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Safety of Industrial Trucks — Dynamic tests for verification of lateral stability — Counterbalanced Trucks

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee MHE/7, Industrial trucks.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Safety of Industrial Trucks - Dynamic tests for verification of lateral stability - Counterbalanced Trucks

Sécurité des chariots de manutention - Essais dynamiques pour la vérification de la stabilité latérale - Chariots en porte-à-faux

Sicherheit von Flurförderzeugen - Prüfung der dynamischen Standsicherheit - Gegengewichtsstapler

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Foreword

This document (EN 16203:2014) has been prepared by Technical Committee CEN/TC 150 “Industrial Trucks - Safety”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2014 and conflicting national standards shall be withdrawn at the latest by December 2014.

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Introduction

This European Standard is a type C standard as stated in EN ISO 12100:2010. This standard has been prepared to be a harmonized standard to provide one means of conforming to the essential safety requirements of the Machinery Directive and associated EFTA regulations.

The extent to which hazards are covered is indicated in the scope of this standard.

NOTE 1 The requirement for a dynamic test is intended to be included in EN 16307-1, *Industrial trucks – Safety requirements and verification – Part 1: Supplementary requirements for self-propelled industrial trucks, other than driverless trucks, variable -reach trucks and burden-carrier trucks.*

The purpose of this standard is to provide a procedure for verifying the lateral stability of the truck while travelling. The procedure can be used as a type test as well as an individual test.

The truck is designed so that when travelling, laden or unladen, it will remain stable while being operated on smooth level ground under conditions of use defined by the manufacturer, e.g. by controlling travelling velocity, steering rate of change, acceleration and deceleration, position of load handling device.

To reduce the risk of lateral instability for lifting, furthermore it is proposed to indicate this misuse of driving with elevated load by signals or by reduction of the driving velocity when exceeding a certain lift height. This requirement is intended to be included in the respective standard in its next revision.

NOTE 2 This standard is not intended to completely eliminate the possibility of a lateral tip over in all working conditions, i.e. it is possible to exceed the lateral stability limits if slightly uneven or sloping surfaces combine with unsafe driving practices.

1 Scope

This European Standard specifies dynamic tests for the verification of lateral stability for counterbalanced lift trucks according to EN ISO 3691-1 that have a centre control, sit down, non-elevating operator, with a rated capacity up to and including 5 000 kg when travelling on smooth level ground with the forks in travelling position. The standard is not applicable for Rough Terrain forklift trucks.

NOTE 1 Experience shows that counterbalanced lift trucks with a rated capacity over 5 000 kg are not significantly affected by lateral instability.

The requirements are specific to the various drive systems (e.g. Electric-/Internal-Combustion-Engine trucks), taking account of their varying influence on dynamic stability performance.

This European Standard does not cover the risk of a lateral tip over associated with driving backwards.

NOTE 2 Research has shown that driving backwards in typical working operations, such as unloading of a lorry, does not cause lateral instability. For this reason, only driving forward needs to be tested.

Risks due to falling off a loading dock or turning on a ramp are not covered by this European Standard.

Risks due to lifting or manoeuvring operations are covered by the respective stability tests.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN ISO 3691-1:2012, *Industrial trucks - Safety requirements and verification - Part 1: Self-propelled industrial trucks, other than driverless trucks, variable-reach trucks and burden-carrier trucks (ISO 3691-1:2011)*

ISO 5053:1987, *Powered industrial trucks - Terminology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5053:1987 and EN ISO 3691-1:2012 and the following apply.

3.1
maximum velocity
maximum designed truck velocity according to the manufacturer's specifications

Note 1 to entry: If the truck velocity is automatically reduced in certain load device positions (i.e. lift height dependent), this reduced velocity is the maximum velocity for that load condition.

