INTERNATIONAL STANDARD

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Road vehicles — Sensitivity to lateral wind — Open-loop test method using wind generator input

Véhicules routiers — Sensibilité au vent latéral — Méthode en boucle ouverte avec génération de vent

Reference number
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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 12021 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

This first edition of ISO 12021 cancels and replaces ISO 12021-1:1996, which has been technically revised.

Introduction

The main purpose of this International Standard is to provide repeatable and discriminatory test results.

The dynamic behaviour of a road vehicle is a very important aspect of active vehicle safety. Any given vehicle, together with its driver and the prevailing environment, constitutes a closed-loop system that is unique. The task of evaluating the dynamic behaviour is therefore very difficult since the significant interaction of these driver-vehicle-environment elements are each complex in themselves. A complete and accurate description of the behaviour of the road vehicle must necessarily involve information obtained from a number of different tests.

Since this test method quantifies only one small part of the complete vehicle handling characteristics, the results of these tests 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 substantial 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 these tests in particular. Consequently, any application of this test method for regulation purposes will require proven correlation between test results and accident statistics.

Road vehicles — Sensitivity to lateral wind — Open-loop test method using wind generator input

1 Scope

This International Standard specifies an open-loop test method to determine the sensitivity to lateral wind of a vehicle by means of a wind generator. It applies to passenger cars as defined in ISO 3833, passenger car-trailer combinations and light trucks. Its applicability to motorcycles is yet to be investigated.

The test conditions specified in this test method are not representative of real driving conditions but are useful to obtain measures of vehicle dynamic response to lateral wind.

NOTE The test conditions in this test method do not simulate natural wind conditions. However, the wind velocity proposed here is representative of fairly severe wind conditions occurring naturally.

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 1176:1990, *Road vehicles — Masses — Vocabulary and codes*

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

ISO 15037-1:2006, *Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8855 apply.

4 Principle

The purpose of this test method is to determine vehicle sensitivity to lateral wind by which the vehicle motion is disturbed. This method requires the measurement of vehicle behaviour under a lateral wind condition. The vehicle behaviour can be characterized by several measures.

In this test method the vehicle is initially driven along a straight path and its response to a crosswind input of a wind generator is then measured. The steering-wheel is held fixed during most of the test.

Two methods for finding the lateral deviation are proposed:

— a direct method by means of direct measurement or with a dye-trail left on the road surface, and

— an indirect method by means of a computation from on-board-measured vehicle motions.

5 Reference system

The reference system specified in ISO 15037-1 shall apply.

6 Variables

The following variables corresponding to the terms and definitions of ISO 8855 shall be measured:

a) yaw velocity, $\dot{\psi}$;

b) lateral acceleration, a_Y;

c) steering-wheel angle, δ_H;

d) longitudinal velocity, v_X.

Measuring the following additional variables is optional:

— lateral deviation, γ;

— roll angle, φ;

— sideslip angle, β;

— lateral velocity, v_Y.

The variables listed in this clause are not intended to comprise a complete list.

7 Measuring equipment

7.1 Description

The variables selected from the list in Clause 6 shall be measured by means of appropriate transducers. Their time histories shall be recorded on a multi-channel recorder having a time base. This is not obligatory for lateral deviation, which can be measured directly after the test has been completed.

The typical operating ranges of the variables and recommended maximum errors of the combined transducers and the recording system are shown in Table 1.

Table 1 — Typical operating ranges of the variables and recommended maximum errors of transducers and recording system

Variable	Range of variable	Recommended maximum error of the combined transducers and recording system
Yaw velocity	−10°/s to +10°/s	±0,1°/s
Lateral acceleration	−5 m/s^2 to +5 m/s^2	±0,05 m/s^2
Steering-wheel angle	−30° to +30°[a]	±1°, but resolution < 0,3°
Longitudinal velocity	0 m/s to 40 m/s	±0,4 m/s
Lateral deviation	5 m	±0,02 m
Roll angle	−10° to +10°	±0,1°
Sideslip angle	−5° to +5°	±0,2°
Lateral velocity	−10 m/s to +10 m/s	±0,2 m/s

NOTE Transducers for some of the listed variables are not widely available and are not in general use. Many such instruments are developed by users. If any system error exceeds the recommended maximum value, this and the actual maximum error shall be stated in the test report (see Annex A).

