INTERNATIONAL STANDARD

ISO 14794

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Heavy commercial vehicles and buses — Braking in a turn — Open-loop test methods

Véhicules utilitaires lourds et autobus — Freinage en virage — Méthodes d'essai en boucle ouverte

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 14794 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 14794:2003), 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 is each complex in itself. 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.

Heavy commercial vehicles and buses — Braking in a turn — Open-loop test methods

1 Scope

This International Standard specifies open-loop test methods for determining the effect of braking on the course-holding and directional behaviour of heavy vehicles or heavy vehicle combinations when braking is accomplished using

- the service-brake system, or
- the retarder or engine brake only.

This International Standard is applicable to heavy vehicles — i.e. commercial vehicles, commercial vehicle combinations, buses and articulated buses as defined in ISO 3833 — covered by Categories M3, N2, N3, O3 and O4 of UNECE (United Nations Economic Commission for Europe) and EC vehicle regulations. These categories pertain to trucks and trailers with a maximum mass above 3,5 t and to buses and articulated buses with a maximum mass above 5 t.

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 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 Principle

3.1 Test objectives

The primary objective of these test methods is to determine the effect of braking on the course-holding and directional behaviour of heavy vehicles.

Constant longitudinal velocity and a steady-state circular path of a given radius define the initial conditions. The brake system is then applied in a step-wise manner. The control inputs and the vehicle responses are measured and recorded during the test. From the recorded signals, characteristic values are calculated.

3.2 General conditions

The applicable provisions for general test conditions specified in ISO 15037-2 shall apply, with the modifications and additions as indicated in the following clauses.

4 Reference system

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).

For the purposes of this International Standard, the reference point shall be the centre of gravity of the vehicle unit.

NOTE This provision overrides the similar provision of ISO 15037-2.

5 Variables

The following variables shall be determined.

a) For single-unit vehicles or for the first vehicle unit of a vehicle combination:

— lateral acceleration, a_Y;

— longitudinal acceleration, a_X;

— brake-application signal;

— longitudinal velocity, v_X;

— steering-wheel angle, δ_H;

— yaw velocity, $\dot{\psi}$.

b) For vehicle combinations:

— articulation angles, Γ, or angular velocity of articulation angles between adjacent vehicle units.

c) For tests using the service-brake system:

— brake pressure at the outlet of the master cylinder or in a brake circuit that activates at least one of the front wheel brakes, p_B, or

— brake-pedal position, s_B, if brake pressure is not the signal that activates the brake system — as, for example, in the case of electronic brake systems.

In addition, the following variables should be determined.

d) For the first vehicle unit:

— wheel rotational speeds, $\omega_{i,\ i=1,\dots n}$,

— sideslip angle, β.

e) For trailing units:

— lateral acceleration, a_Y,

— yaw velocity, $\dot{\psi}$,

— wheel rotational speeds, $\omega_{i,\ i=1,\dots n}$,

— sideslip angle, β.

Other variables which may be determined are given in ISO 15037-2.

6 Measuring equipment

The measuring and recording equipment shall be in accordance with ISO 15037-2.

Typical operating ranges and recommended maximum errors for the transducer and recording systems of the variables not given in ISO 15037-2 are shown in Table 1.

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

Variable	Range	Recommended max. error of combined transducer and recorder system
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
Brake-pedal position, if rotational	0° to 45°	± 0,5°
Brake-pedal position, if translational	0 m to 0,2 m	± 0,001 m
Wheel rotational speed	0 °/s to 6 000 °/s	± 5 °/s

7 Test conditions

Limits and specifications for the ambient and the vehicle test conditions shall be in accordance with ISO 15037-2. Although the standard condition specified by ISO 15037-2 is a dry clean road, because it could be particularly useful, this test may be conducted on other relevant surfaces with appropriate adjustments to levels and increments of accelerations.

8 Tests

8.1 General

The braking-in-a-turn test consists of a series of test runs, in each of which the vehicle is initially placed in a steady-state turn of specified speed and lateral acceleration and is then subjected to a rapid application of either the service-brake system or the retarder or engine brake.

In conducting the braking-in-a-turn test, the general test specifications shall be in accordance with ISO 15037-2.

Test runs shall be conducted using both left- and right-hand turns. All the data may be taken in one direction followed by all the data in the other direction. As an alternative, data may be taken successively in each direction for each acceleration level proceeding from the lowest to the highest level. The method chosen shall be noted in the general data. (See Annex A.)

The series of tests should be performed at least three times.

8.2 Brake temperature

An acceptable range for initial brake temperature shall be specified for tests in which braking is to be accomplished using the service brakes. Prior to each individual run of such tests, the brakes shall be warmed up or allowed to cool as required such that the initial brake temperatures are within the specified range. The initial temperature of the brakes shall be reported in the general data. (See Annex A.)

8.3 Initial driving condition

The initial driving condition for this test method shall be in accordance with that given for steady-state circular runs in ISO 15037-2. In this initial condition, the vehicle shall be steered such that the reference point of the vehicle moves along the desired circular path. The standard radius of this path is 100 m. Optionally, larger or smaller radii (to a minimum of 30 m) may be used. However, as it is known that the significance of the results and the ability to discriminate between different vehicles increase with increasing test speed, testing should be carried out on larger radii at appropriately higher speeds.

The initial lateral acceleration of the vehicle, or of the first vehicle unit of vehicle combinations, shall be appropriate to the test surface. The recommended lateral acceleration is 3 m/s^2 on the standard surface. However, for safety reasons, the maximum lateral acceleration should not be more than 75 % of the estimated rollover limit or of the estimated road adhesion limit. The initial lateral acceleration level shall be noted in the test report.

Outriggers should be used in order to prevent rollover.

When the initial steady-state driving condition has been reached, the steering wheel shall be held at a constant angle by a mechanical device; alternatively, it shall be firmly held by the driver. The steering wheel shall be held fixed until the test run is completed.

8.4 Application of braking

8.4.1 General

The braking effort in the initial test run shall correspond to a mean longitudinal acceleration of 1 m/s^2. Subsequently, braking shall be increased by increments of not more than 1 m/s^2. If the results vary rapidly with longitudinal acceleration, or when operating on low-friction surfaces, smaller increments should be selected.

8.4.2 Test procedure

8.4.2.1 Service-brake systems

Release the accelerator pedal as quickly as possible and apply the brakes in accordance with 9.3. For vehicles with manual transmissions, conduct the test in the highest gear compatible with the conditions of the test. The clutch may be disengaged immediately upon release of the accelerator or at a predefined engine speed. Indicate the method in the test report (see Annex A). For vehicles with automatic transmission, maintain the shift lever in the initial position. Report the position of the shift lever in the test report (see Annex A). For all vehicles, apply the brakes until the vehicle comes to a full stop.

Make the test runs for each combination of radius and lateral acceleration at increasing levels of longitudinal acceleration until

— the maximum value of the mean longitudinal acceleration has been achieved (see 9.3.3), or

— lock-up of at least one wheel occurs.

The latter case would typically apply to vehicles without antilock systems. In such cases, the test may be continued to higher braking efforts resulting in additional wheels locking as desired. However, testing under these conditions may result in rapid and large changes of tyre characteristics, which could cause wide variations in test results.

NOTE The service-brake system is the braking system activated by the brake pedal and can include retarder and engine braking.

8.4.2.2 Retarder and/or engine braking only

Run the vehicle in the lowest gear compatible with the chosen speed. On vehicles with automatic transmissions, maintain the shift lever in the initial position. Release the accelerator pedal as quickly as possible. If the retarder or engine brake is applied manually, apply the brake within 0,2 s of the release of the accelerator pedal. Maintain application of the retarder or engine brake until it is automatically released by the system or until a predefined engine or vehicle speed is reached. Report this speed in the test report (see Annex A).

NOTE Some retarders require a relatively long rise time to achieve full response. In such cases, steady state may be established with the retarder already applied. Release of the accelerator pedal then results in a quicker application of brake torque.

9 Data evaluation and presentation of results

9.1 General

General data shall be presented in the test report in accordance with Annex A. The general data shall include an accurate record of any and all changes in the test vehicle (loading, tyre changes, etc.).