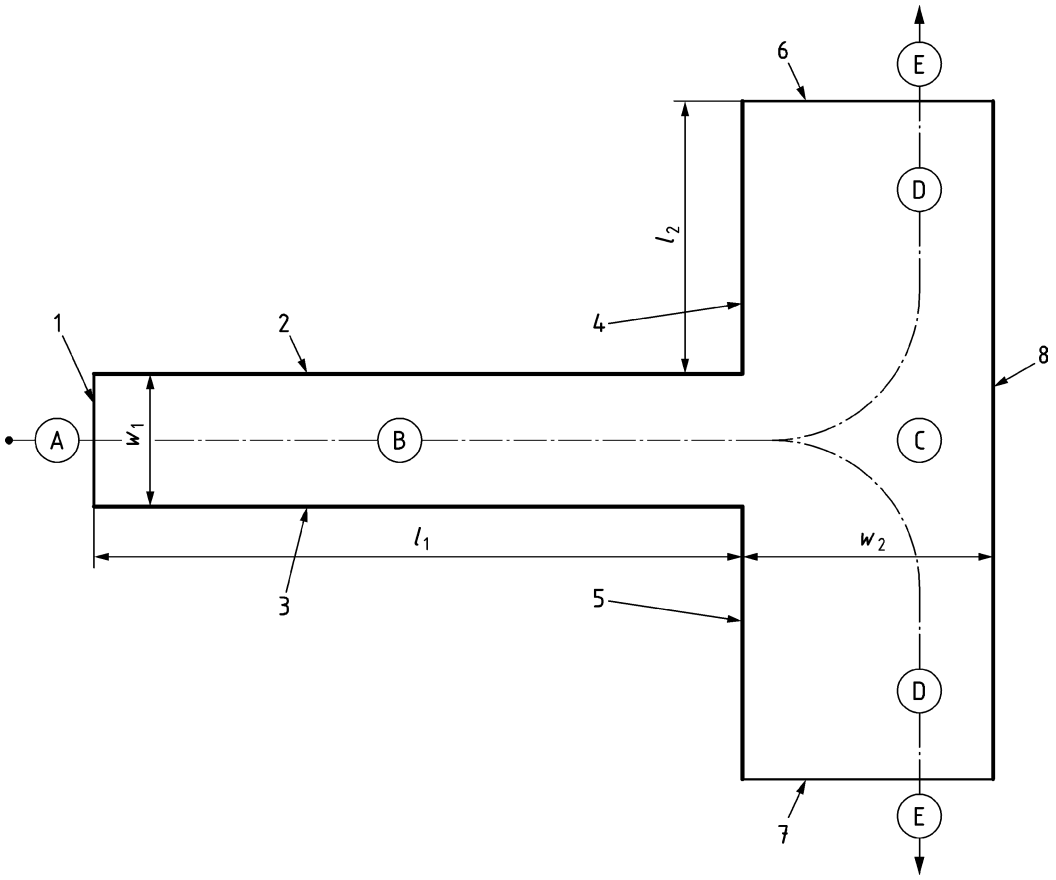
3.2
test velocity
velocity greater than 90 % of the maximum velocity

4 Test equipment

4.1 Test area

The test area shall be a flat and smooth area with a hard, clean and dry surface made of concrete, asphalt or equivalent. The lanes shall have no more than 2 % slope in any direction of travel and the slip friction coefficient μ of tyres and surface shall be between $\mu = 0.6$ and $\mu = 0.8$. The slip friction coefficient can be measured as described in Annex B. The slip friction coefficient may change by environmental influences (temperature, moisture, intermediary medium) as well as by type and wear condition of tyres and road surface. Therefore, a friction measurement shall be carried out before each test series. The area shall be clear of all loose chippings, sand or anything similar.

The test track shall consist of two perpendicular crossing lanes (see Figure 1). The lanes are defined by lines 1 to 8, of which at least lines 2, 3, 4, 5 and 8 shall be continuously marked on the ground (e.g. by painted lines, adhesive tape, non-fixed wooden lathes, ropes or chains, etc.). The defining lines shall be marked so they are clearly visible to the operator whilst driving. Whilst the preferred test track will have a shape similar to those of Figure 1, alternative test tracks in accordance with Annex A may be used.