[a] Assuming a conventional steering system.

7.2 Transducer installation

7.2.1 General

Subclause 4.2 of ISO 15037-1:2006 shall apply.

7.2.2 Lateral deviation

The lateral deviation may be measured either by direct measurement using appropriate instrumentation or by means of a dye-trail, or by means of a computational method (see 11.3.3). The dye-trail shall be made on the test track by means of a water jet. The water outlet should be 0,02 m above the track surface. An elastic tube may be used to extend this outlet.

The water jet should be positioned as close as possible to the z-axis of the intermediate axis system. If this is not the case, a correction can be applied to achieve values within the tolerance for lateral acceleration.

7.3 Data processing

The recording system and data processing requirements contained in 4.3 of ISO 15037-1:2006 shall apply.

8 Test conditions

8.1 General

The test conditions specified in 5.1 of ISO 15037-1:2006 and the conditions of 8.2 and 8.3 in this International Standard shall apply. Any deviations shall be specified in the test report (see Annex A), including individual diagrams for the presentation of results (see Annex B).

8.2 Test track

All tests shall be carried out on a uniform hard road surface which is free of contaminants. The gradient, as measured over the full width of the track in the lateral direction and over a distance of at least 50 m in the longitudinal direction, shall be $<2{,}5$ %.

It is recommended that the track have either a smooth surface (asphalt or concrete) or a high-friction surface.

The test surface shall be at least 5 m wide, from at least 100 m before to 100 m after the wind zone. The width of the track after the wind zone shall be at least 7 m.

Increased run-off area should be provided in addition to the specified test surface.

8.3 Weather conditions

During the time frame of the experiment, ambient wind velocity should be as low as possible, and shall not exceed 3 m/s regardless of the wind direction. The standard test condition of a dry road surface should be used. However, a wet road with no measurable water depth may be used.

Weather conditions shall be recorded in the test report (see Annex A).

8.4 Test vehicle

The provisions of 5.4 of ISO 15037-1:2006 shall apply.

8.5 Vehicle loading conditions

8.5.1 General

Tests shall be carried out at the minimum loading condition and at the maximum loading condition defined below. Tests may be carried out at other loading conditions of interest.

The maximum authorized total mass (Code: ISO-M08) and the maximum authorized axle load (Code: ISO-M13), both defined by ISO 1176:1990, 4.8 and 4.13, 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 (see Annex A).

8.5.2 Minimum loading condition

For the minimum loading condition, the total vehicle mass shall consist of the complete vehicle kerb mass (Code: ISO-M06) plus the masses of the driver and the instrumentation. The complete vehicle kerb mass is defined by ISO 1176:1990, 4.6. The mass of the driver and the instrumentation should not exceed 150 kg.

8.5.3 Maximum loading condition

For the maximum loading condition, the total mass shall be equal to the maximum authorized total mass (Code: ISO-M08).

9 Wind generators

Lateral wind shall be generated by wind generators which produce an average wind velocity of 20 m/s ± 3 m/s (for an ambient wind condition of <1 m/s). The average shall be calculated over the length of the wind zone on the datum course line (see Figure 1) and over the height of the test vehicle. As a further specification of the wind input, the nominal wind angle relative to the datum course line and graphs of the wind velocity profiles over the length and over the height of the wind zone shall be presented in the test report (see Annex A). The nominal length of the wind zone, usually composed of a series of wind generators, shall not be less than 15 m and should preferably be more than 25 m. The nominal length of the wind zone shall be noted in the test report (see Annex A).

10 Test procedure

10.1 Warm-up

The provisions of 6.1 of ISO 15037-1:2006 shall apply.

10.2 Test speed

The test speed is defined as the nominal value of the longitudinal velocity. The standard test speed is

— 100 km/h.

Other test speeds of interest may be used (preferably in 20 km/h steps).

For each test run, the longitudinal velocity shall be within a tolerance of ±2 km/h before the start of the wind zone x_0. After that point the accelerator pedal shall be held fixed.