For each test run, it shall be confirmed that the initial conditions of steady-state turning were established in accordance with ISO 15037-2.

The mean, minimum and maximum values of the characteristic values from repeated tests shall be reported.

9.2 Time histories

Test data shall be presented in the form of graphical time histories for purposes of both analyses of vehicle performance and the monitoring of correct test performance and proper functioning of the transducers, etc. For every test run, a time history of each of the variables determined (see Clause 5) shall be presented.

In addition, the following time histories shall be produced for each test run:

— yaw velocity and reference yaw velocity on the same graph;

— lateral acceleration and reference lateral acceleration on the same graph.

See 9.4 for reference yaw velocity and reference lateral acceleration definitions.

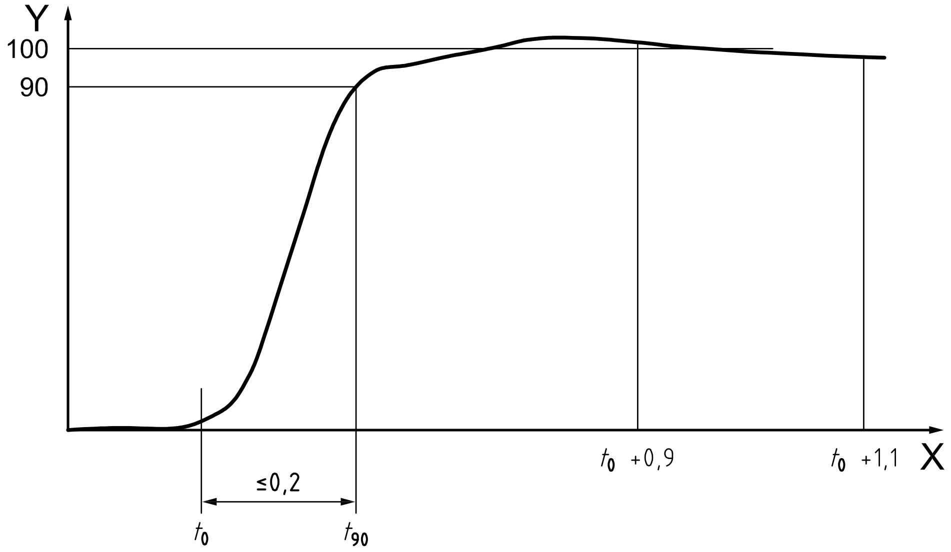
9.3 Brake application

9.3.1 Reference time, t_0

The reference time, t_0, used in defining the following characteristic values is the moment of brake actuation. When available, the onset of the brake-light signal should be used to define t_0. Alternatively, other electrical brake-application signals may be used.

9.3.2 Definition of times and requirement

The brake-application rise time shall not exceed 0,2 s in tests using the service-brake system (see Figure 1). The brake-application rise time is the difference between time t_0 and time t_{90}, where t_{90} is the time when the brake pressure or brake pedal position reaches 90 % of its value at 1 s after t_0. The brake pressure at 1 s after t_0 is evaluated by taking the mean value during the time interval between 0,9 s and 1,1 s after t_0.



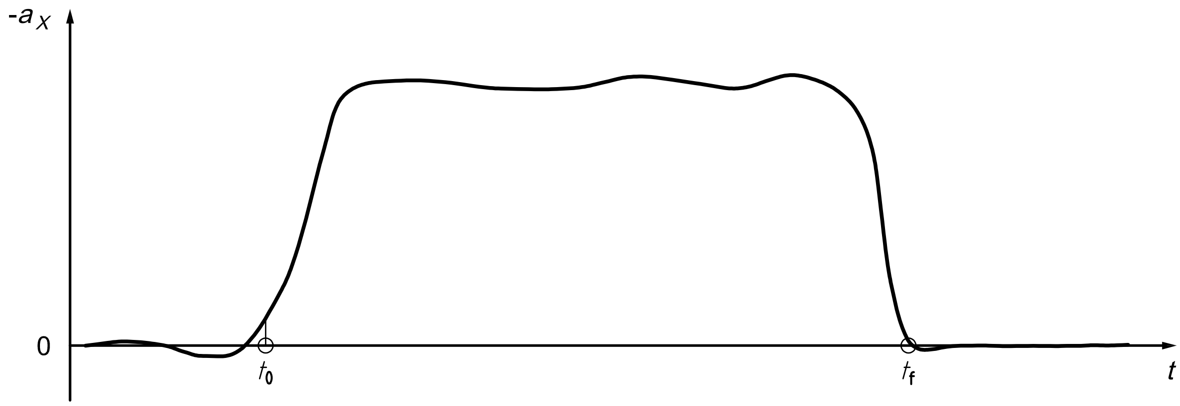
Key

X time, t, in seconds

Y brake pressure, p_B, or brake pedal position, s_B

Figure 1 — Braking step input — Definition of times

In the case of a service-brake test, the time t_f is the time when the longitudinal acceleration reaches the value zero at the end of the brake application (see Figure 2). In the case of the retarder or engine-brake test, t_f is the moment at which the electrical signal used to define t_0 turns off.



Key

$-a_X$ longitudinal acceleration

t time

Figure 2 — Definition of times

9.3.3 Mean longitudinal acceleration, $-\overline{a}_X$

The mean longitudinal acceleration, $-\overline{a}_X$, for a test run is the average value of longitudinal acceleration measured during the time interval t_0 to t_f (see Figure 2).

9.4 Reference variables and steady-state values

The steady-state values of the variables $v_{X,\text{ss}}$, $\dot{\psi}_{\text{ss}}$, $a_{Y,\text{ss}}$, and β_{ss} are defined as their mean values during the time interval 1,3 s to 0,3 s prior to t_0.

The reference values of yaw velocity and lateral acceleration at a given time, t, are the values of those variables that would result from the actual longitudinal velocity at time t, i.e. $v_{X,t}$, had the initial radius of turn been maintained by the vehicle. They are defined as follows.

— Reference yaw velocity:

$$\dot{\psi}_{\text{Ref},t} = \frac{v_{X,t}}{v_{X,\text{ss}}} \dot{\psi}_{\text{ss}}$$

— Reference lateral acceleration:

$$a_{Y,\text{Ref},t} = \frac{v_{X,t}^2}{v_{X,\text{ss}}^2} a_{Y,\text{ss}}$$

NOTE These reference values are meaningful only when yaw acceleration and sideslip angle are small.

A graph containing the time history of the variable and its reference shall be presented for each variable.

9.5 Characteristic values

9.5.1 General

At the present level of knowledge, it is not known which variables or which characteristic values best describe the dynamic reaction of vehicles. The characteristic values presented here therefore represent only examples of ways by which the results of this test method can be evaluated.

The characteristic values chosen for use shall be determined and presented as a function of the mean longitudinal acceleration (see 9.3.3). The characteristic values are determined for the time period beginning at t_0 and ending at t_f.

9.5.2 Characteristic values related to the initial overshoot

9.5.2.1 The maximum value of the ratio of yaw velocity during braking to its initial, steady-state value (see Figure B.1):

$$\left.\frac{\dot{\psi}}{\dot{\psi}_{\text{ss}}}\right|_{\max} = f_1(-\bar{a}_X)$$

The time of occurrence for this maximum value should also be determined.

9.5.2.2 The maximum value of the ratio of lateral acceleration during braking to its initial, steady-state value (see Figure B.2):

$$\left.\frac{a_Y}{a_{Y,\text{ss}}}\right|_{\max} = f_2(-\bar{a}_X)$$

The time of occurrence for this maximum value should also be determined.

9.5.3 Characteristic values related to deviation from the reference behaviour

9.5.3.1 The maximum value of the absolute difference between yaw velocity during braking and reference yaw velocity (see Figure B.3):

$$\left|\dot{\psi} - \dot{\psi}_{\mathrm{Ref}}\right|_{\mathrm{max}} = f_3(-\bar{a}_X)$$

The time of occurrence for this maximum value should also be determined.

