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# Road vehicles — Heavy commercial vehicle combinations and articulated buses — Lateral stability test methods

*Véhicules routiers — Ensembles de véhicules utilitaires lourds et autobus articulés — Méthodes d'essai de stabilité latérale*



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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 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 14791 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

Annexes A and B form a normative part of this International Standard. Annexes C and D are for information only.



 

## Introduction

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

Because they quantify only a small part of the whole vehicle handling field, the results of the tests specified in this International Standard can only be considered significant for a correspondingly small part of the overall handling behaviour of heavy commercial vehicle combinations and articulated buses.

In addition, the results obtained from these tests apply only for combinations of identical types of vehicle units. The results will not describe the behaviour of the vehicle units separately.

Moreover, insufficient knowledge is available concerning the relationship between overall vehicle dynamic properties and accident avoidance. Since the number of variants of heavy truck combinations is tremendously large, each truck combination is unique. So the measured result is valid only for the tested vehicle or combination and the transition of the results to obviously similar vehicle combinations is, especially for heavy trucks, not possible. Therefore, it is not possible to use these test methods and the test results for regulation purposes.

# Road vehicles — Heavy commercial vehicle combinations and articulated buses — Lateral stability test methods

## 1 Scope

This International Standard specifies test methods to determine the lateral stability of heavy commercial vehicle combinations as defined in ISO 3833, including truck centre-axle trailer combinations and articulated buses. It is applicable to trucks and trailers having a mass exceeding 3,5 t and buses having a mass exceeding 5 t, i.e. vehicle categories N2, N3, O3, O4 and M3 according to 92/53/EEC.

The manœuvres specified in these test methods are not fully representative of real driving conditions, but are useful for determining the lateral stability of a heavy vehicle combination.

## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC 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 8855:1991, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*.

ISO 9815:1992, *Passenger-car/trailer combinations — Lateral stability test*.

EC Council Directive No. 92/53/EEC. Annex II, *Definition of vehicle categories and vehicle types*.

## 3 Terms and definitions

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

**3.1**
**vehicle unit**
rigid (i.e. non-articulating) vehicle element operating alone or in combination with one or more other rigid elements joined at yaw-articulation joints

EXAMPLES Tractor, semitrailer and dolly.

**3.2**
**rearward amplification**
ratio of the maximum value of the motion variable of interest of a following vehicle unit to that of the first vehicle unit during a specified manœuvre

**3.3**
**offtracking**
lateral deviation between the path of the centreline point of the front axle of the vehicle and the path of the centreline point of some other part of the vehicle

NOTE 1 See 8.3 for determination of offtracking.

NOTE 2 In a single-lane-change manœuvre where the path of the other part of the vehicle is farther from the projection of the original path of the vehicle than is the path of the front axle, the path of the other part is said to “overshoot” the path of the front axle at that point. If the opposite is true, the path of the other part is said to “undershoot” the path of the front axle.

**3.4**
**zero-damping speed**
speed at which the damping coefficient of the free oscillatory yaw movements of the vehicle combination equals zero

**3.5**
**reference-damping speed**
speed at which the damping coefficient of the free oscillatory yaw movements of the vehicle combination equals 0,05

**3.6**
**centreline point**
point at the intersection of the ground plane and the $x$-$z$ plane of symmetry of the part of interest, which point lies directly below a longitudinal reference position

NOTE For an axle, the longitudinal reference point is the wheel-spin axis. For other parts, the longitudinal reference point should be stated.



**3.7**
**yaw-articulation angle**
yaw angle of the $x$-axis of the intermediate axis system of a more forward vehicle unit in the intermediate axis system of a following vehicle unit, i.e. the angle between the $x$-axes of the two units with polarity determined by the rotation of the leading unit in the axis system of the following unit

NOTE The units involved are usually adjacent, but not necessarily so.

## 4 Test objectives

The primary objective of these tests is to determine the lateral stability of heavy commercial vehicle combinations and articulated buses.

The lateral stability is characterized by:

— rearward amplification of lateral acceleration and yaw velocity;

— dynamic offtracking;

— zero-damping speed;

— yaw damping, including mode-shape information.

Of these four performance measures, two, rearward amplification and dynamic offtracking, relate to forced response properties and the other two, zero-damping speed and yaw damping, relate to free response properties.

 

For a complete set of measurements, it is necessary to determine:

— steering-wheel angle;

— longitudinal velocity;

— yaw velocity of the first and the last vehicle units;

— lateral acceleration of the front axle of the first vehicle unit at or below the height of the wheel centre, and lateral acceleration of the centre of gravity of the last vehicle unit;

— articulation angles or articulation angular velocity between the vehicle units;

— offtracking of the most severely offtracking axle of the vehicle combination.

