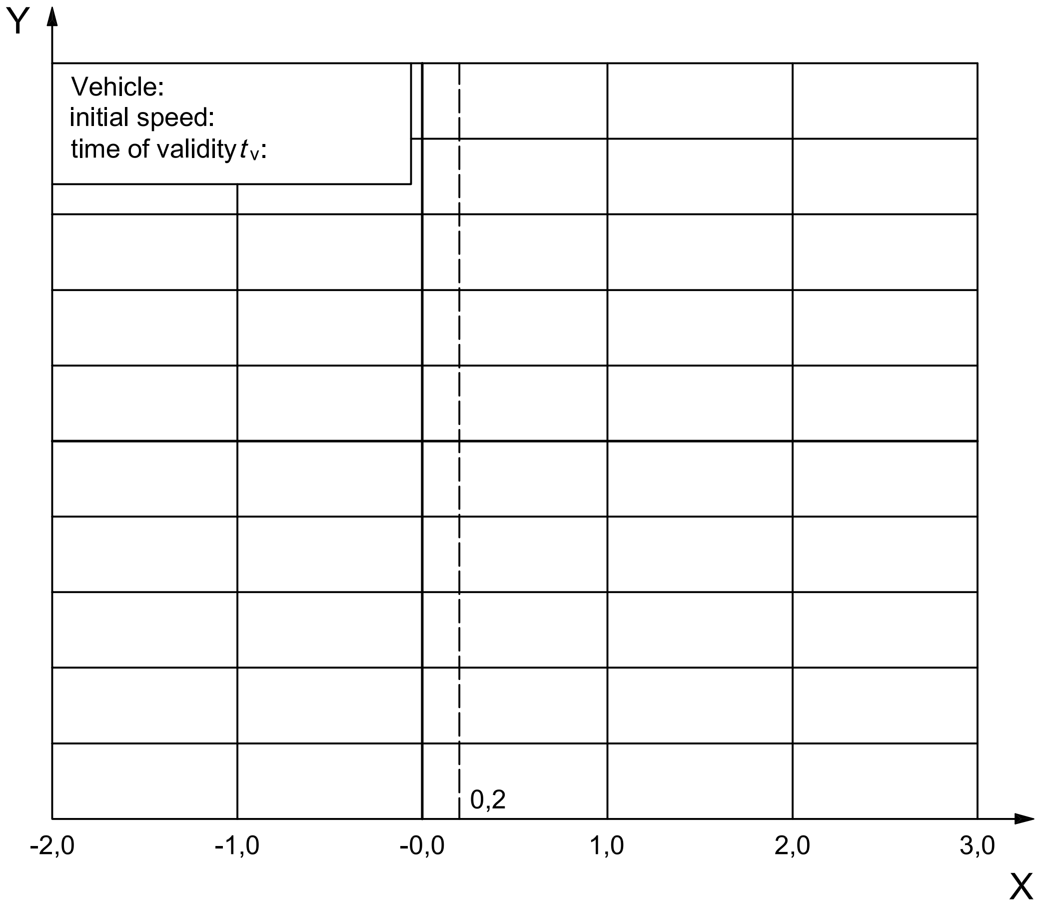
The test report for test conditions shall be as given in ISO 15037-2:2002, Annex B, with the following additions.

Test conditions:	Transmission programme:	……………………………..
	Friction coefficient right side:	……………………………..
	Friction coefficient left side:	……………………………..
	Start time of evaluation t_e:	……………………………..
	Duration of evaluation t_d:	……………………………..

Annex B
(normative)

Test report — Presentation of results

See Figures B.1 to B.5.

