

Distr.  
GENERAL

TRANS/WP.29/GRRF/2000/19  
28 June 2000

Original: ENGLISH

ECONOMIC COMMISSION FOR EUROPE

INLAND TRANSPORT COMMITTEE

World Forum for Harmonization of Vehicle Regulations (WP.29)

Working Party on Brakes and Running Gear (GRRF)  
(Forty-eighth session, 11-13 September 2000,  
agenda item 2.)

PROPOSAL FOR DRAFT AMENDMENTS TO THE DRAFT REGULATION  
ON UNIFORM PROVISIONS CONCERNING THE APPROVAL OF TANK VEHICLES  
OF CATEGORIES N AND O WITH REGARD TO ROLLOVER STABILITY

Transmitted by the expert from the Netherlands

Note: The text produced below was prepared by the experts from the GRRF ad-hoc working group "Dynamic Rollover Stability" following the GRRF request expressed during its forty-third session. It contains the proposed amendments to the draft Regulation (see document TRANS/WP.29/705) and a proposal for a physical test and an alternative simulation procedure for the dynamic rollover stability of vehicles of categories M, N and O.

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Note: This document is distributed to the experts on brakes and running gear only.

Paragraph 1.(including footnote 1/), amend to read:

"1. SCOPE

This Regulation applies generally to vehicles of category M, N and O 1/ having a maximum permissible mass greater than 3500kg and in particular to tank vehicles of category N2, N3, O3 and O4, 1/, intended for the carriage of dangerous .....

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1/ Categories M, N and O as defined .....

Insert a new paragraph 2.2.1.,to read:

"2.2.1. the manufacturer of the base chassis;

Paragraphs 2.2.1. and 2.2.2. (former), renumber as paragraphs 2.2.2. and 2.2.3.

Paragraphs 2.2.3. (former), renumber as paragraphs 2.2.4.1.

Insert a new paragraph 2.2.4.,to read:

"2.2.4. the type of body to be fitted to a vehicle in service as authorised by the chassis manufacturer;"

Paragraphs 2.2.4. to 2.2.10.(former), renumber as paragraphs 2.2.5.to 2.2.11.

Paragraphs 5.1.1. to 5.2.,amend to read:

"5.1.1. a tilt table test in accordance with annex 3 to this Regulation, which simulates a non-vibratory steady-state turn, or

as an alternative, a static calculation method in accordance with annex 4 to this Regulation. If there is any doubt or dispute a tilt table test shall be used.

5.1.2. a dynamic test in accordance with annex 5 to this Regulation, or

as an alternative a simulation procedure in accordance with annex 6 to this Regulation. If there is any doubt or dispute a dynamic test shall be used.

5.2. The results of paragraphs 5.1.1. and 5.1.2. shall be considered satisfactory if the conditions set out in paragraph 5.3. and, in the case of the physical tests, paragraph 5.4. below are satisfied."

Paragraph 5.3.1., amend to read:

"5.3.1. Using the corresponding annex to this Regulation, the vehicle shall fulfil the following conditions:"

Paragraph 5.3.1.1., amend to read:

"5.3.1.1. Tilt table test method:

When tested in accordance with annex 3 the static rollover stability of the vehicle shall be such that overturning shall not occur before a tilt table angle of 23° ...."

Paragraph 5.3.1.2., amend to read:

"5.3.1.2. Static calculation method:

..... "

Insert new paragraphs 5.3.1.3. and 5.3.1.3.1., to read:

"5.3.1.3. Dynamic test and dynamic simulation method:

The dynamic rollover stability shall be such that using either the physical test procedure given in annex 5 or the simulation procedure given in annex 6, overturning shall not occur before the vehicle reaches a minimum lateral acceleration level of 4 m/s<sup>2</sup> measured at the centre of gravity of the vehicle. Note that it is permissible for any wheel to achieve zero wheel load or to lose contact with the road surface at this level of lateral acceleration, provided that the vehicle remains stable.

If the vehicle fails in one of the three tests for a specific direction (right or left), it is allowed to do one consecutive (re)test.

5.3.1.3.1. In the case of a vehicle equipped with any stability enhancement system which is not purely mechanical, such as an electronically controlled stability system, it shall also fulfil a Failure Mode Level. Until such time as this failure level has been established it shall be considered to be the minimum level specified in 5.3.1.3.