Key

A	accelerating area	w_1	width of the entry lane
B	entry lane	w_2	width of the exit lane
C	manoeuvring area	l_1	length of the entry lane
D	exit lane	l_2	length of the exit lane
E	braking area		

lines 1 – 8 limiting the test track

Figure 1 — Layout of the test track

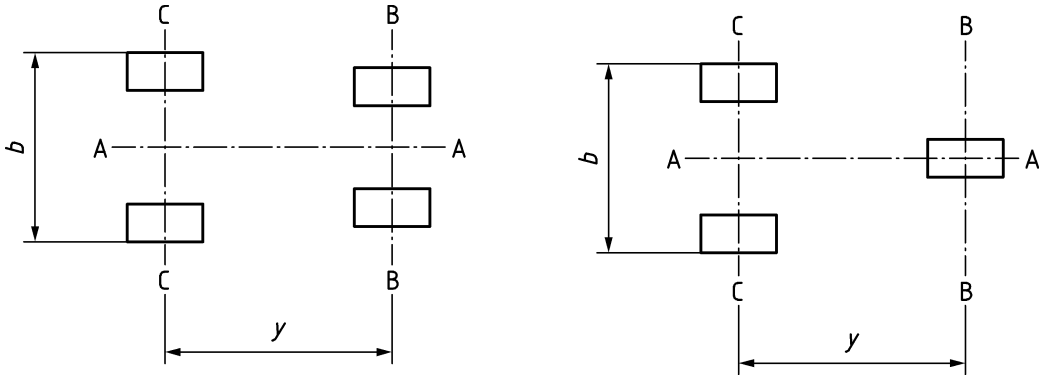
The overall dimensions of the test track shall include a sufficient area A to accelerate to reach the test velocity prior to the entry lane B and a sufficient area E for stopping. The dimensions depend on the type and size of the truck and are defined as follows:

$w_1 = 1{,}5 \cdot b$ [m] with the truck width b as shown in Figure 2

$l_1 = 3 \cdot y$ [m] with the wheelbase y as shown in Figure 2

$l_2 = 4 \cdot y$ [m] with the wheelbase y as shown in Figure 2

The dimension w_2 is defined in 6.2.



Key

A-A	longitudinal plane of truck
B-B	steering axle
C-C	load axle
b	truck width [m]
y	wheelbase [m]

Figure 2 — measures of 3-wheel and 4-wheel trucks

4.2 Test set-up and test equipment

An appropriate sensor shall be used to measure the travel velocity during the test or, at least, when the forklift truck crosses line 1 (velocity sensor, velocity barrier, etc.). Additional appropriate measures shall be used to verify that the accelerator pedal is fully pressed while driving between line 1 and line 6 or line 7 (e.g. contact sensor under the accelerator pedal). Furthermore, appropriate sensors, a video camera or human observers are necessary to detect whether the test is valid.

4.3 Protective equipment and precautions

To enable tests with minimal risk to the driver the truck shall be fitted with:

a) an operator restraint system, preferably a seat belt, which maintains the driver safety;

b) outrigger type stabilizers as protective equipment to prevent the truck tip-over:

   1) The test truck shall be equipped with stabilizers on both sides of the truck.

   2) The clearance between the stabilizers and the ground shall be such that tip-over of the vehicle is prevented but a rear wheel lift-off is still possible. For trucks with articulating steer axles, full articulation shall be possible before the stabilizers make contact with the ground.

3) The stabilizers shall be fixed rigidly and securely to the truck.

4) The total mass of the stabilizers shall be less than 10 % of the weight of the unladen truck.

5) The position of the centre of gravity of the truck shall not be lowered by attaching the stabilizers.

4.4 Test Load

Test shall be carried out with the unladen truck as defined in Clause 5.