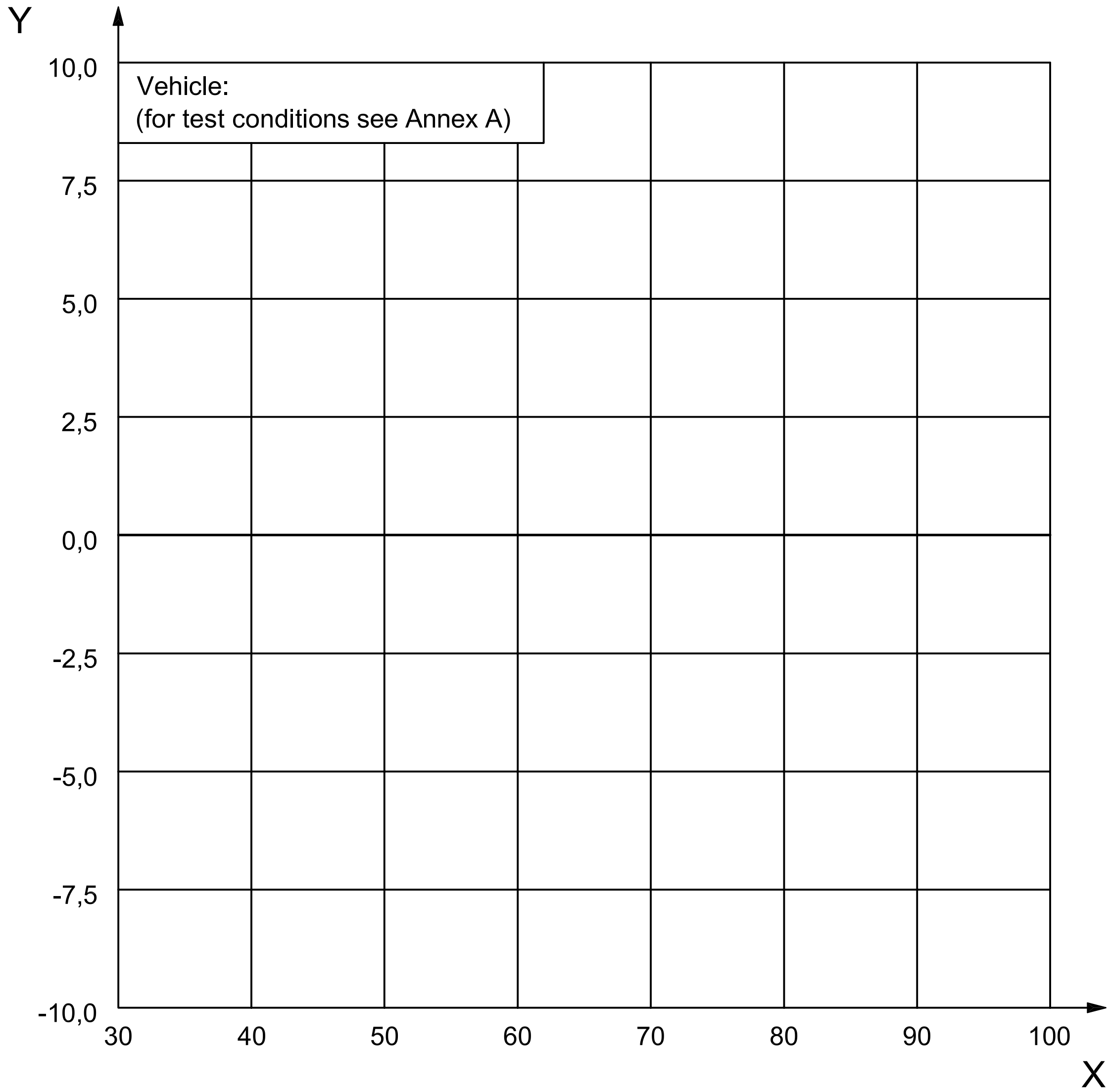


Key

X time, t, measured from t_0, in s

Y values and dimensions of Clause 6

Figure B.1 — Variables measured during the period −2,0 s to 3,0 s around time of brake actuation as time history (see 9.3)