10.3 Steering

Test runs shall be made by driving the vehicle at the test speed along a straight path, the datum course line. When approaching the wind zone, steering corrections are permitted to enable the vehicle to maintain the datum course line, but the steering-wheel shall be held fixed from 40 m before the start of the wind zone (see Figure 1) to at least a distance corresponding to 2 s of travel at the test speed after the start of the wind zone (x_d).

The maximum deviation of the steering-wheel angle from its average value shall be less than 2°, until the vehicle has passed point x_d.

As the quality of the test run can be improved by making use of subsidiary equipment to fix the steering-wheel, such equipment should be used.

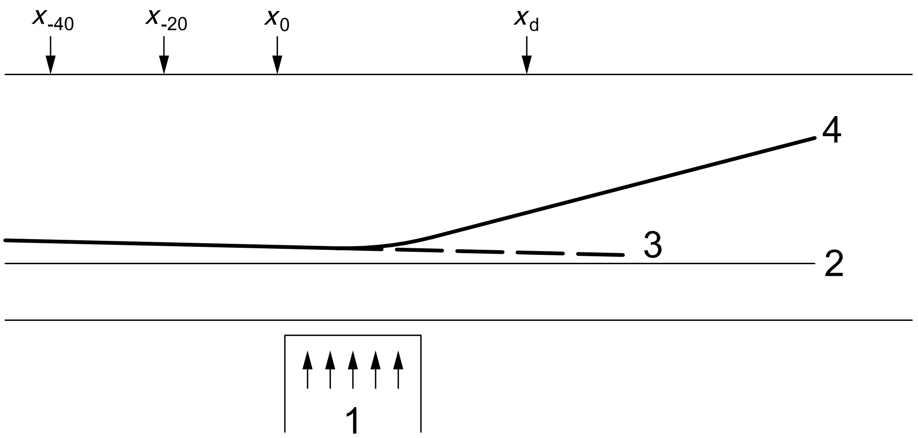
10.4 Number of test runs

A minimum of five test runs shall be carried out.

10.5 Measuring points of lateral position using the dye-trail method

If the lateral deviation, i.e. the lateral position shift due to lateral wind (see 11.3.2), is measured by means of the dye-trail method, four points of the lateral position shall be measured (see Figure 1): 40 m, 20 m, and 0 m before the start of the wind zone (x_0), and at a distance corresponding to 2 s of travel at the test speed after the start of the wind zone (x_d). Intermediate points may be measured if desired.

NOTE The lateral position can be measured through the dye-trail on the road surface.



Key

1 wind generators

2 datum course line

3 reference line

4 trajectory

x_{-40} is the measuring point 40 m before the start of the wind zone

x_{-20} is the measuring point 20 m before the start of the wind zone

x_0 is the start of the wind zone, defined as the intersection of the leading edge of the wind generator and the datum line

x_d is the distance corresponding to 2 s of travel at the test speed after the start of the wind zone

Figure 1 — Test track layout — Measuring points

10.6 Data excluded from the computation method

To minimize the initial condition error in the computation method, results of test runs that have a lateral position shift greater than 0,2 m[1)] between the points of 40 m and 0 m before the start of the wind zone shall be excluded.

NOTE At present, the on-board type of transducer for measuring vehicle position is neither widely available nor in general use; therefore, it may be decided by the observer whether or not each test run might be within the permissible range.

11 Data analysis

11.1 General

The results shall be presented either as peak values or as pulse values (see Figure 2). If peak values are to be used, consideration shall be given to the bandwidth of the measurement system. A small bandwidth is recommended.

1) In the computational method the initial condition greatly affects the final result. A lateral position shift of 0,2 m between the points of 40 m and 0 m before the start of the wind zone is a permissible error.

11.2 Yaw velocity and lateral acceleration

The yaw velocity and the lateral acceleration shall be presented as specified in Annex B.

If required, the pulse values of the yaw velocity and lateral acceleration shall be calculated as follows. This pulse value is defined as the average signal level during the time that the signal exceeds 50 % of the peak value (see Figure 2).