9.5.3.2 The maximum value of the absolute difference between lateral acceleration during braking and reference lateral acceleration (see Figure B.4):

$$\left|a_Y - a_{Y,\mathrm{Ref}}\right|_{\mathrm{max}} = f_4(-\bar{a}_X)$$

The time of occurrence for this maximum value should also be determined.

9.5.3.3 The mean value of the difference between yaw velocity during braking and reference yaw velocity (see Figure B.5):

$$\overline{\dot{\psi} - \dot{\psi}_{\mathrm{Ref}}} = f_5(-\bar{a}_X)$$

9.5.3.4 The ratio of the mean value of yaw velocity during braking to the mean value of reference yaw velocity (see Figure B.6):

$$\frac{\bar{\dot{\psi}}}{\bar{\dot{\psi}}_{\mathrm{Ref}}} = f_6(-\bar{a}_X)$$

9.5.3.5 The maximum absolute value of the difference between the yaw angle and the reference yaw angle (see Figure B.7):

$$\Delta\psi_{\mathrm{max}} = \left|\int_{t_0}^{t} \left(\dot{\psi} - \dot{\psi}_{\mathrm{Ref}}\right)\mathrm{d}t\right|_{\mathrm{max}} = f_7(-\bar{a}_X)$$

9.5.4 Characteristic value related to the final position

The difference between yaw angle and reference yaw angle after standstill (see Figure B.8):

$$\Delta\psi_{t_f} = \int_{t_0}^{t_f} (\dot{\psi} - \dot{\psi}_{\mathrm{Ref}})\mathrm{d}t = f_8(-\bar{a}_X)$$

9.5.5 Characteristic values related to vehicle combinations

9.5.5.1 The maximum and minimum values of the articulation angles between vehicle units (see Figures B.9 and B.10):

$$\Gamma_{\mathrm{max}} = f_9(-\bar{a}_x) \qquad \Gamma_{\mathrm{min}} = f_{10}(-\bar{a}_x)$$

9.5.5.2 The maximum and minimum values of the angular velocity of articulation angles between vehicle units (see Figures B.11 and B.12):

$$\dot{\Gamma}_{n,\mathrm{max}} = (\dot{\psi}_n - \dot{\psi}_{n+1})_{\mathrm{max}} = f_{11}(-\bar{a}_x)$$

$$\dot{\Gamma}_{n,\mathrm{min}} = (\dot{\psi}_n - \dot{\psi}_{n+1})_{\mathrm{min}} = f_{12}(-\bar{a}_x)$$

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

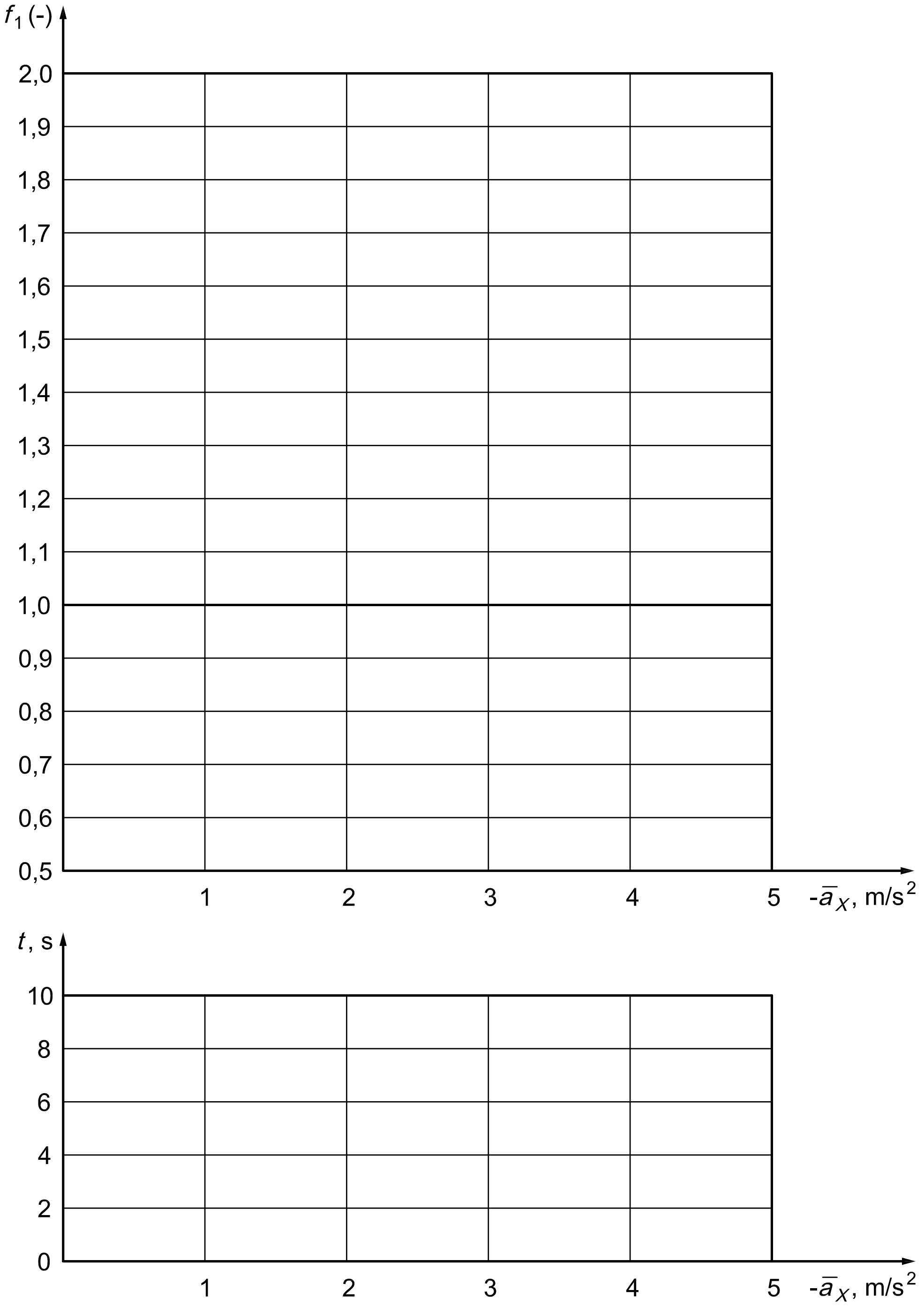
The test report for test conditions shall be as given in ISO 15037-2:2002, Annex B, with the following additions.

Test conditions:	Engaged gear:	....
	Time of clutch disengagement:	START / END
	Gear selector position:	....
	Transmission programme:	....
	Engine speed for disengagement of engine brake or retarder:	.... r/min
	Reference point for sideslip angle and lateral acceleration:	.... mm
	Initial temperature front brakes:	.... °C
	Initial temperature rear brakes:	.... °C
	Method for verifying the uniformity of initial conditions	
	standard deviation:	☐
	mean value difference:	☐
	Lateral acceleration at initial conditions:	.... m/s^2
	Test sequence:	-L-R-L-R- / -L-L-R-R-

Annex B
(normative)

Test report — Presentation of results

See Figures B.1 to B.12.

