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Passenger car/trailer combinations — Lateral stability test

Ensemble voiture particulière/remorque — Essai de stabilité latérale

Reference number
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Contents

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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.

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 9815 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Sub-Committee SC 9, *Vehicle dynamics and road-holding ability*.

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

Introduction

The dynamic behaviour of a passenger car/trailer combination is a most important part of active vehicle safety. Any given passenger car/trailer combination, together with its driver and the prevailing environment, forms a unique closed loop system. The task of evaluating dynamic behaviour is therefore very difficult because of the significant interaction of these driver/car/trailer-combination/road elements, each of which is in itself complex. A complete and accurate description of the behaviour of passenger car/trailer combinations must necessarily involve information obtained from a number of tests of different types.

Because they quantify only one small part of the whole handling field, the results of this test can only be considered significant for a correspondingly small part of the overall handling behaviour of passenger car/trailer combinations.

In addition, the results obtained from this test will apply only for combinations of the same type of car drawing the same type of trailer under the same loading and operating conditions. The results will not describe the behaviour of either the car or the trailer separately.

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 and test results for regulation purposes.

Passenger car/trailer combinations — Lateral stability test

1 Scope

This International Standard specifies a test procedure to determine the damping characteristic of trailer oscillation excited by a defined steering impulse.

The passenger car/trailer combination is initially driven in a straight line and its response to a specified steering input is then measured. After applying the steering input, the steering-wheel is held fixed in the straight ahead position. Tests are conducted at several constant speeds, which shall be increased in discrete intervals.

Thus it is necessary to measure:

— steering-wheel angle;

— forward velocity;

— lateral acceleration of the trailer;

— articulation angle between towing vehicle and trailer.

It is desirable to measure:

— yaw velocity of the towing vehicle;

— yaw velocity of the trailer.

NOTE 1 These variables are not intended to comprise a complete list.

This International Standard applies to passenger car/trailer combinations, vehicles as defined in ISO 3833.

If non-periodic instability is of interest, a steady-state circular test may be performed in accordance with annex C.

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

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

ISO 4114:—[1], *Road vehicles — Static load on ball couplings of caravans and light trailers.*

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

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

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 8855 and the following definition apply.

3.1 trailer axis system (x, y, z): Right-hand orthogonal axis system fixed in the trailer such that its origin is in the centre of gravity of the empty trailer. The x-axis is in the longitudinal direction, the y-axis in the lateral direction and the z-axis is vertical.

1) To be published. (Revision of ISO/TR 4114:1979)

4 Measuring equipment

4.1 Description

Those of the variables listed in the scope which are selected for test purposes shall be monitored using appropriate transducers, and the data recorded on a multi-channel recorder having a time base. The typical operating range and recommended maximum error of the transducer/recording system are as shown in table 1.

The minimum overall bandwidth of the entire measurement system including transducers and recorder should be 8 Hz.

4.2 Installation

Transducer installation and orientation will vary according to the type of instrumentation used. However, if a transducer does not measure the required variable directly, appropriate corrections for linear and angular displacement shall be made to its signals so as to obtain the required level of accuracy.

4.2.1 Steering-wheel angle

A transducer shall be installed as specified by the manufacturer to obtain steering-wheel angle relative to the sprung mass.

4.2.2 Forward velocity

A velocity transducer shall be installed as specified by the manufacturer. If it is not aligned so as to operate in the x-z plane, and parallel to the test track surface, its output shall be corrected for any linear or angular displacement therefrom.

4.2.3 Lateral acceleration of trailer

An accelerometer shall be installed as specified by the manufacturer and mounted either

a) on the sprung mass at the whole trailer centre of gravity and aligned with the trailer y-axis. In this case, it will measure "lateral acceleration"; or

b) on the sprung mass at any position and aligned parallel to the trailer y-axis. In this case, its output shall be corrected for its position relative to the centre of gravity, which will give "lateral acceleration".

4.2.4 Articulation angle of trailer

A transducer shall be installed as specified by the manufacturer so as to measure the angle between the vehicle x-axis and the trailer x-axis in the horizontal plane.

4.2.5 Yaw velocity

A transducer shall be installed as specified by the manufacturer with its axis aligned with or parallel to the vehicle z-axis.