First define the time of the maximum output, t_{peak}, and the initial peak value using the signal zero (see Figure 2) as the initial reference value. Time t_0 shall initially be defined as the time when the signal becomes smaller than 0,15 times the peak value, looking back in time. Since the steering-wheel shall be held fixed from 40 m before the start of the wind zone (see 10.3), the reference value of the output signal shall be calculated as the mean from 0,2 s after that point (t_{-40}) to 0,2 s before t_0. Note that t_{-40} depends on the longitudinal velocity; it may, however, be calculated using the test speed.

Using this reference value the following are calculated iteratively:

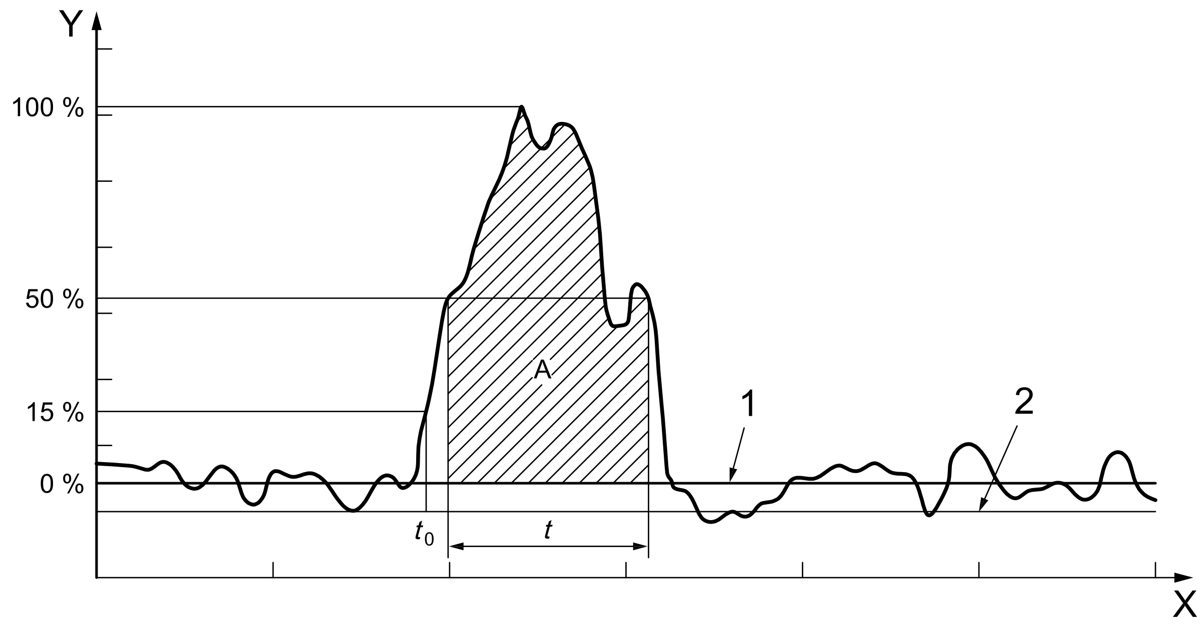
— the peak value;

— t_0;

— a new reference value;

until the difference between two successive reference values becomes smaller that 0,5 % of the peak value. The final peak value and the pulse value shall be calculated using the final reference value.

If optional quantities are measured, the peak or the pulse values of those signals shall be calculated also.



Key

1 reference value

2 signal zero

X time (s)

Y response variable

$$\frac{\text{Area } A}{\text{Time } t} = \text{Pulse value}$$

Figure 2 — Definition of pulse value (a response variable)

11.3 Lateral deviation

11.3.1 General

The lateral deviation may be determined by either the direct measurement of the dye-trail or the computation method.

11.3.2 Dye-trail method

The lateral deviation in the dye-trail method is obtained from the dye trace left on the road surface. It is characterized by the lateral deviation at the point x_d, corresponding to 2 s after the start of the wind zone. This lateral deviation shall be obtained as the perpendicular difference between the dye-trail and the reference line, defined below.

The reference line shall be the regression line calculated using the three measuring points before and including the start of the wind zone.