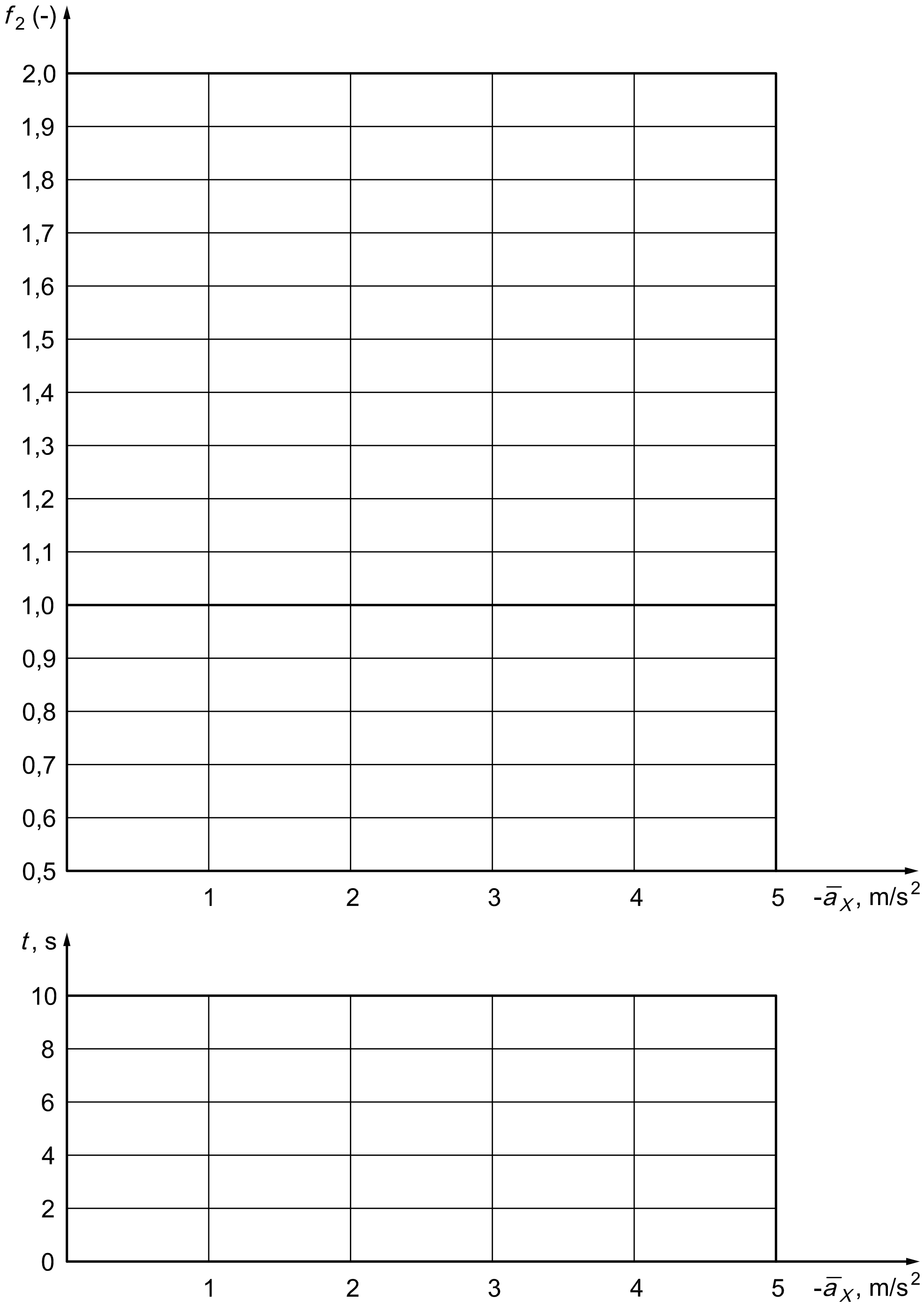


Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.1 — Maximum value of ratio of yaw velocity during braking to its initial steady-state value

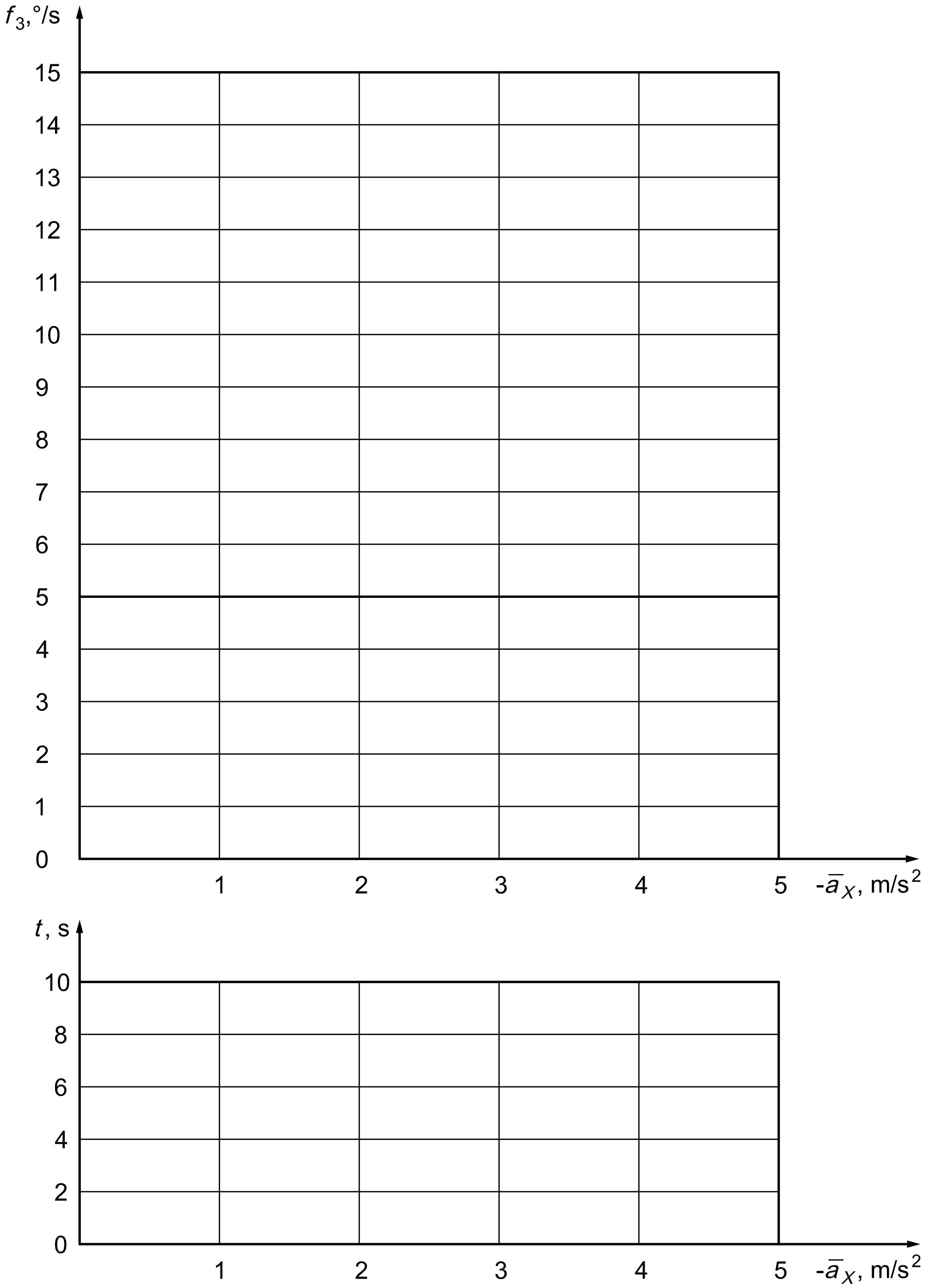


Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.2 — Maximum value of ratio of lateral acceleration during braking to its initial steady-state value