5 Test truck

The truck to be tested shall be in a safe and functional state. All equipment attached shall be in accordance to the specification of the manufacturer of the truck. If the test is to be performed on a sample that is representative for a range of trucks, the test shall be carried out on the truck with the most disadvantageous stability values.

The fuel tanks of internal combustion engine trucks shall be filled if stability is thereby decreased.

All other tanks shall be filled to their correct operating levels, as applicable.

The test truck shall be fitted with new tyres (max. 10 % of tread wear) which shall comply with the specifications of the manufacturer of the truck. Pneumatic tyres shall be inflated to their correct pressure specified by the truck manufacturer.

6 Requirements

6.1 General − Dynamic lateral stability

The dynamic lateral stability shall be verified by testing as defined in this standard.

Simulation as calculations, computer modelling or other equivalent simulating methods may be used, provided that the results are validated by testing as defined in this standard.

6.2 Test Criteria

The truck shall run the test according to Clause 7 for the measurement w_2. w_2 is defined by the formula:

$$w_2 = w_3 + \frac{b}{2} \text{ [m]} \quad (1)$$

The measurement w_3, for electric driven trucks given in Figure 3 and for IC-driven trucks given in Figure 4, depends on the maximum velocity and the truck width b is shown in Figure 2.

EXAMPLE To determine the width of the exit lane, w_2, for an electric driven truck with a maximum velocity of 10 km/h: Find the maximum truck velocity along the x-axis and record the value of w_3 on the y-axis where a vertical line from the maximum truck velocity crosses the graph curve: in this case w_3 = 5 m. Substitute w_3 in Formula (1) in 6.2 to determine w_2 for this specific truck.

This requirement is fulfilled if three successful attempts are obtained within a maximum number of twenty attempts.

An attempt is successful in the case that it is:

a) a valid attempt;

and

b) the subsequent relevant criteria are fulfilled:

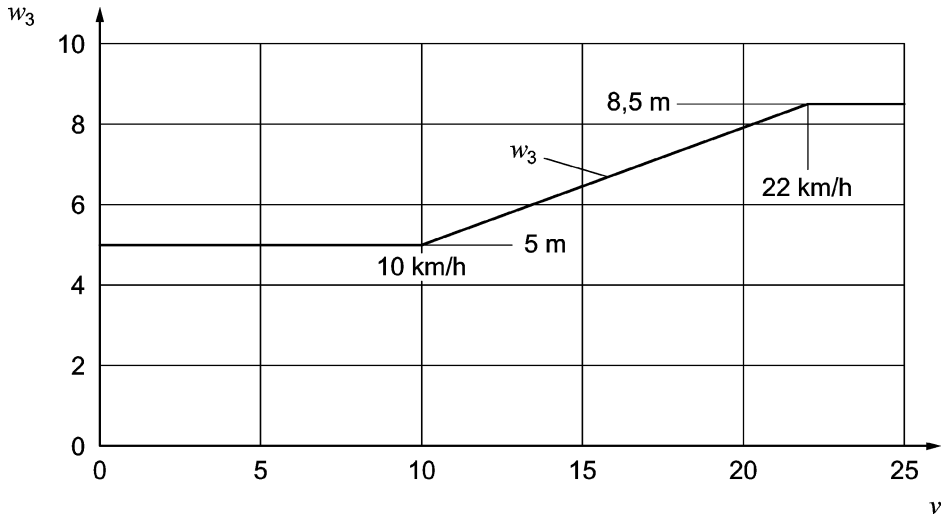
1) for a three wheel truck with 1 wheel on the rear axle this rear wheel has contact to the ground; or

2) for a three wheel truck with twin centre rear wheels at least one of these two wheels has contact to the ground; or

3) for a four wheel truck with an articulating rear axle the inner rear wheel has contact to the ground.

A lift off of the inner front wheel is allowed.