11.3.3 Computation method

From the recorded data of lateral acceleration, yaw velocity and longitudinal velocity, the lateral deviation at 2 s after the start of the wind zone can be obtained using the following equations:

$$\psi = \int \dot{\psi} \mathrm{d}t$$

$$\beta = \int \left(\frac{a_Y}{v_X} - \dot{\psi} \right) \mathrm{d}t$$

$$\gamma = \int \left[v_X \sin(\psi + \beta) \right] \mathrm{d}t = \int \left[v_X (\psi + \beta) \right] \mathrm{d}t$$

where

$\dot{\psi}$ is the yaw velocity;

a_Y is the lateral acceleration;

ψ is the yaw angle;

β is the sideslip angle;

v_X is the longitudinal velocity;

γ is the lateral deviation.

In the computation method, the reference line is assumed to be nominally a straight line along the centreline of the road. Alternatively, a dye-trail should be used to obtain a reference line as defined in 11.3.2.

12 Data presentation

General data shall be presented in the test report described in Annex A.

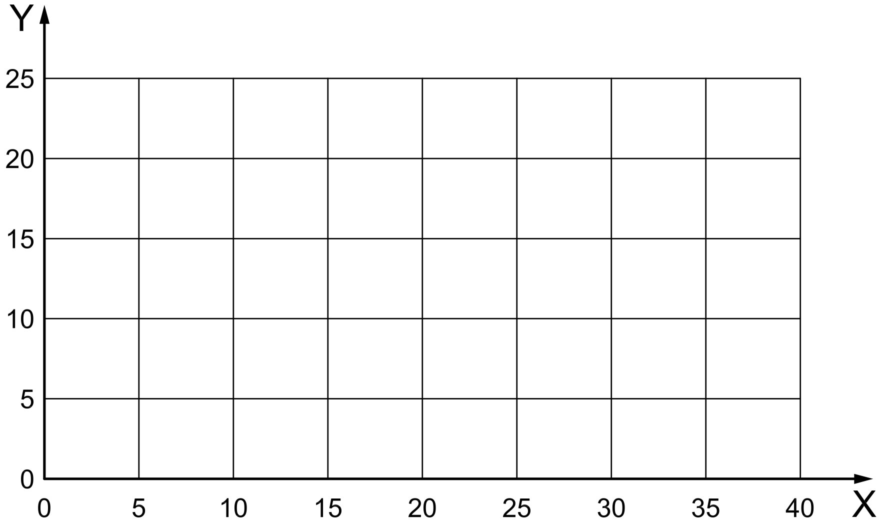
Time histories of all variables listed in Clause 6 for each trial shall be plotted as shown in Annex B, Figure B.1.

If tests are carried out for several test speeds, characteristics shall be plotted as in Annex B, Figure B.2.

Annex A
(informative)

Test report — General data

Vehicle identification:	Make, year, model, type:	....		
	Vehicle identification number:	....		
	Steering type:	....		
	Suspension type - Front:	....		
	- Rear:	....		
	Engine size, optional equipment:	.... cm³		
	Tyres: make, size, condition:	....		
	Tyre pressure	**Front**	**Rear**	
	- Cold:	.... kPa	.... kPa	
	- Hot, after warm-up (if measured)	.... kPa	.... kPa	
	- Hot, after test (if measured)	.... kPa	.... kPa	
	Rims:	....		
	Wheelbase:	....		
	Track - Front:	....		
	- Rear:	....		
	Projected frontal area:			
	Other data (in particular, relevant suspension settings)	....		
		....		
		....		
		....		
Vehicle loading:		**Left**	**Right**	**Sum**
	Vehicle kerb mass:	Front: .... kg	Front: .... kg	.... kg
		Rear: .... kg	Rear: .... kg	.... kg
				Total: .... kg
	Loading condition and location:	....		
	Vehicle mass as tested:	Front: .... kg	Front: .... kg	.... kg
		Rear: .... kg	Rear: .... kg	.... kg
				Total: .... kg
Test conditions:	Test speed:	.... km/h		
	Nominal length of the wind zone:	.... m		
	Nominal wind velocity:	.... m/s		
	Nominal wind angle relative to the datum course line:	.... °		