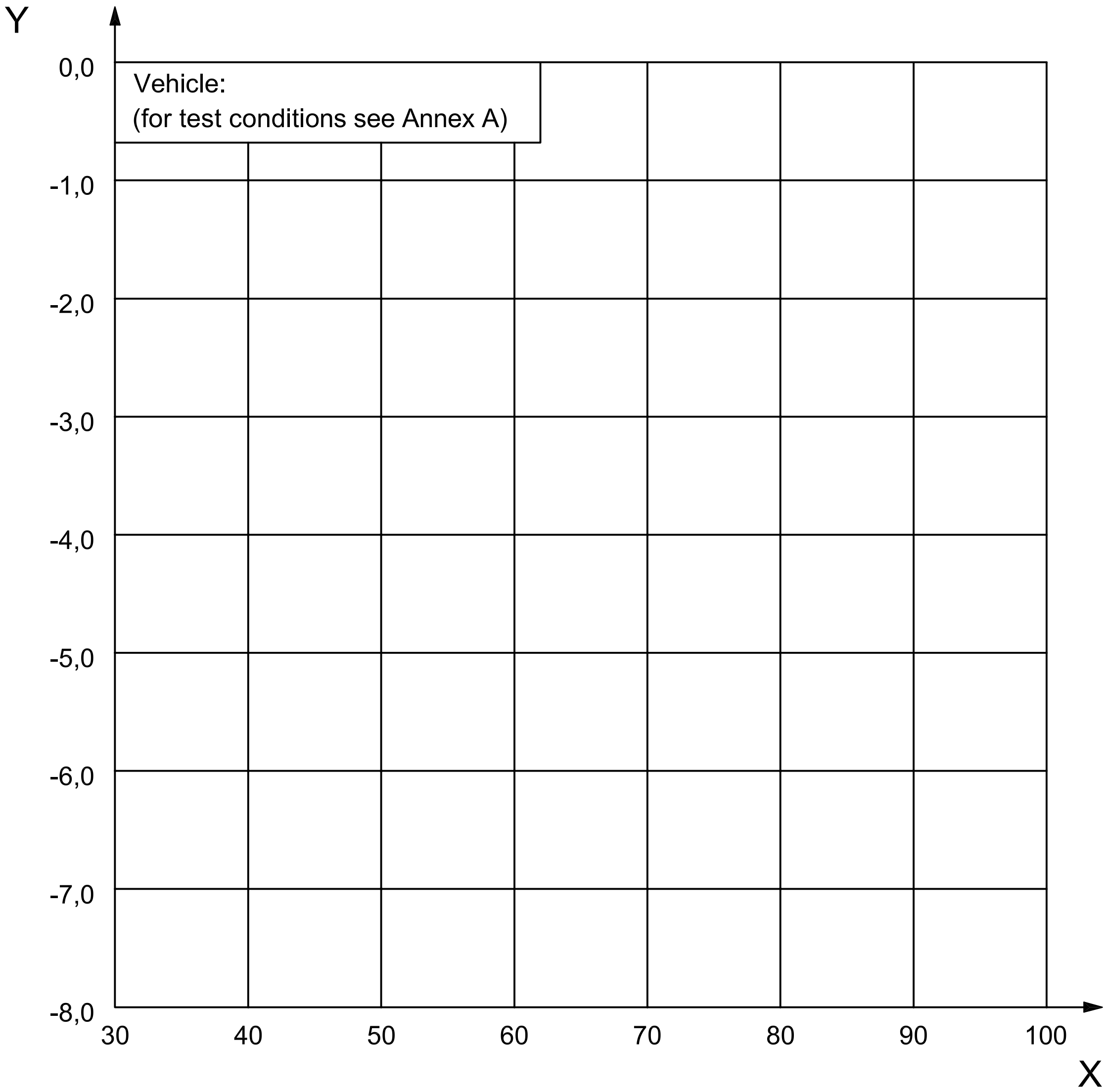


Key

X initial speed $\bar{v}_{x0}$ (km/h)

Y mean yaw acceleration $\ddot{\psi}_{\text{linear}}$ (°/s²)

Figure B.2 — Mean yaw acceleration $\ddot{\psi}_{\text{linear}}$ during the evaluation period as a function of the initial speed $\bar{v}_{x0}$ (see 9.4.2)