Annex 1,

Insert new items 3.2. and 3.3., to read:

"3.2. if applicable, body; make, model: .....

3.3. in case of a tank type of vehicle:"

Items 3.2. and 3.3.(former), renumber as items 3.5.1. and 3.5.2.

Insert new items 3.5.3. to 3.5.5., to read:

"3.5.3. cross-section of the tank: circular/elliptical/maxi-volume 2/

3.5.4. filling factor of the test load (% fill of the tank): .....

3.5.5. test load (water, etc.): ..... "

Item 7., should be deleted.

Items 8 to 10 (former), renumber as items 7. to 9.

Insert a new item 10., to read:

"10.                   in case of a stability enhancement system which is not purely mechanical; make, model, type: .....

Items 11.3. and 11.4., should be deleted.

Insert new annexes 5 and 6, to read:

"Annex 5

DYNAMIC LATERAL STABILITY TEST PROCEDURE

The dynamic lateral stability of motor vehicles, trailers and semi-trailers of categories M, N and O, having a maximum permissible mass greater than 3.5t, shall be determined by a single sinusoidal steer input test procedure. In the case of any trailer, a typical powered towing vehicle shall be used for the test.

The tests and requirements shall not apply to a towing vehicle specifically designed not to carry any load other than that imposed by a semi-trailer through a fifth wheel coupling device.

1.                   GENERAL CONDITIONS

1.1.                The test track

All tests shall be carried out on a smooth, clean, dry and uniformly paved road surface. The gradient of the paved test surface shall not exceed 2.5 per cent in any direction when measured over any distance equal to or larger than the maximum lateral measurement over the outer sidewalls of the tyres fitted to any axle.

1.2.                Weather conditions

The maximum average lateral wind speed shall be 3 m/s with lateral wind gusts up to 5 m/s maximum.  
The ambient temperature shall be between -5° C and +30° C.

1.3.                Tyres

The tyres used for the tests shall be chosen from the standard range of tyres specified by the manufacturer for the vehicle concerned. The choice of the tyres shall be made by the type approval authority or technical service in consultation with the vehicle manufacturer.

The tyres shall be inflated to pressures specified by the vehicle manufacturer for the vehicle in service at the laden condition.

The tolerance for the inflation pressure when cold is  $\pm 0.1$  bar.

The tyres shall have been run in for at least 200 km and shall have a tread depth of at least 90 per cent of the original depth across the entire breadth of the tread and around the entire circumference of the tyres.

1.4. Operating components

1.4.1. All operating components likely to influence the results of this test (e.g. condition and setting of springs and other suspension components and suspension geometry) shall be as specified by the vehicle manufacturer for a vehicle in service.

1.4.2. Height-levelling systems should be in the correct equilibrium condition immediately before the vehicle enters the test area.

1.5. Vehicle warm up

The vehicle and tyres shall be warmed up prior to the tests by driving at the test speed for at least 10 km.

2. MEASURING ACCURACY OF THE SIGNALS

2.1. The following variables shall be determined:

- forward velocity of the vehicle;
- lateral acceleration at the longitudinal position of the centre of gravity;
- roll angle of the body at the longitudinal position of the centre of gravity;
- steering-wheel angle.

2.2. The accuracy of the measured variables shall be better than 1 per cent for the combined transducer and recording system (including data manipulations and digital filtering).

3. NON POWER-DRIVEN VEHICLES

In the case of a non-powered vehicle, it shall be tested using a typical power-driven vehicle to be agreed by the type approval authority or technical service in consultation with the manufacturer of the non-powered vehicle.

4. VEHICLE LOADING CONDITION

The standard test condition shall be the maximum permissible mass distributed between the axles as declared by the vehicle manufacturer.

The standard type of load shall be considered to be a fixed load with properties (mass, mass distribution and maximum recommended height of the centre of gravity) specified by the manufacturer taking into account the type of body fitted or expected to be fitted to a vehicle in service.

In the case of a tank type vehicle the normally intended load may be substituted by water or any other non-dangerous fluid provided that the conditions specified in paragraph 5 (a) of annex 3 to this Regulation are met.

5. SAFETY

Outriggers may be used to prevent rollover during the test but these shall be arranged so that there is minimal or no interference with the test.