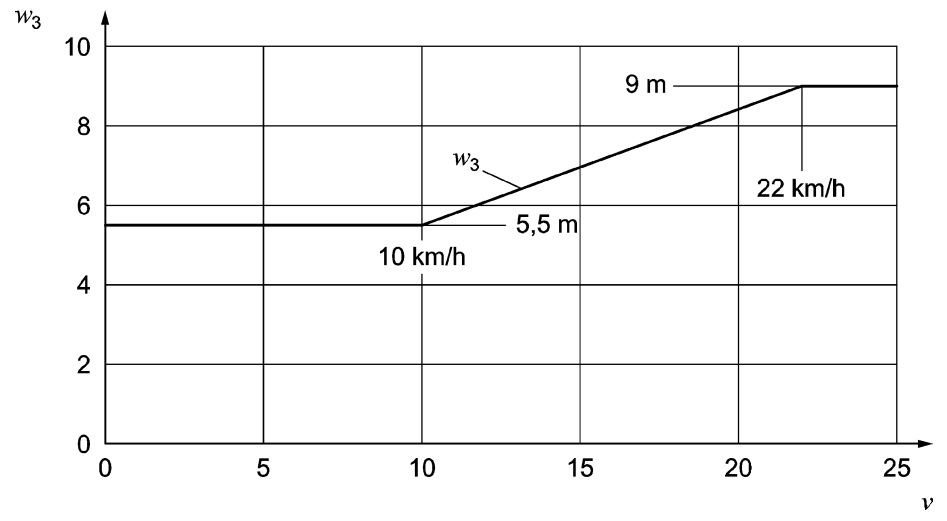
A valid attempt is obtained if no part of the truck touches the limiting lines 2, 3, 4, 5 and 8 (see Figure 1) of the test track or the ground beyond under the test conditions described in Clause 7.



Key

v velocity in km/h

Figure 3 — Required measure w_3 for electric driven trucks



Key

v velocity in km/h

Figure 4 — Required measure w_3 for IC-driven trucks

According to the experience gained by application of this standard to a large number of trucks the limits should be re-examined in the next revision of the standard.

7 Verification

7.1 General

The readings shall be carried out at an environmental temperature range of 5 °C to 40 °C.

An experienced operator is needed to drive the forklift truck in this test. It is permitted to train the driver on this test procedure.

7.2 Test procedure

For the measuring to take place, the truck and the tyres shall be at operating temperature (a minimum warm-up period of 10 min is required, before the test starts).

Tyre pressures shall be checked directly before the testing takes place to verify that the manufacturer's recommendations are fulfilled.

For the test procedure, the lift height of the fork shall be 300 mm above the ground and the mast position shall be tilted back to the end position.

For an attempt the forklift truck accelerates in area A. The truck shall cross line 1 with test velocity. After passing the entry corridor B and entering the manoeuvring area C the driver shall steer the truck quickly but steadily to the exit corridor D to leave this corridor across line 6 or 7. Between line 1 and line 6 or 7 the accelerator pedal shall be fully depressed. Behind line 6 or 7 in the area E the truck can be stopped immediately. With the appropriate means described in 4.2 it shall be determined if the attempt is successful as defined in Clause 6.

This procedure shall be performed for the turning direction (right or left), whichever has the least stable condition.

If the direction with the least stable condition is unknown, the test shall be performed in both directions.

Any sliding or spinning of the vehicle is allowed as long as the truck does not fail the criteria for test validity (touching/crossing of the track limits or releasing of the accelerator pedal).

When performing the test it shall be ensured that no operating personnel or observers stay within the test area. A safety clearance wide enough to prevent danger should be provided.

