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Heavy commercial vehicles and buses — Steady-state rollover threshold — Tilt-table test method

Véhicules utilitaires lourds et autobus — Seuil statique de renversement — Méthode d'essai du plateau incliné

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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 16333 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

Introduction

The dynamic behaviour of heavy road vehicles is a most important part of active vehicle safety. Any given heavy commercial vehicle or bus, together with its driver and the prevailing environment, forms a unique closed-loop system. The task of evaluating the dynamic behaviour is therefore very difficult since there is a significant interaction between these driver–vehicle–environment elements, each of which is complex in itself.

Moreover, insufficient knowledge is available concerning the relationship between overall vehicle-dynamic properties and accident avoidance. Since the number of variants of heavy vehicles is tremendously large, each vehicle is unique. Accordingly, results obtained using this test method apply only to the individual test vehicle and not to other vehicles, regardless of how similar they may appear to be.

Test conditions also have a strong influence on test results. Therefore, only vehicle-dynamic properties obtained under virtually identical test conditions are comparable to one another.

Additionally, this International Standard is limited to the specification of a method for estimating the *steady-state* rollover threshold of heavy commercial vehicles and buses. While this property is known to be an important component of the *dynamic* roll stability, it is not the only component. In particular, this document in no way accounts for the advantages that can result from the use of dynamic roll-stability control systems, and cannot alone be considered sufficient to establish a complete overview of the roll stability of a heavy commercial vehicle or bus.

Heavy commercial vehicles and buses — Steady-state rollover threshold — Tilt-table test method

1 Scope

This International Standard specifies a tilt-table test method for estimating the steady-state rollover threshold of a heavy commercial vehicle or bus, i.e. the maximum lateral acceleration that the test vehicle could sustain in steady-state turning without rolling over.

It is applicable to complete roll units/combinations of roll-coupled vehicle units — e.g. single-unit vehicles, tractor–semitrailer combinations, articulated buses, full trailers, B-train combinations — of commercial vehicles, commercial vehicle combinations, buses or articulated buses as defined in ISO 3833, and under Categories M3, N2, N3, O3 and O4 of ECE and EC vehicle regulations (trucks and trailers with maximum weights above 3,5 t and buses and articulated buses with maximum weights above 5 t).

It does not cover transient, vibratory or dynamic rollover situations; nor does it consider the influences of dynamic stability control systems. Furthermore, the quality of the estimate of the steady-state rollover threshold provided by the test method decreases as the tilt angle required to produce rollover increases. Even so, the results for heavy vehicles with high rollover thresholds can be used for comparing their relative steady-state roll stability.

NOTE For further limitations of the specified test method, see Annex B.

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 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8855 and ISO 15037-2, and the following apply.

3.1
critical tilt angle
ϕ_{Tc}
angle at which critical wheel lift occurs

3.2
critical wheel lift
first moment at which one or more wheels lift from the table surface, following which, stable roll equilibrium of the vehicle cannot be established

3.3
roll unit
essentially self-supporting combination of roll-coupled vehicle units, the combination being free to roll independently of other units

NOTE Typically, vehicle units joined by fifth-wheel couplings (which provide roll coupling) belong to the same roll unit, while vehicle units joined by pintle hitches (which do not provide roll coupling) belong to different roll units. Roll units including converter dollies could require minor vertical support at the drawbar pintle hitch.

3.4
steady-state rollover threshold
maximum magnitude of lateral acceleration that a vehicle can sustain during steady-state cornering on a flat surface without rolling over

3.5
tilt angle
ϕ_{T}
angle between the horizontal and a vector that is in the plane of the tilt-table surface and is perpendicular to the tilt axis

3.6
tilt-table
apparatus for supporting a vehicle on its tyres on a nominally planar surface and for tilting the vehicle in roll by tilting that surface about an axis nominally parallel to the X-axis of the vehicle

NOTE A tilt-table can be composed either of a single structure supporting all tyres of the vehicle on a contiguous surface or of multiple structures supporting one or more axles on separate, but nominally coplanar, surfaces.