Table 1 — Variables, operating ranges and recommended maximum errors

Variable	Typical operating range	Recommended maximum error of combined transducer/recorder system
Steering-wheel angle	± 360° 1)	± 2° for angles < 180° ± 4° for angles ⩾ 180°
Forward velocity	0 to 40 m/s	± 0,4 m/s
Lateral acceleration of trailer	± 15 m/s^2	± 0,15 m/s^2
Articulation angle	± 20°	± 0,2°
Yaw velocity of towing vehicle	± 50°/s	± 0,5°/s
Yaw velocity of trailer	± 50°/s	± 0,5°/s
NOTE — These values are tentative and provisional until more experience is available.		
1) Assuming conventional steering system.		

4.2.6 Steering-wheel stop

A steering-wheel stop or marking may be used. The use of a steering machine is optional.

5 Test conditions

5.1 Test track

All tests shall be carried out on a uniform hard surface which is free of contaminants and has no more than 2 % gradient, as measured over the full width of the track laterally and over a distance of at least 50 m longitudinally. For a standard test condition, a smooth dry pavement of asphalt or cement concrete or a high-friction test surface is recommended. The test surface shall be maintained over a track of 8 m minimum width. It is recommended that increased runoff area be provided in addition to the specified test surface.

5.2 Wind velocity

The wind velocity shall not exceed 2,5 m/s and shall be recorded in the test report.

5.3 Tyres

The test may be performed with tyres in any state of wear so long as, at the end of the test, they still have 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 the tyre.

For standard tyre conditions, new tyres shall be used. They shall be run-in for at least 150 km in the appropriate position on the test car without excessive 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 not have been manufactured more than 1 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 ± 0,05 bar[2)] for pressures up to 2,5 bar and ± 2 % for pressures above 2,5 bar.

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.

2) 1 bar = 10^5 Pa = 10^5 N/m^2

5.4 Operating components

All operating components likely to influence the results of this test (for example shock absorbers, springs and suspension parts) shall be inspected to ensure they meet manufacturer's specifications and shall be properly adjusted and secured.

5.5 Loading conditions

5.5.1 Towing vehicle

The total mass of the towing vehicle shall consist of the complete vehicle kerb mass as defined in ISO 1176, plus the combined mass of the driver and the instrumentation which preferably shall not exceed 150 kg. The location of the instrumentation shall be such as to minimize its effect on the yaw moment of inertia of the towing vehicle.

It is recommended that the tests are repeated at a maximum loading condition and/or at other loading conditions of interest. For the maximum loading condition, the total mass of a fully laden vehicle shall consist of the complete vehicle kerb mass, plus 68 kg for each seat in the passenger compartment, the static load at the coupling ball and the remaining maximum luggage mass equally distributed over the luggage compartment according to ISO 2416. Loading of the passenger compartment shall be such that the actual wheel loads are equal to those obtained by loading each seat with 68 kg according to ISO 2416. The mass of instrumentation shall be included in the vehicle mass. Care shall be taken to give minimum error in the moments of inertia as compared to the loading conditions of the vehicle in normal use.

5.5.2 Trailer

The trailer shall be loaded up to its maximum authorized total mass as defined in ISO 1176. If the type of the trailer allows various load distributions, the load shall be distributed in such a way as to produce realistic and representative values of the yaw moment of inertia and the centre of gravity height. For caravans, one-third of the load shall be placed at the foremost and one-third at the rearmost parts of the floor, and one-third approximately in the middle to achieve the desired static load at the coupling ball as specified in 5.5.3.

Optionally, tests may be conducted with any other towed mass of interest.

The mass and the yaw moment of inertia of the trailer as tested shall be measured and noted in the general data (see annex A).

5.5.3 Static load on coupling ball

Tests shall be conducted with the maximum permissible static load on the coupling ball of the towing vehicle or of the trailer, whichever is the lower. Optionally, tests may also be conducted with the minimum permissible static load at the coupling ball (see ISO 4114).

6 Test method

6.1 Warm-up

The test vehicle combination shall be warmed up prior to the test by driving at a suitable speed over a distance of at least 5 km.