8 Documentation

The test report shall contain the following details:

a) reference to this European Standard;

b) specification of the tested truck in respect to the information plate;

c) in case of type testing: reference to the type series;

d) position of the truck’s centre of gravity with respect to the load axle centrelines in x-y planes;

e) specification of truck equipment (e.g. attachment, cabin, etc.);

f) specification of tyres (manufacturer, type (SE or pneumatic tyre), dimensions, pressure);

g) air pressure of pneumatic tyres;

h) set-up parameters of the truck;

i) description of stabilizers (mass, centre of gravity) and position on the truck plus photographs of front and side views of the truck fitted with the stabilizers;

j) description of the test track (material, slope, smoothness, friction coefficient);

k) test velocity of the truck;

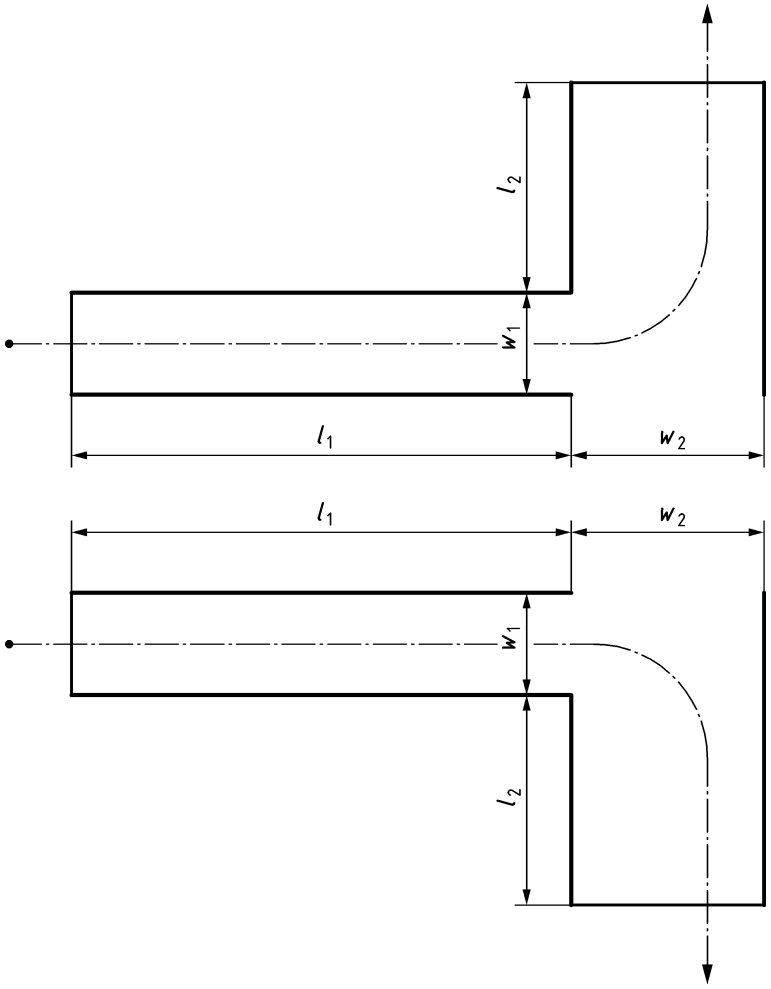
l) test result (passed/failed, no. of attempts/ valid attempts /successful attempts);

m) date and name of the tester and witness.

Annex A
(normative)

Equivalent test track layouts

A.1 Two courses with L-shape for left and right turns

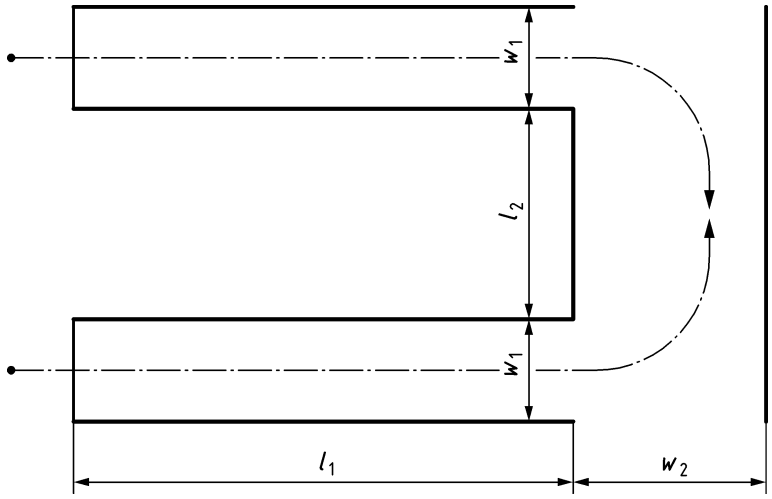


Key

w_1 width of the entry lane
w_2 width of the exit lane
l_1 length of the entry lane
l_2 length of the exit lane