3.7
tilt-table ratio
TTR
tan (ϕ_{Tc}), i.e., tan(ϕ_{T}), at the occurrence of critical wheel lift

3.8
trip rail
rail or kerb fixed to the tilt-table surface and oriented longitudinally beside the low-side tyre(s) in order to prevent the tyre(s) from sliding sideways

3.9
wheel lift of the i^{th} axle
$l_{\mathrm{w}i}$
condition in which either all left or all right tyres of the i^{th} axle are out of contact with the surface of the tilt-table

NOTE It is a logical variable with values of 1 (true) or 0 (false).

4 Principle

The tilt-table test is a physical simulation of the roll-plane behaviour of a vehicle in a quasi-steady-state turn of gradually increasing severity. In this test, the vehicle is mounted on a tilt-table with the vehicle's longitudinal axis located parallel to an axis about which the table can be tilted. The tilt-table is then gradually tilted up to the point at which the vehicle becomes unstable in roll. Safety restraints are used to prevent the actual rollover of the vehicle.

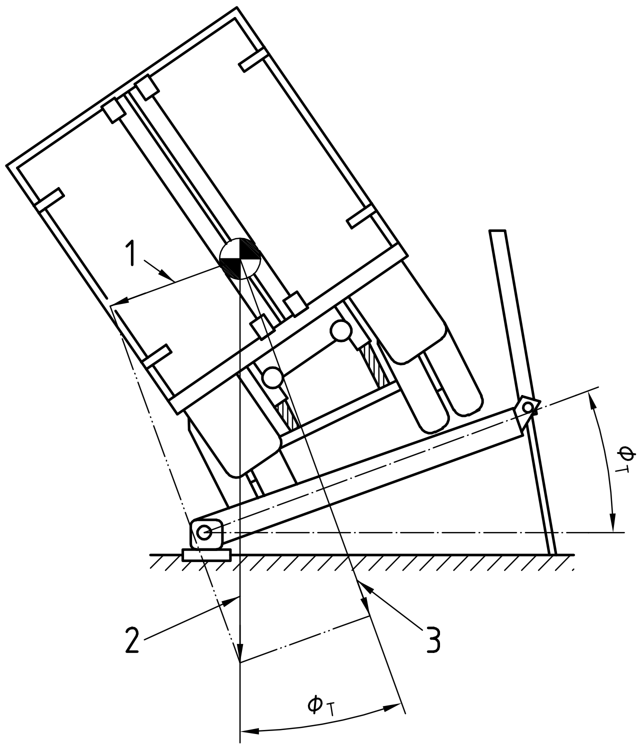
When the table is at a non-zero tilt angle, the test simulates a non-vibratory steady turn. As shown in Figure 1, the component of gravitational forces parallel to the table surface provides a simulation of the centrifugal forces experienced by a vehicle in turning manoeuvres. The progressive application of these forces by slowly tilting the table serves to simulate the effects of quasi-statically increasing lateral acceleration in steady turning manoeuvres.

When the table is tilted, the centrifugal force is simulated by the component of the gravitational force parallel to the table surface, $m \cdot g \cdot \sin(\phi_T)$, and the weight of the vehicle is simulated by the component of the gravitational force that is perpendicular to the table, $m \cdot g \cdot \cos(\phi_T)$, where m is the mass of the vehicle, g is the gravitational acceleration and ϕ_T is the tilt angle. Since the primary mechanism of actual rollover depends on the *ratio* of the centrifugal forces to the vertical forces, it is appropriate to take the ratio of the simulated lateral acceleration forces to the simulated weight to represent the lateral acceleration. At the moment of roll instability, i.e. when critical wheel lift occurs, the tangent of the tilt angle, i.e. the tilt-table ratio (TTR), is an estimate of the steady-state rollover threshold, expressed in gravitational units:

$$TTR \equiv \tan(\phi_{Tc}) = \frac{m \times g \sin(\phi_{Tc})}{m \times g \cos(\phi_{Tc})} \quad (1)$$