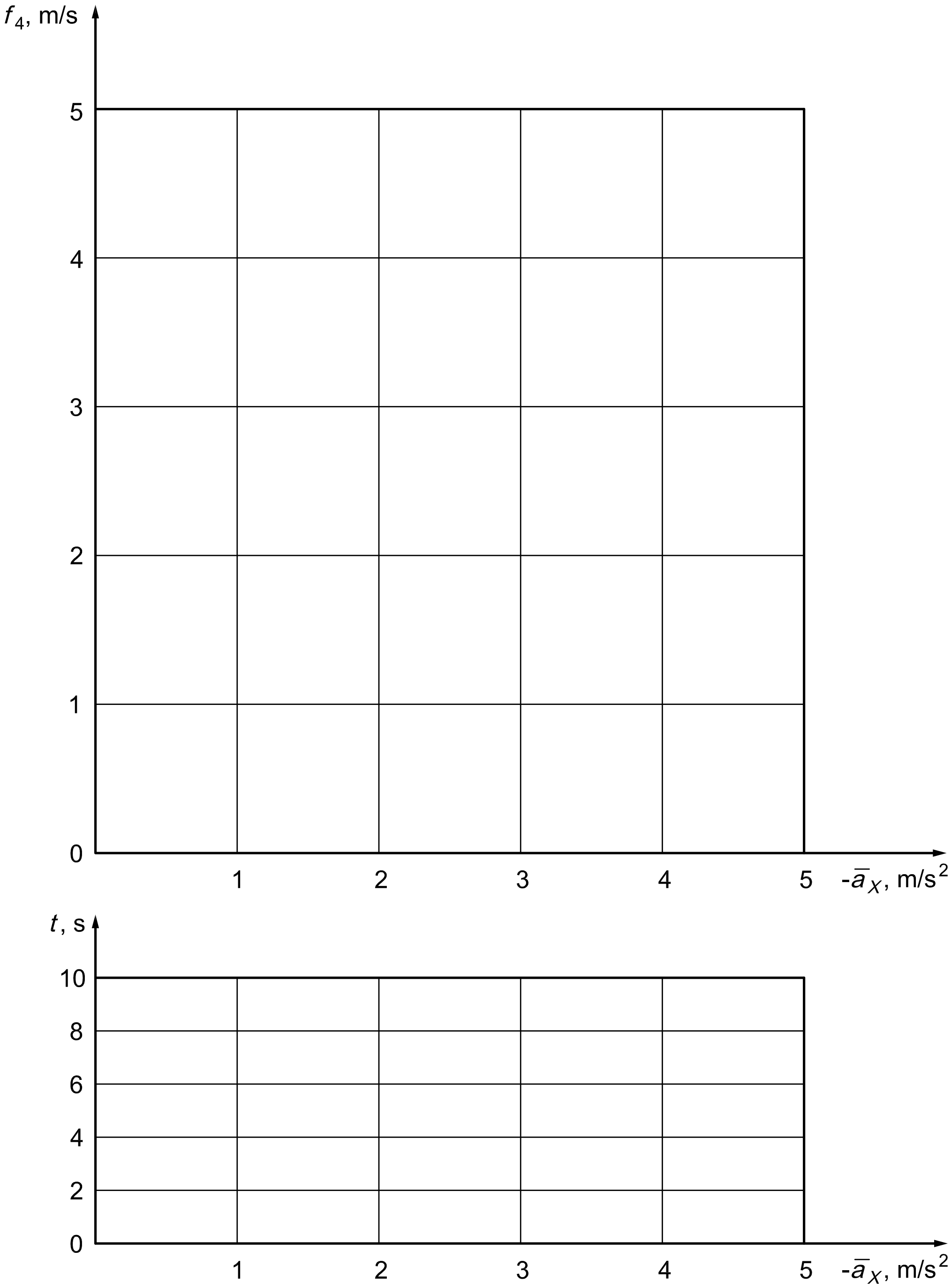


Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.3 — Maximum value of absolute difference between yaw velocity during braking and reference yaw velocity

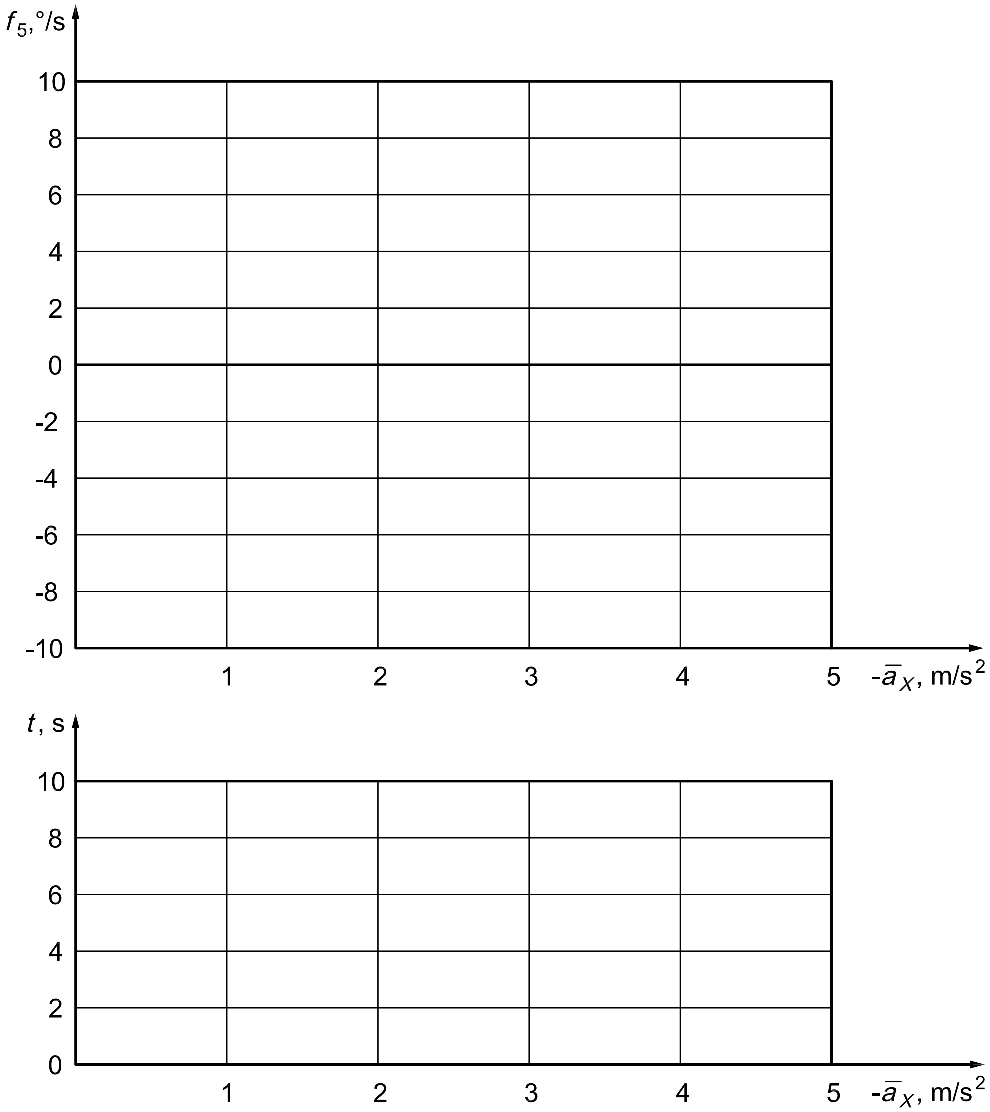


Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.4 — Maximum value of absolute difference between lateral acceleration during braking and reference lateral acceleration