Figure A.1 — Layout of two courses test track

A.2 Equivalent course with U-shape



Key

w_1 width of the entry lane
w_2 width of the exit lane
l_1 length of the entry lane
l_2 length of the exit lane

Figure A.2 — Layout of U-shape

Annex B
(informative)

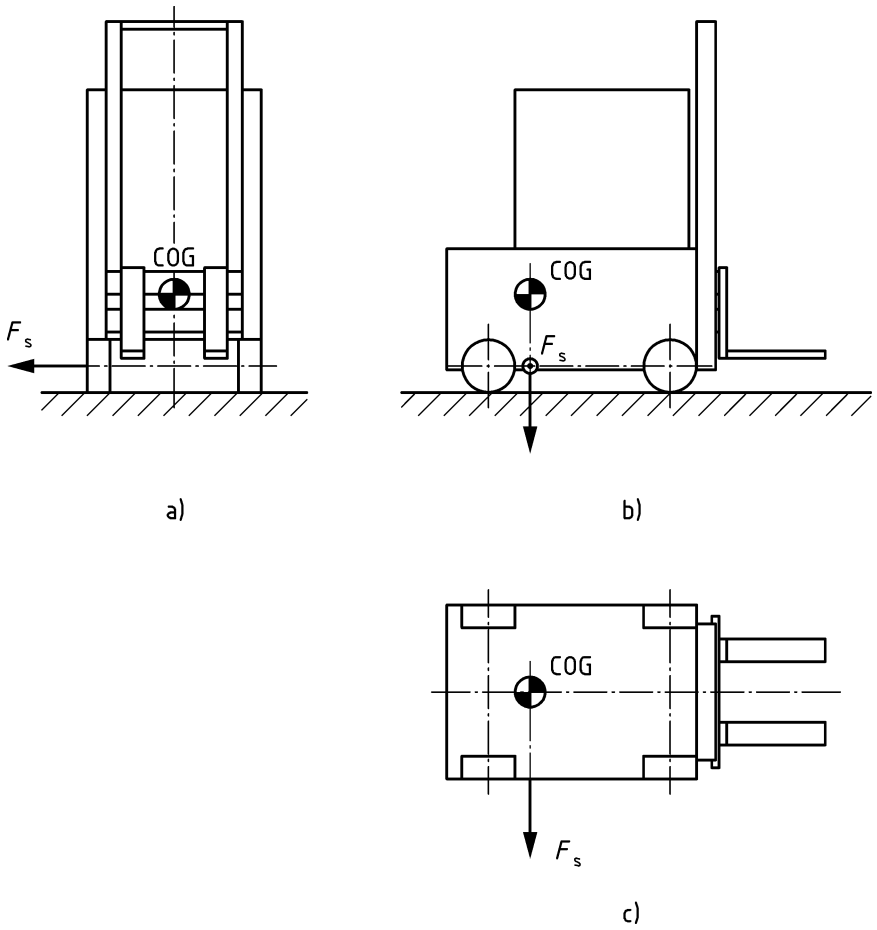
Friction measurement

B.1 General

The friction measurement described in this annex allows an estimate of the actual slip friction coefficient between the tyres of the truck and the road surface as demanded in this standard.

B.2 Test setup

The friction measurement should be conducted on the same surface that is intended for the stability test.