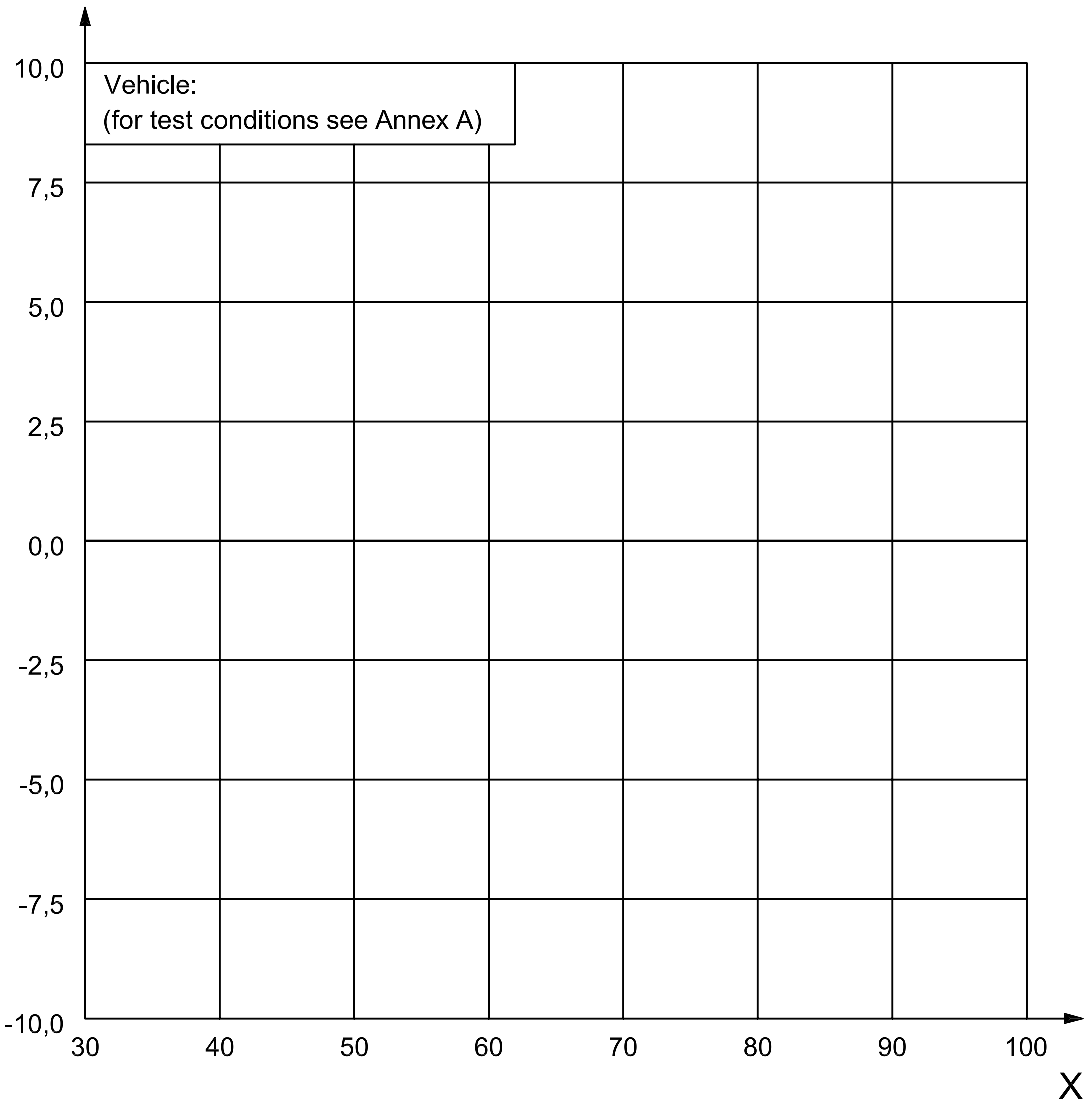


Key

X initial speed $\bar{v}_{x_0}$ (km/h)

Y mean longitudinal acceleration $a_{x,\text{linear}}$ (m/s²)

Figure B.3 — Mean longitudinal acceleration $a_{x,\text{linear}}$ during the period of evaluation as a function of initial speed $\bar{v}_{x_0}$ (see 9.4.3)