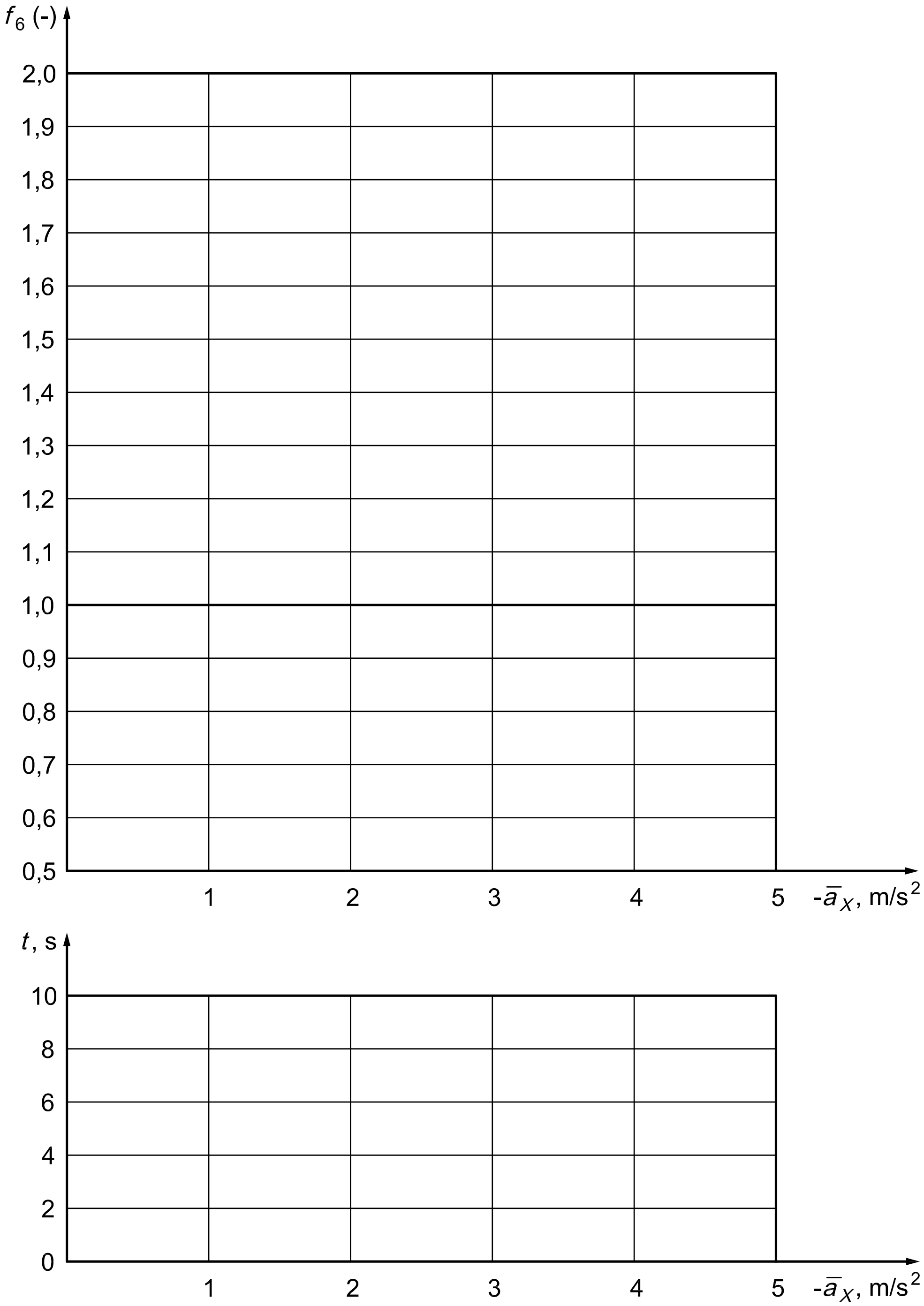


Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.5 — Mean value of difference between yaw velocity during braking and reference yaw velocity

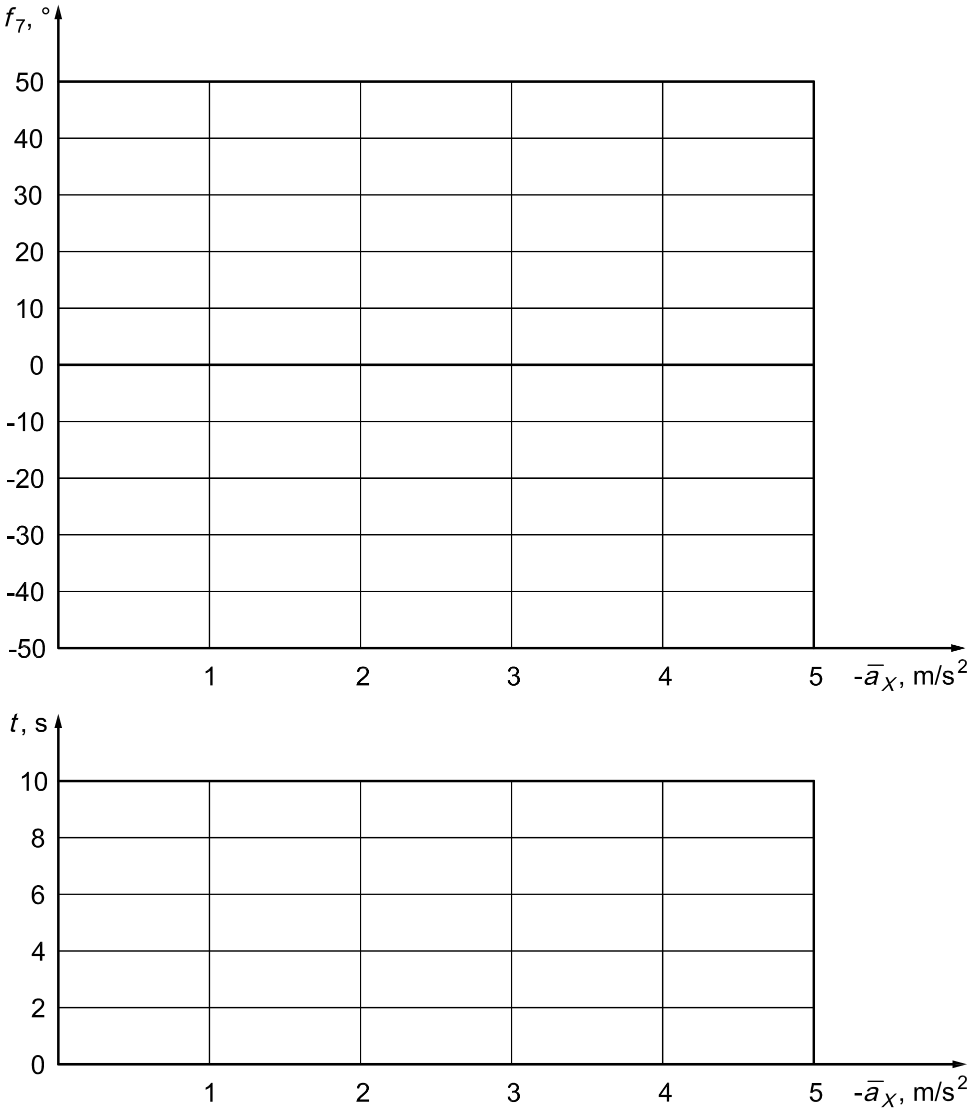


Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.6 — Ratio of mean of yaw velocity during braking to mean of reference yaw velocity