In order to acquire a deeper understanding of the behaviour of the vehicle combination, it is desirable to determine:

— lateral acceleration in the centre of gravity of each vehicle unit;

— yaw velocity of each vehicle unit;

— the roll angle of each vehicle unit, preferably above the rearmost axle;

— lateral velocity or slip angle of the rearmost axle of each vehicle unit;

— dynamic wheel loads of each vehicle unit;

— lateral motion of each axle in the combination;

— offtracking of the most severely offtracking point, other than an axle, of the vehicle combination.



The following test methods can be used to determine the various characteristics of the lateral stability:

— pseudo-random input;

— single lane-change;

— pulse input.

Pseudo-random input can be used to determine the maximum rearward amplification. It provides complete information about the frequency dependency of the rearward amplification.

With a single lane-change, rearward amplification and dynamic offtracking can be determined for a specific, realistic manœuvre. The single lane change may be carried out by applying either a single sine-wave steering input or by following a path producing a single sine-wave lateral acceleration input.

NOTE Rearward amplification measurements obtained using pseudo-random input and single lane-change will differ. The two test methods have a fundamental difference. The pseudo-random input method is intended to yield a full representation of the system gain in the frequency domain. The single-lane-change method, however, provides only the composite gain of the system as results from the distributed frequency content of the specific lane-change performed in the test.

Also, the measurements obtained from the two lane-change methods should be expected to differ, because the frequency content of the steering input will be different in the two cases. With the single sine-wave steering method, the steer input is defined, while for the path-following method the lateral acceleration is defined. In the first method, lateral acceleration depends on the dynamics of the vehicle combination and the properties of the steering system, e.g. lash and compliance. In the second method, steering depends on the same influences. This yields a different composite gain of the system as measured by the two methods.

The pulse input is used for determining zero-damping speed, yaw damping and yaw-velocity ratio.

The analyses for the pseudo-random method are made in the frequency domain. All other analyses are made in the time domain.

The methods chosen shall be indicated in the general data presentation (see annex A) and in the presentation of the test results (see annex B).

## 5 Measuring equipment

### 5.1 Description

Those of the variables listed in clause 4 which are selected for test purposes shall be monitored using appropriate transducers, and the data shall be recorded on a multichannel recorder with a time base. The typical operating ranges and recommended maximum errors of the transducer/recorder system are given in Table 1.

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

| Variable | Typical operating range | Recommended maximum error of combined system |
|---|---|---|
| Steering-wheel angle | ± 180° | ± 2° |
| Longitudinal velocity | 0 to 35 m/s | ± 0,3 m/s |
| Lateral acceleration | ± 15 m/s$^2$ | ± 0,15 m/s$^2$ |
| Articulation angles between vehicle units | ± 30° | ± 0,3° |
| Articulation angular velocity | ± 50°/s | ± 0,5°/s |
| Yaw velocity | ± 50°/s | ± 0,5°/s |
| Lateral displacement of vehicle axle centre-line points relative to the path of the front axle centreline point | ± 10 m | ± 0,05 m |
| Wheel loads | 0 to rated axle load | ± 2 % of full scale |
| Roll angle | ± 15° | ± 0,2° |
| Lateral velocity | ± 10 m/s | ± 0,2 m/s |
| Slip angle | ± 10° | ± 0,5° |



Some of the transducers listed are neither widely available nor in general use. Many such instruments are developed by users. If any system error exceeds the maximum values recommended, this fact and the actual system error shall be stated in the general data.

### 5.2 Transducer installation

The required variables may be measured directly or indirectly. 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.

Transducers for measuring lateral acceleration shall be installed on the sprung mass.

Optionally, the transducer for measuring the lateral acceleration of the front axle of the first vehicle unit may be mounted on the front axle if this is a solid axle. In this case, the transducer shall be mounted at or below the height of the wheel centre, and the signal from this transducer need not be corrected for errors associated with roll.

 

## 5.3 Data processing

### 5.3.1 General

The frequency range relevant to these tests is between zero and the maximum utilized frequency, $f_{max} = 2$ Hz. According to the chosen data-processing method, i.e. analog or digital processing, the following stipulations shall be observed.

### 5.3.2 Analog data processing

The bandwidth of the entire combined transducer/recorder system shall be not less than 8 Hz.

In order to execute the necessary filtering of signals, low pass filters with order 4 or higher are required. The width of the passband (– 3 dB at frequency $f_0$) shall be not less than 8 Hz. Amplitude errors less than ± 0,5 % have to be attained in the relevant frequency range of 0 to 2 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 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 mentioned in 5.3.2 is preferable.