6.2 Preliminary tests

6.2.1 Determination of estimated zero damping speed

Preliminary tests or analysis should be conducted to produce an initial estimate of the zero damping speed. This can be done by driving the combination at stepwise-increased speeds and applying a steering input to achieve trailer oscillation. The zero damping speed should be approached cautiously, using moderate steering inputs. The estimated zero damping speed can also be projected based on the results of the first few test runs.

6.2.2 Predetermined test speeds

The tests shall be conducted at predetermined test speeds. The lowest test speed shall be 50 km/h below the estimated zero damping speed, or 40 km/h, whichever is the higher. Additional test speeds shall be performed at increments of not more than 20 % of the difference between the lowest test speed and the estimated zero damping speed.

6.2.3 Magnitude of steering impulse

For each predetermined test speed, the magnitude of steering-wheel angle shall be that which produces a maximum lateral acceleration at the trailer centre of gravity (c.g.) of 4 m/s^2 $\pm$ 1 m/s^2 in response to the steering impulse.

6.3 Test runs

6.3.1 Speed

The test runs shall be made by driving the vehicle/trailer combination at the predetermined test speeds (see 6.2.2) in a steady-state straight ahead condition. The mean deviation of the actual average speed from the predetermined test speed shall be less than 3 km/h. To avoid significant deviations caused by linear extrapolation (see 7.3), the highest test speed shall be at least 90 % of the zero damping speed, which results from the curve fitting. To ensure that this criterion is met, at least three test runs shall be performed at a speed of at least 90 % of the zero damping speed.

For each test run the speed shall be maintained within a tolerance of $\pm$ 2 km/h.

6.3.2 Steering impulse

The trailer oscillation shall be initiated by applying to the towing vehicle a steering impulse of one half a period according to 6.2.3 within 0,5 s. The magnitude of the steering-wheel angle shall be that which produces a maximum lateral acceleration at the trailer centre of gravity (c.g.) of 4 m/s^2 $\pm$ 1 m/s^2 in response to the steering impulse. The steering impulse may be completed by returning the steering-wheel directly to its initial position as in figure 1 a) or by applying a subsequent steering correction in the opposite direction as in figure 1 b) in order that the towing vehicle may reapproach its initial path. After the steering impulse and any subsequent correction, the steering-wheel shall be held fixed in the straight ahead position. The duration $(t_2 - t_1)$ of any steering correction shall not exceed 1,5 s.

The time t_2 is defined as the time after which the steering-wheel angle remains within the limits that are imposed by the tolerance demand (i.e. $\pm\, d_{2,\,\max}$).

Starting from time t_2, the mean deviation, d_1, of the steering-wheel angle from the straight ahead position shall not exceed $\pm$ 10 % of the magnitude of the initial steering impulse. Oscillations (d_2) shall not exceed an additional amount of $\pm$ 5 % of the initial steering impulse.