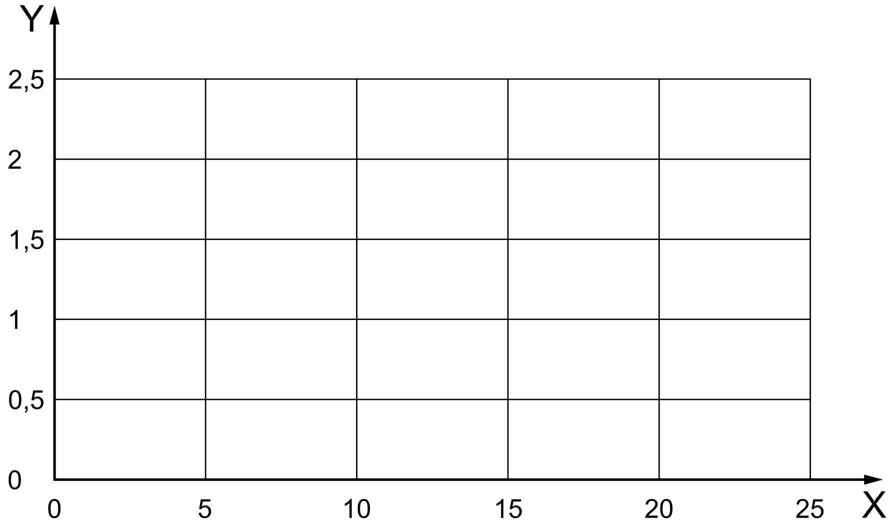


Key

X distance (m)

Y wind velocity (m/s)

Figure A.1 — Graph of wind velocity profile over the length of the wind zone



Key

X wind velocity (m/s)

Y height above test track (m)

Figure A.2 — Graph of wind velocity profile over the height of the wind zone

Other data

Weather conditions

- Temperature: .... °C
- Wind velocity: .... m/s

Test personnel

- Driver: ....
- Observer: ....
- Data analyst: ....

General comments ....

....

....

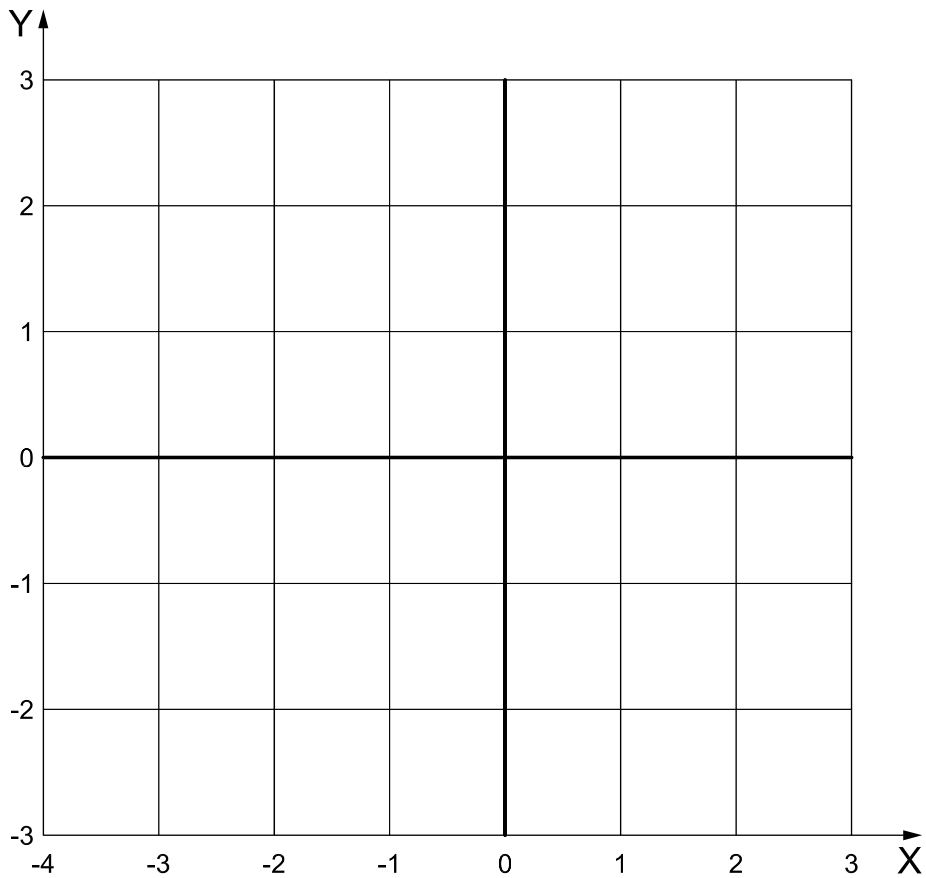
....