Key

COG	centre of gravity of the truck
F_s [N]	pulling force

Figure B.1 — Pulling direction

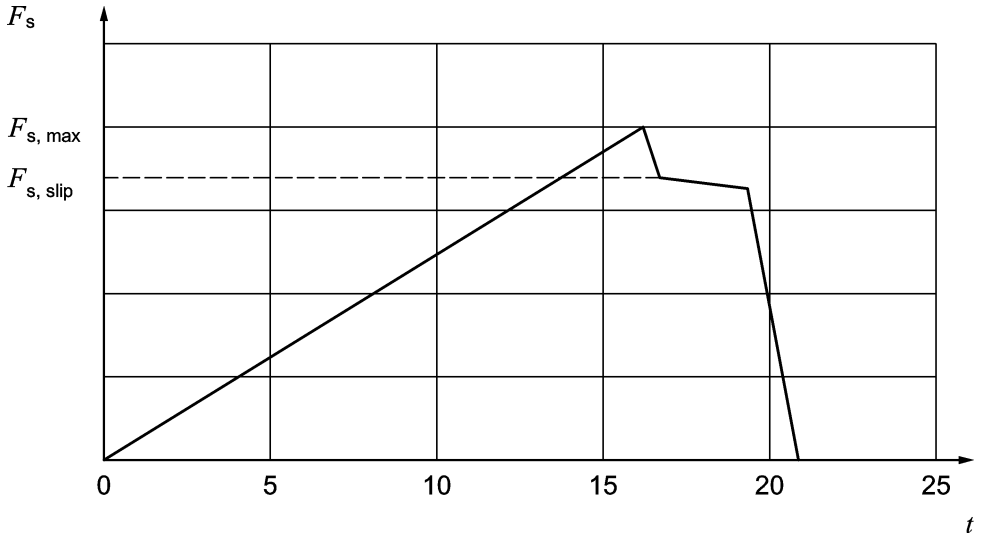
The truck should be pulled sideways as shown in Figure B.1. Therefore, ropes or equivalent devices should be attached to the truck. To keep the truck's longitudinal direction rectangular to the pulling direction, the line

of action of the applied force should have the same longitudinal coordinate as the centre of gravity of the truck. The force should be applied as low as possible above the ground. A practical attaching height is the height of the rotating axis of the wheels.

An appropriate device (e.g. a tractor or a winch) should be used to apply a soft and steady increase of the force required up to a maximum value when the truck starts to slip over the surface. The pulling device should be equipped with a force sensor that allows continuously measuring the pulling force F_s.

B.3 Test procedure

The side force should be increased slowly and steadily. After reaching a maximum value $F_{s,\,max}$ of static stick friction, the truck will start to move sideways whilst pulled to achieve a near constant force $F_{s,\,slip}$. With an enduring slow movement, the slip friction coefficient should be determined. After a short distance of movement the applied force should be reduced to stop the test. An example of the curve obtained for the pulling force is shown in Figure B.2.



Key

$F_{s,max}$	maximum pulling force [N]
$F_{s,slip}$	measured slipping force [N]
t	time [s]

Figure B.2 — Example for a measurement result

The slip friction coefficient is calculated with the slipping force $F_{s,slip}$, the mass of the truck m_{truck} and the acceleration of gravity g as follows:

$$\mu = \frac{F_{s,slip}}{m_{truck} \cdot g} \tag{B.1}$$

where

$F_{s,slip}$ [N] is the measured slipping force;

m_{truck} [kg] is the mass of the truck;

g [m/s^2] is the acceleration of gravity.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2006/42/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 2006/42/EC.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard confers, within the limits of the scope of this standard, a presumption of conformity with the relevant Essential Requirements of that Directive and associated EFTA regulations.

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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[2] LEMERLE P. HÖPPNER O., REBELLE J. Dynamic stability of forklift trucks in cornering situations: Parametrical analysis using a driving simulator. *Veh. Syst. Dyn.* 2011, **49** (10) pp. 1673–1693

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