As the vehicle is progressively tilted during the tilt-table test, vertical load is progressively transferred from tyres on one side of the vehicle to tyres on the other side. Tyres on the unloaded side will eventually lift off of the table surface. Typically, wheel lift does not take place simultaneously for all axles; rather, lift-off occurs at different axles at different angles of tilt. Tyres that lift off of the table early in the process may rise well off the table surface before the critical wheel lift occurs and the vehicle becomes unstable in roll. It is often the case that the vehicle will become unstable even though all tyres of one or more axles (often the steer axle) remain firmly on the table surface. The tilting motion of the table should be stopped simultaneously with the vehicle becoming unstable in roll, and safety restraints should be arranged to arrest the roll motion of the vehicle immediately following that critical tyre-lift event.

Annex B presents further discussion of the tilt-table test method dealing with conceptual and practical sources of error.



Key

1 simulated centrifugal force = $m \cdot g \cdot \sin(\phi_T)$

2 actual weight = $m \cdot g$

3 simulated weight = $m \cdot g \cdot \cos(\phi_T)$

Figure 1 — Schematic diagram of tilt-table test

5 Variables

The following variables shall be determined:

a) wheel lift at each axle (l_{wi});

b) tilt angle at each axle of the vehicle (ϕ_{Ti}).

Alternatively, where it is independently assured that all values of ϕ_{Ti} are within a range of ± 0,1°, tilt angle (ϕ_T) shall be determined.

Some or all of the following variables should be determined, in order to aid in analysing the vehicle's behaviour:

— roll angle(s) relative to the tilt-table surface at relevant positions on the sprung mass(es);

— roll angle(s) relative to the tilt-table surface of unsprung mass(es);

— lateral suspension deflections;

— tyre deflections;

— air-spring pressures;

— lateral deflections of relevant elements of the chassis or payload.

It is also recommended that the data record include event markers to indicate the occurrence of significant events of interest, e.g. the transition through spring lash.

6 Measuring equipment

6.1 General

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

6.2 Description

All variables shall be measured by means of appropriate transducers, whose time histories should be recorded by a multi-channel recording system. Typical operating ranges and recommended maximum errors of the transducer recording systems for the variables not listed in ISO 15037-2 are shown in Table 1.

Table 1 — Typical operating ranges and recommended maximum errors of variables not listed in ISO 15037-2

Variable	Typical operating range	Recommended max. error of combined system
Tilt angle(s)	40°	± 0,1°
Roll angles relative to the tilt-table surface	15°	± 0,1°
Lateral deflections	± 50 mm	± 1 mm
Air-spring inflation pressures	1 500 kPa	15 kPa

6.3 Data processing

The tilt-table test is a quasi-static test so that data processing concerns relating the natural frequencies of vehicle responses and the frequency response of the instrument system do not apply in the usual manner. However, the bandwidths of the analog data systems and the sampling rates of digitising systems, in relationship to the maximum tilt rate of the table and the maximum roll rates of the vehicle and its components, influence the overall accuracy of the measurement system. Specifications should be in accordance with ISO 15037-2. In any case, the time response and latencies of all analog and digital elements of the measurement system shall be properly considered in evaluating measurement accuracy.

7 Test conditions

7.1 General

Limits and specifications for the tilt-table, ambient conditions and vehicle test conditions indicated below shall be maintained during the test. Any deviations shall be reported in the test report.

7.2 Tilt-table properties

The tilt-table facility shall have the properties given in Table 2. In addition, the tilt-table facility shall provide lateral constraint of the vehicle through adequate surface friction or, optionally, through the use of a trip rail, as specified in 8.1.2.