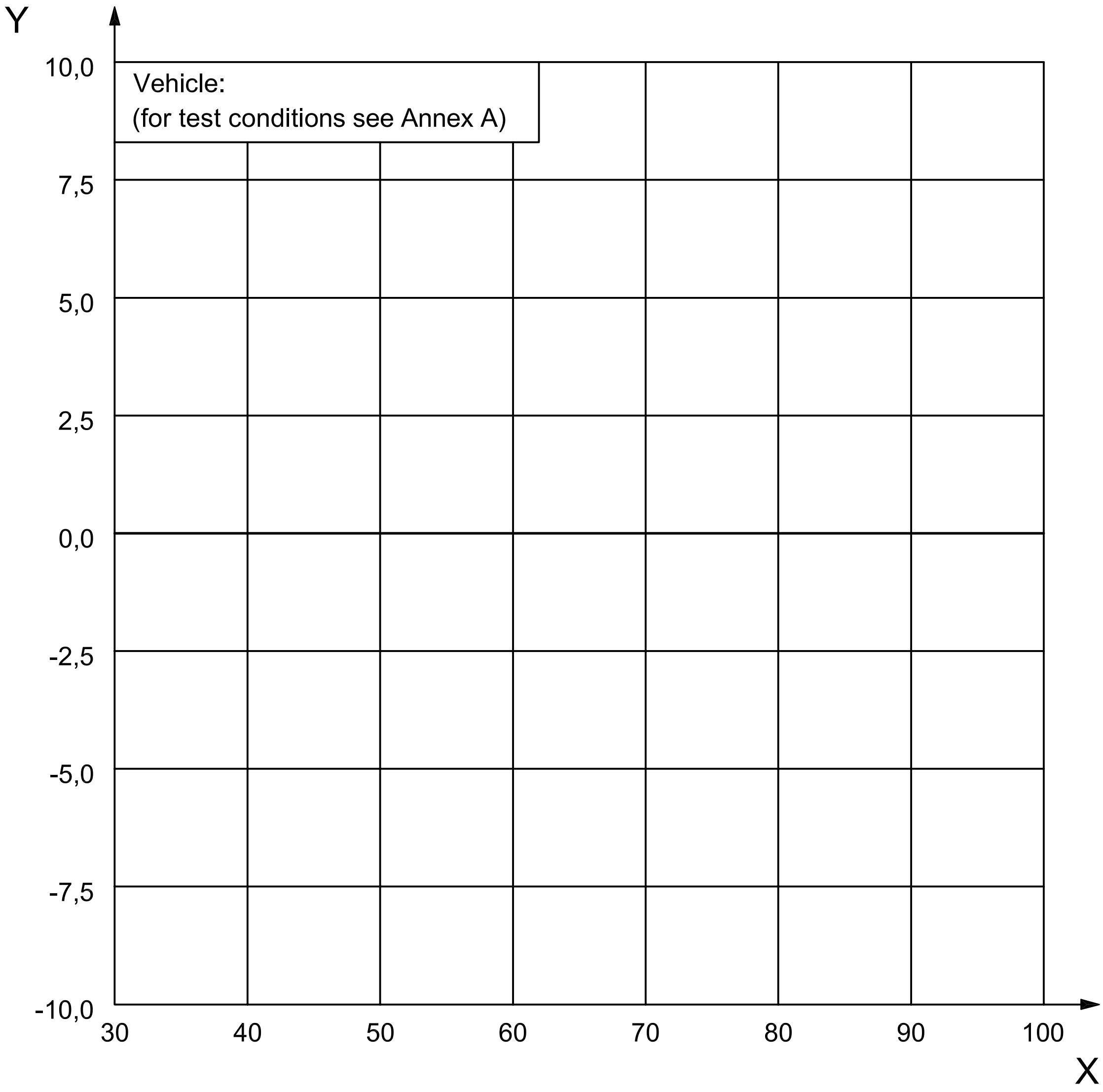


Key

X initial speed $\bar{v}_{x_0}$ (km/h)

Y mean articulation-angle velocity $\dot{\Gamma}_{\mathrm{linear}}$ (°/s²)

Figure B.4 — Mean articulation-angle velocity $\dot{\Gamma}_{\mathrm{linear}}$ during the period of as a function of initial speed $\bar{v}_{x_0}$ (see 9.4.4)



Key

X initial speed $\bar{v}_{x_0}$ (km/h)

Y yaw velocity $\dot{\psi}_{t_0+1s}$ (°/s2)

Figure B.5 — Yaw velocity at t_0 + 1 s $\dot{\psi}_{t_0+1s}$ **as a function of initial speed** $\bar{v}_{x_0}$ **(see 9.4.5)**

Bibliography

[1] ISO 8349:2002, *Road vehicles — Measurement of road surface friction*

[2] ECE Regulation No. 13, *Uniform provisions concerning the approval of vehicles of categories M, N and O with regard to braking*

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