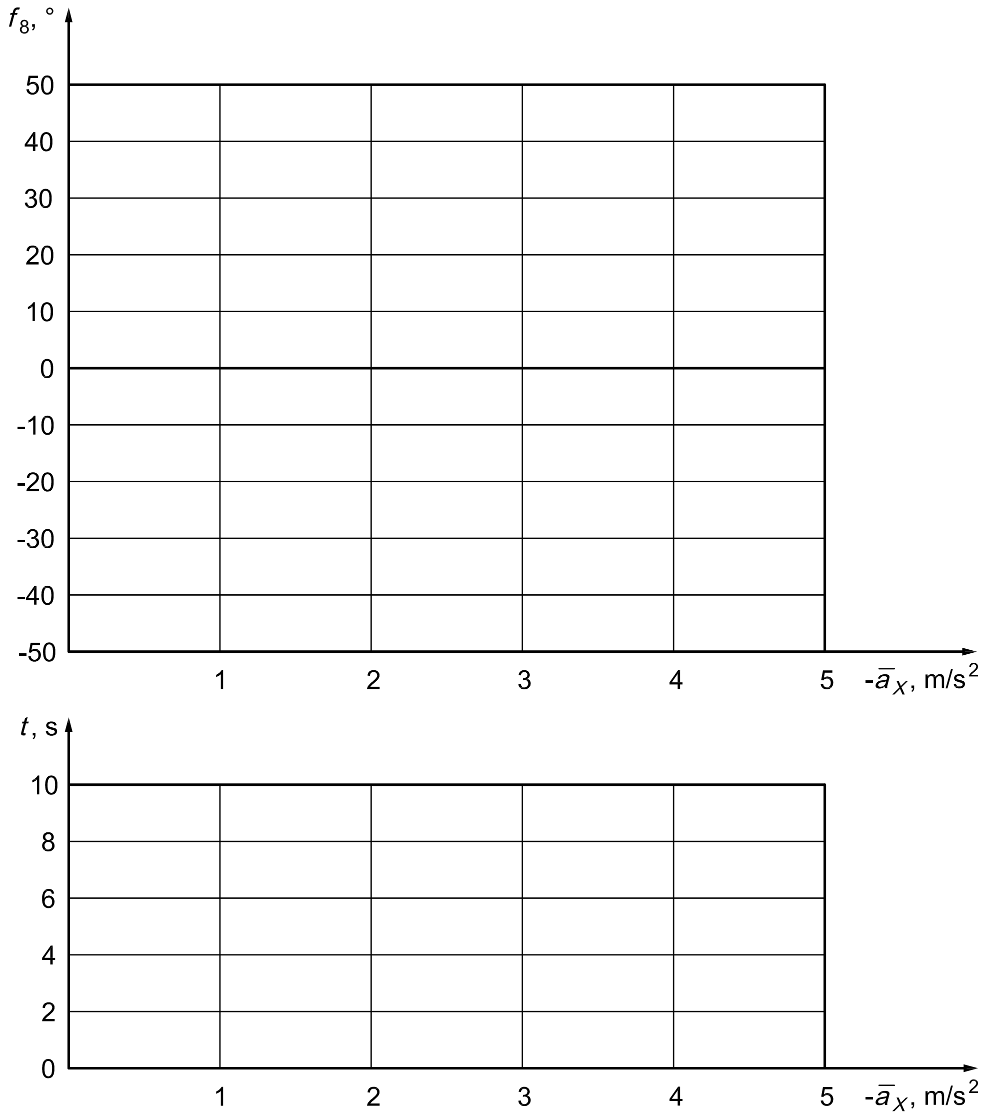


Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.7 — Maximum absolute value of difference between yaw angle and reference yaw angle

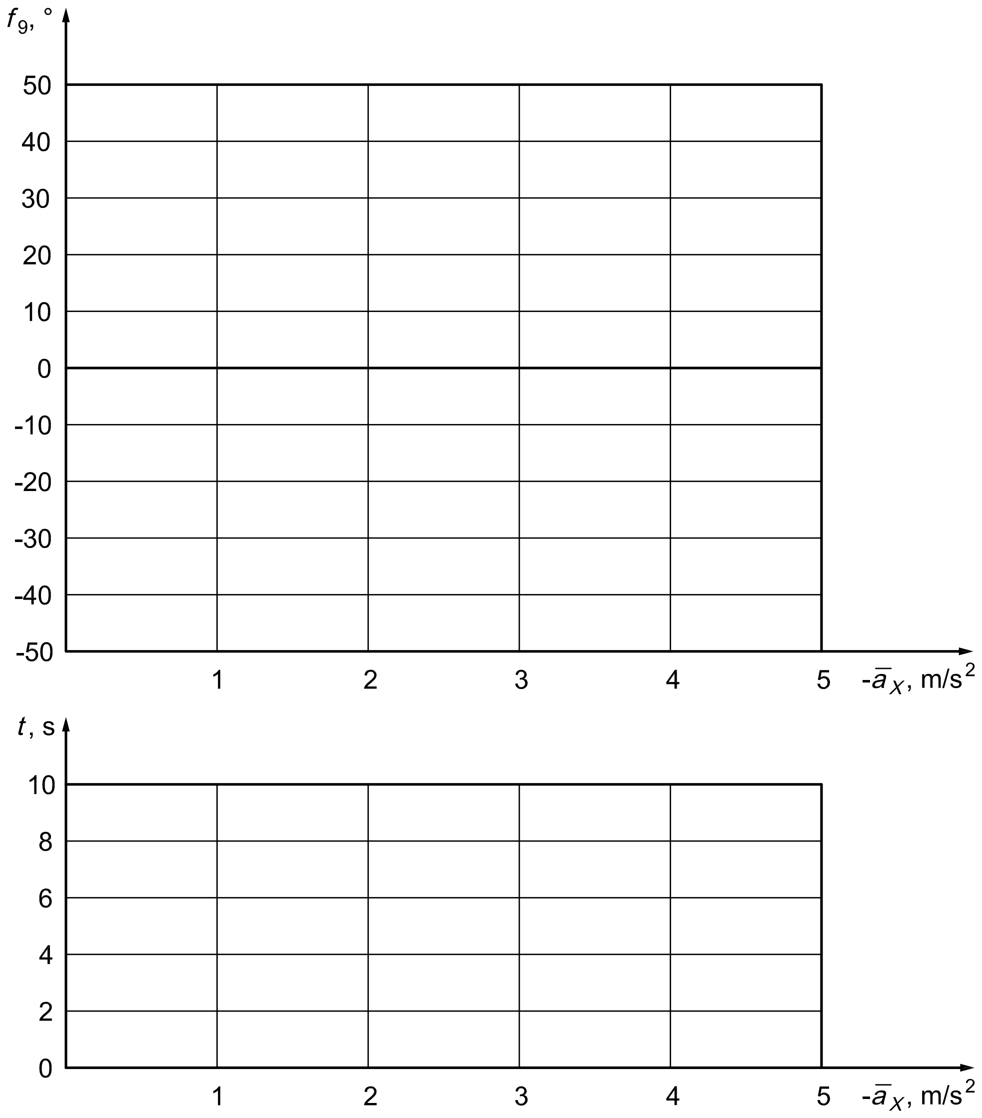


Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.8 — Value of difference between yaw angle and reference yaw angle after standstill

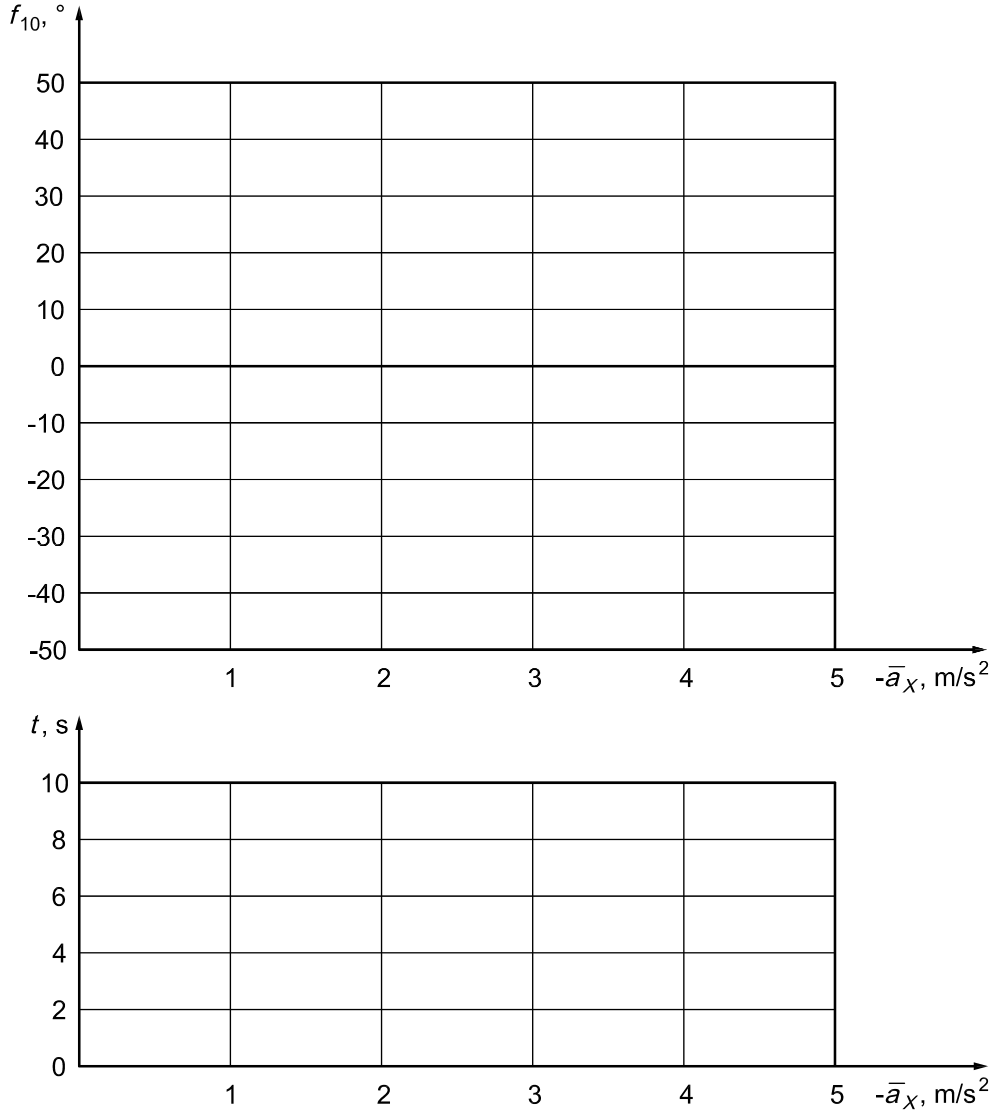


Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.9 — Maximum value of articulation angles between vehicle units