### 5.3.3 Digital data processing

#### 5.3.3.1 Preparation of analog signals



In order to avoid aliasing, the analog signals shall be filtered before digitizing. In this case low pass filters with order 4 or higher shall be employed. The width of the passband (– 3 dB at frequency $f_0$) shall be $f_0 > 5\, f_{max}$.



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 phase characteristics sufficiently similar to ensure that time delay differences lie within the required accuracy for time measurement.

Additional filters shall be avoided in the data acquisition system.

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

#### 5.3.3.2 Digitizing

The sampling rate, $f_s$, shall be such that the attenuation of the anti-aliasing filter at all frequencies greater than $f_s - f_{max}$ is at least 60 dB.

In order not to exceed an amplitude error of 0,5 % in the relevant frequency range from zero to $f_{max}$, the sampling rate, $f_s$, shall be at least $30\, f_{max}$.

#### 5.3.3.3 Digital filtering

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

— the passband shall range from 0 to 2 Hz;

— the stopband shall begin at < 6 Hz;

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

— the filter gain in the stopband shall be < 0,01 (< 1 %);

— the filter gain between the passband and the stopband shall drop as fast as feasible.

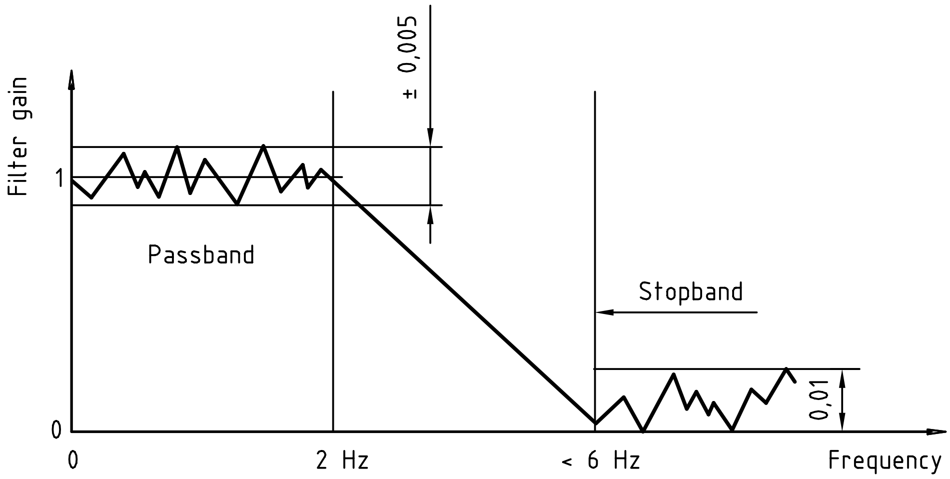


**Figure 1 — Digital filter characteristics**

## 6 Test conditions

### 6.1 Test tracks

All tests shall be carried out on a uniform hard surface which is free from contaminants and has not more than 2 % gradient as measured over any distance of 5 m or more in any direction and not more than 1 % gradient as measured over any distance of 25 m or more along the path of the vehicle. For standard test conditions, a smooth dry pavement of asphalt or cement concrete or a high-friction test surface is recommended.



The ambient wind speed shall not exceed 5 m/s. Wind velocity and direction shall be reported.

The test surface should be maintained over a minimum of 8 m track width. For the pseudo-random-input test, a track length sufficient to permit at least 30 s running at the test speed, in addition to the run-up and stopping requirements should be provided.

Yaw damping of vehicle combinations is known to be sensitive to the longitudinal slope of the test surface. Where this slope approaches the maximum allowable value (1 %), it is recommended that the test be conducted in both directions. Results should be averaged as described in 8.4.2.

### 6.2 Tyres

For standard test conditions, the tyres on the vehicle shall have been run in for at least 200 km, and they shall have a tread depth of at least 90 % of the original value over the whole tread width and circumference of the tyres. The tyres shall have been stored according to the tyre manufacturer's recommendation and shall not have been manufactured more than two years before the test. The date of manufacture of all tyres shall be reported.

The tread depth of any tyre shall not decrease more than 2 mm during the test. Tread depth and wear shall be reported.

Tyres shall be inflated to pressures as specified by the vehicle manufacturer for the test vehicle configuration at the ambient temperature. The tolerance for the cold-inflation pressure is ± 2 %.

Because tread depth may have a significant influence on test results, it is recommended that tread depth be taken into account when comparing vehicles or tyres.