6.3.3 Number of test runs

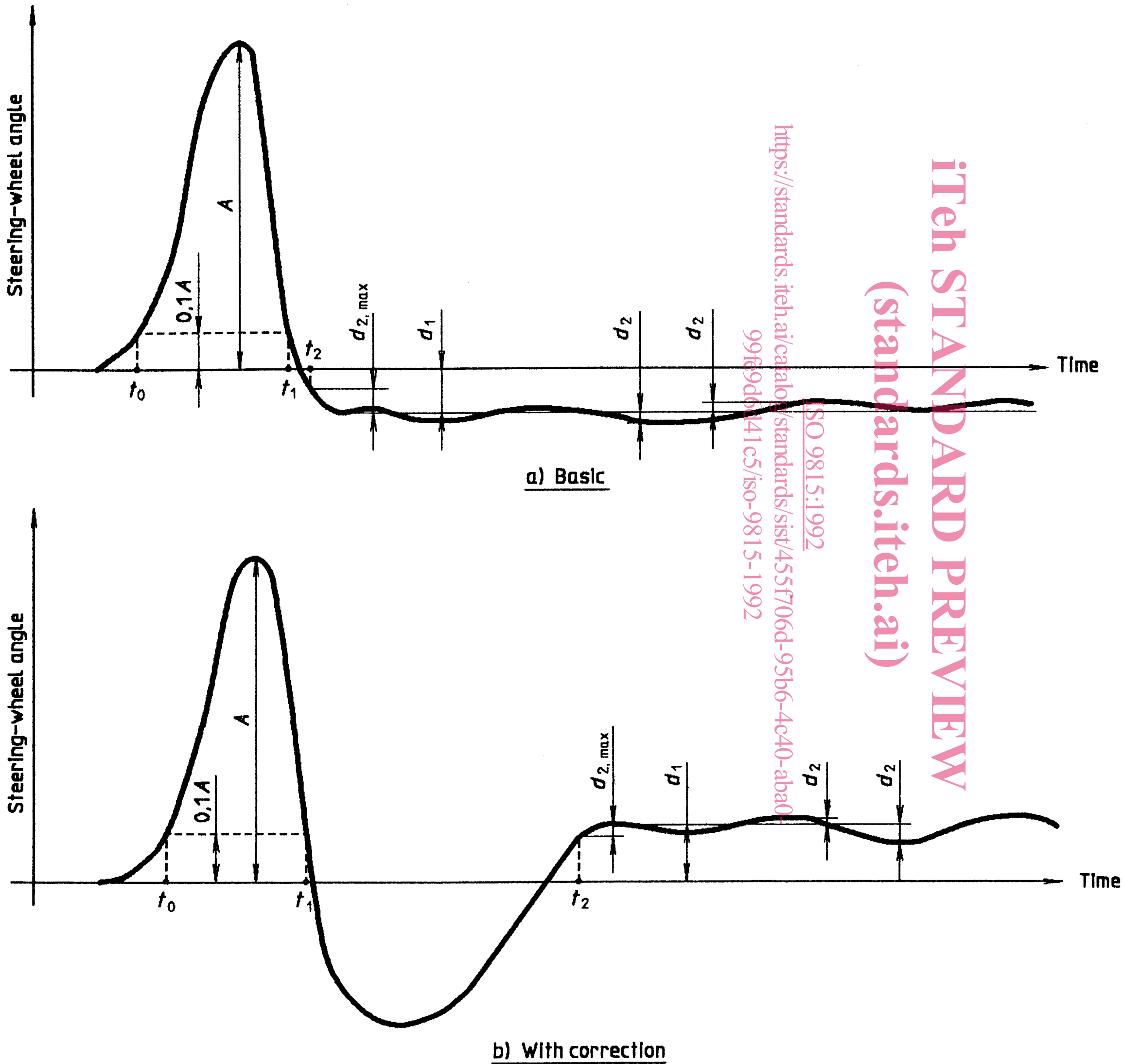
For sufficient repeatability, at least five test runs shall be conducted at each predetermined test speed.

7 Data analysis

7.1 General

Due to the large amount of data, computer analysis is recommended. If data are digitized, a minimum sampling frequency of 50 Hz shall be used.

The recorded time history of articulation angle shall be displayed and examined visually. Results which are considered not to be representative shall be discarded.



$t_1 - t_0 \leqslant 0{,}5$ s $\qquad |d_1|_{\max} = 0{,}1|A|$

$t_2 - t_1 \leqslant 1{,}5$ s $\qquad |d_2|_{\max} = 0{,}05|A|$

Figure 1 — Steering impulses

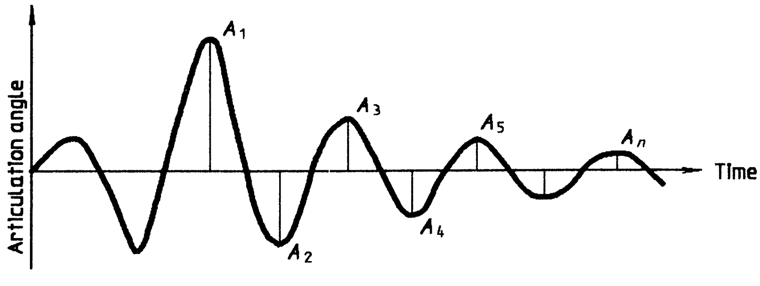


Figure 2 — Determination of amplitudes

7.2 Damping of articulation angle oscillation

From the time history of articulation angle, all amplitudes starting with the third amplitude shall be determined (see figure 2). If the zero crossing preceeding the third amplitude occurs before time t_2 (see 6.3.2), the next amplitude shall be taken as A_1.