....

Annex B
(normative)

Test report — Presentation of results

Vehicle:	....	
Test speed:	....	km/h
Nominal length of wind zone:	....	m
Nominal wind velocity:	....	m/s
Nominal wind angle relative to datum course line:	....	°



Key

X time (s)

Y lateral deviation (m)

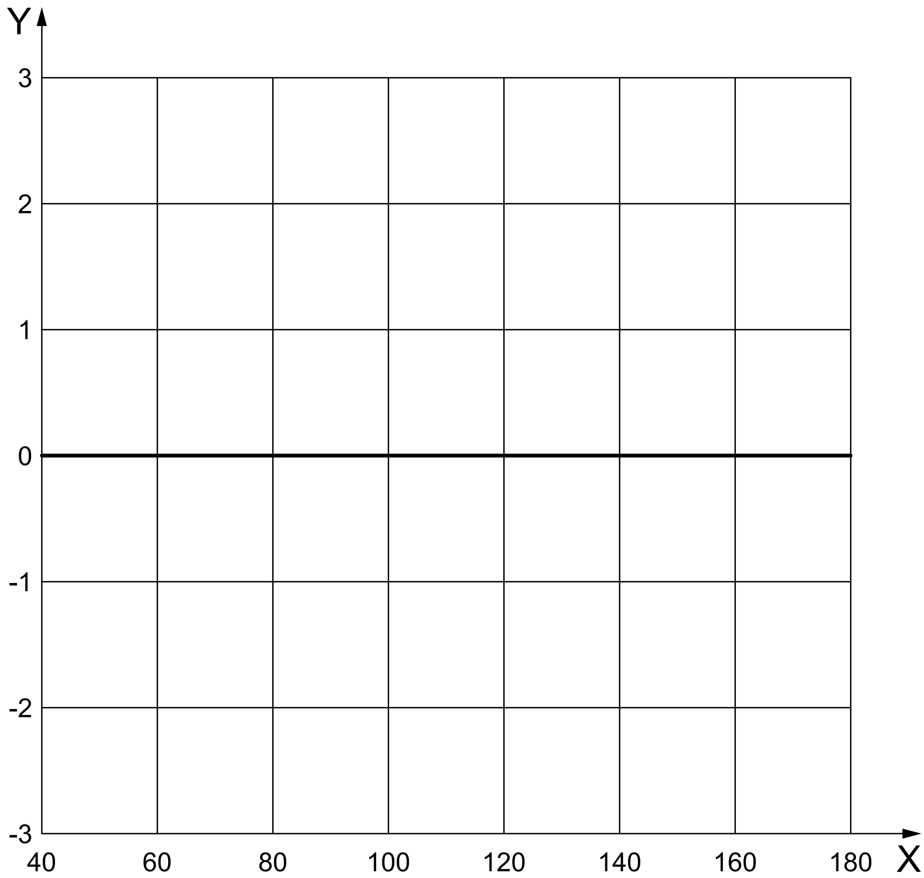
yaw velocity (°/s)

lateral acceleration (m/s^2)

Figure B.1 — Time histories of measured quantities

If tests are carried out for several test speeds, characteristics shall be plotted as in Figure B.2.

Vehicle:	....
Nominal length of wind zone:	.... m
Nominal wind velocity:	.... m/s
Nominal wind angle relative to datum course line:	.... °



Key

X longitudinal velocity (km/h)

Y lateral deviation (m)
yaw velocity (°/s)
peak/pulse value[1)]
lateral acceleration (m/s^2)
peak/pulse value[1)]

1) delete as appropriate

Figure B.2 — Characteristics of measured quantities

Bibliography

[1] ISO 3833, *Road vehicles — Types — Terms and definitions*

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