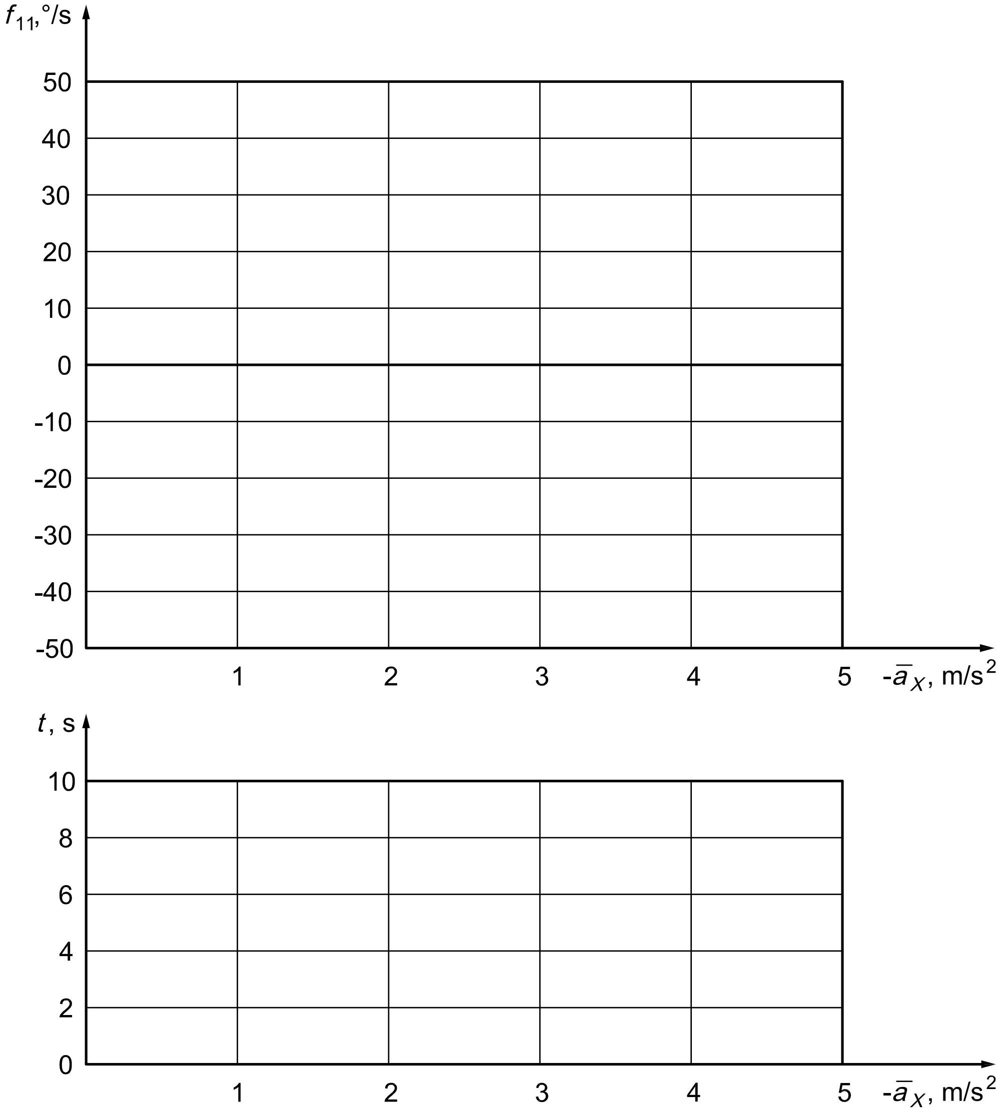


Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.10 — Minimum value of articulation angles between vehicle units

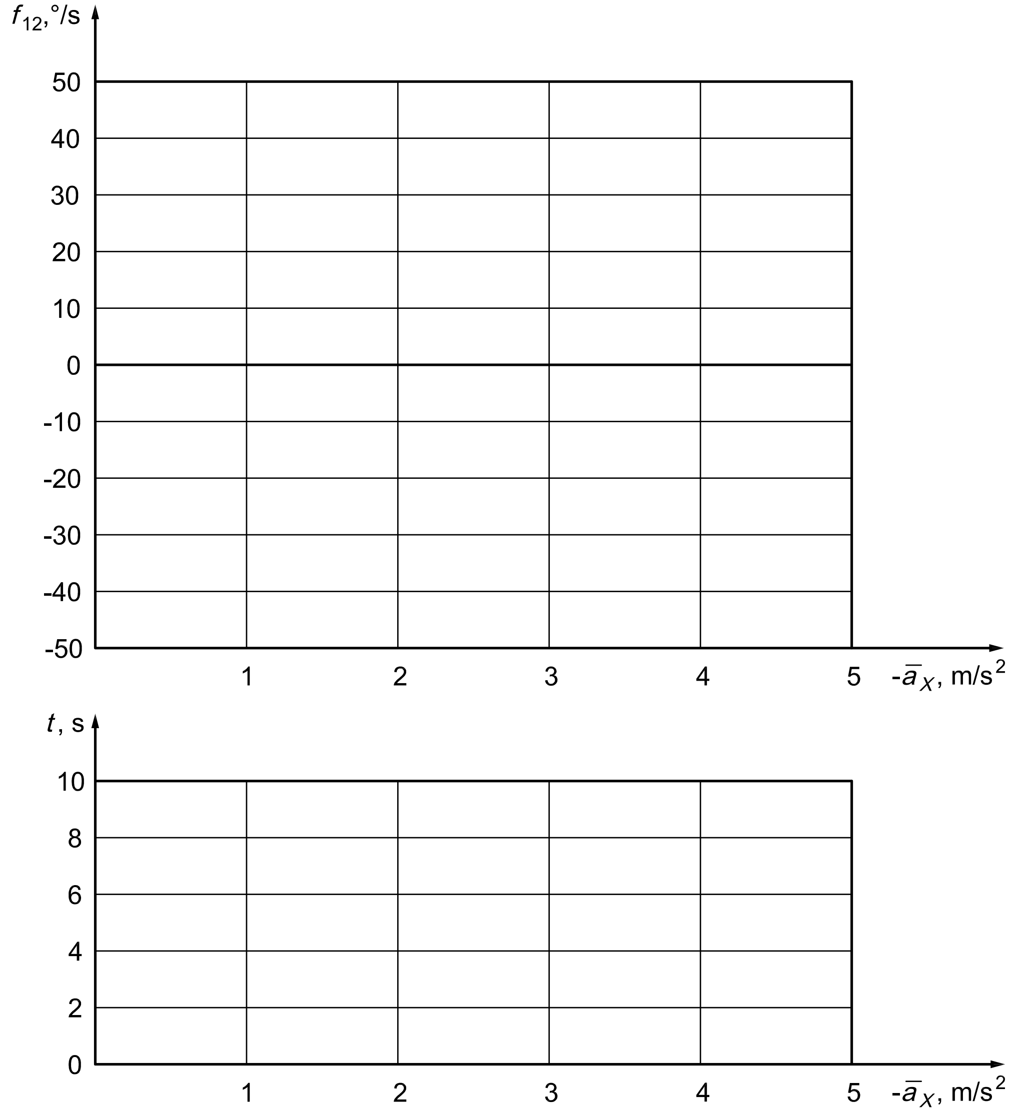


Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.11 — Maximum value of angular velocity of articulation angles between vehicle units



Key

t time for occurrence

$-\bar{a}_X$ mean longitudinal acceleration

Figure B.12 — Minimum value of angular velocity of articulation angles between vehicle units

Bibliography

[1] ISO 1176, *Road vehicles — Masses — Vocabulary and codes*

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