The mean value of the amplitude ratios, r, shall be calculated using the following formula:

$$r = \frac{1}{n-2}\left(\frac{A_1 + A_2}{A_2 + A_3} + \frac{A_2 + A_3}{A_3 + A_4} + \frac{A_3 + A_4}{A_4 + A_5} + \dots + \frac{A_{n-2} + A_{n-1}}{A_{n-1} + A_n}\right)$$

$A_{n-1} + A_n$ shall be at least 10 % of $A_1 + A_2$.

The calculation of r shall be based upon at least seven amplitudes, unless the 10 % limit is reached before the seventh amplitude.

The damping, D, is calculated according to:

$$D = \frac{\ln r}{\sqrt{\pi^2 + (\ln r)^2}}$$

7.3 Zero damping speed v_{zd}

The zero damping speed is defined as the speed at which the damping equals zero. It shall be determined from the plotted values of damping versus test speed by linear curve fitting, through the following regression:

$$D = C_1 + C_2 v_{zd} = 0$$

$$v_{zd} = -\frac{C_1}{C_2}$$

where C_1 and C_2 are the regression coefficients.

At least three test runs shall have been performed at a speed of at least 90 % of the zero damping speed which resulted from the curve fitting (see 6.3.1). If this requirement is not met or if for safety reasons driving at 90 % of the zero damping speed is not feasible, the criterion "zero damping speed" shall not be used in the presentation of results (see annex B).

7.4 Reference damping speed

Reference damping speed is defined as the speed at a damping level of 0,05. It shall be determined in the same way as the zero damping speed (see 7.3) using the following formula:

$$v_{0,05} = \frac{0,05 - C_1}{C_2}$$

where C_2 is expressed in hours per kilometre.

7.5 Reference speed damping

Reference speed damping is defined as the damping at the speed of 80 km/h. It shall be determined according to 7.3 using the following formula:

$$D_{80} = C_1 + 80C_2$$

where C_2 is expressed in hours per kilometre.

7.6 Yaw velocity ratio

When the yaw velocity of the towing vehicle and of the trailer are measured, calculate the yaw velocity ratio according to the following formula:

$$R_{\dot\psi} = \frac{1}{n-1}\left(\frac{\dot\psi_{c,1} + \dot\psi_{c,2}}{\dot\psi_{t,1} + \dot\psi_{t,2}} + \frac{\dot\psi_{c,2} + \dot\psi_{c,3}}{\dot\psi_{t,2} + \dot\psi_{t,3}} + \frac{\dot\psi_{c,3} + \dot\psi_{c,4}}{\dot\psi_{t,3} + \dot\psi_{t,4}} + \dots + \frac{\dot\psi_{c,n-1} + \dot\psi_{c,n}}{\dot\psi_{t,n-1} + \dot\psi_{t,n}}\right)$$

where

$\dot\psi_c$ is the yaw velocity of the towing vehicle;

$\dot\psi_t$ is the yaw velocity of the towed vehicle.

NOTE 3 For determination of amplitudes see 7.2 and figure 3.

8 Data presentation

General data shall be presented on the summary form as shown in annex A.

The damping of the articulation angle as determined in 7.2 shall be plotted as a function of driving speed as shown in annex B. No test results shall be presented or published without reference to the relevant test conditions.

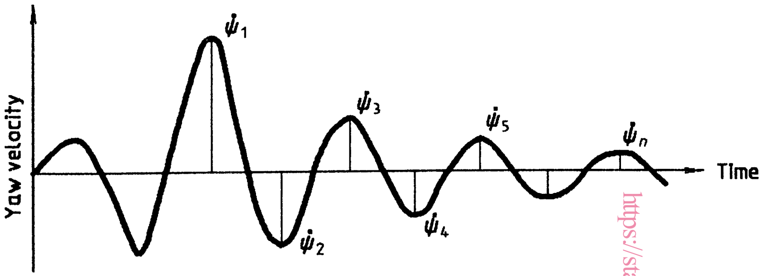


Figure 3 — Determination of amplitudes