6. TEST PROCEDURE

The test procedure for the single sinusoidal steer input test consists of two phases. The first phase, the preliminary test, will determine, under safe test conditions, the steering input frequency which gives the highest roll motion (roll frequency). In the second phase the dynamic rollover stability will be determined at the steering input frequency established by the preliminary test.

6.1. Preliminary single sinusoidal steer input test

The vehicle shall be driven at a constant speed of 80 km/h or at the maximum design speed if this is less than 80 km/h. The tolerance for the speed is  $\pm 2$  km/h. Starting with straight line driving at the test speed, one full period sinusoidal steering-wheel input shall be applied with a steering frequency in the range of 0,2 Hz to 2,0 Hz. The amplitude error of the actual waveform compared to the true sine wave shall be within 10 per cent of the first peak value (see Figure 1).

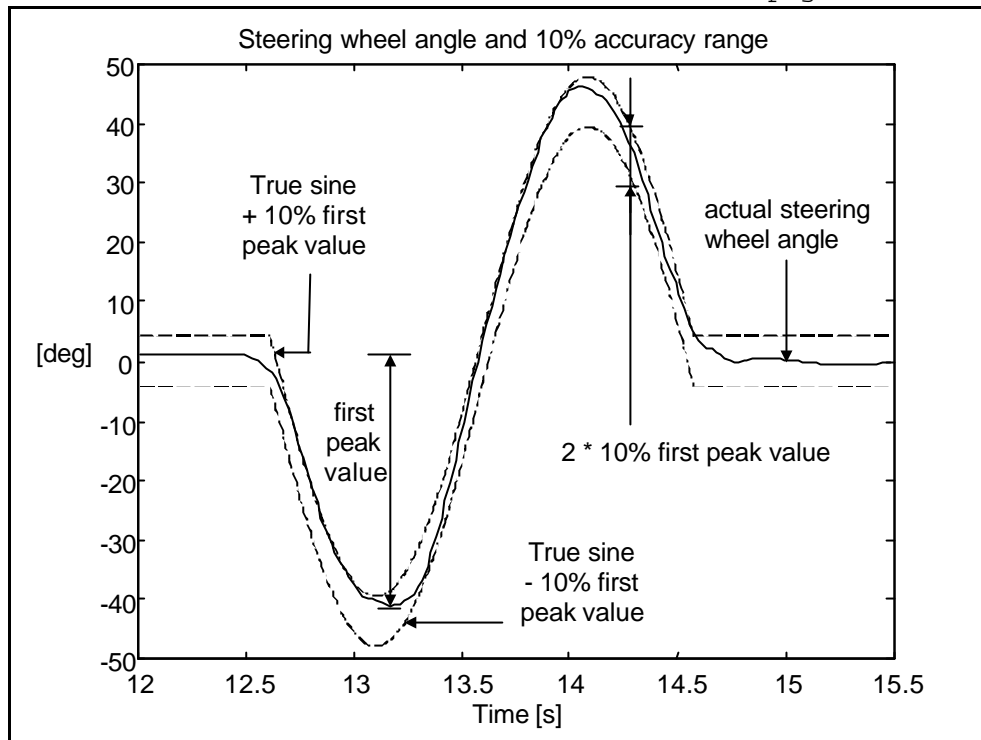


Figure 1: Steering wheel angle and true sine error band

The signals as mentioned in paragraph 2.1. above shall be recorded whilst rotating the steering wheel initially both to the left and to the right. All the tests may be done in one direction followed by all the tests in the other direction. As an alternative, the tests may be done successively in each direction for each steering wheel angle amplitude level.

The steering-wheel angle amplitude shall be determined for a frequency of 0.2 Hz and a lateral acceleration level of approximately 2 m/s<sup>2</sup>. The same steering wheel angle amplitude shall then be used whilst increasing the frequency from 0,2 Hz to 2,0 Hz in steps of 0,2 Hz. The step level may be reduced to more positively establish the peak roll frequency value.

NOTE: The maximum frequency depends on the type of vehicle, light trucks may have higher roll frequencies.

If the vehicle is equipped with any stability enhancement system which is not purely mechanical, the tests shall be repeated with the system deactivated (failure mode).

The characteristic value to be determined by this preliminary test is the maximum value of the ratio of the peak roll angle to the peak lateral acceleration (see Figure 2). The frequency value at which this occurs shall then be used in the single sinusoidal steer input test (see paragraph 6.2 below).

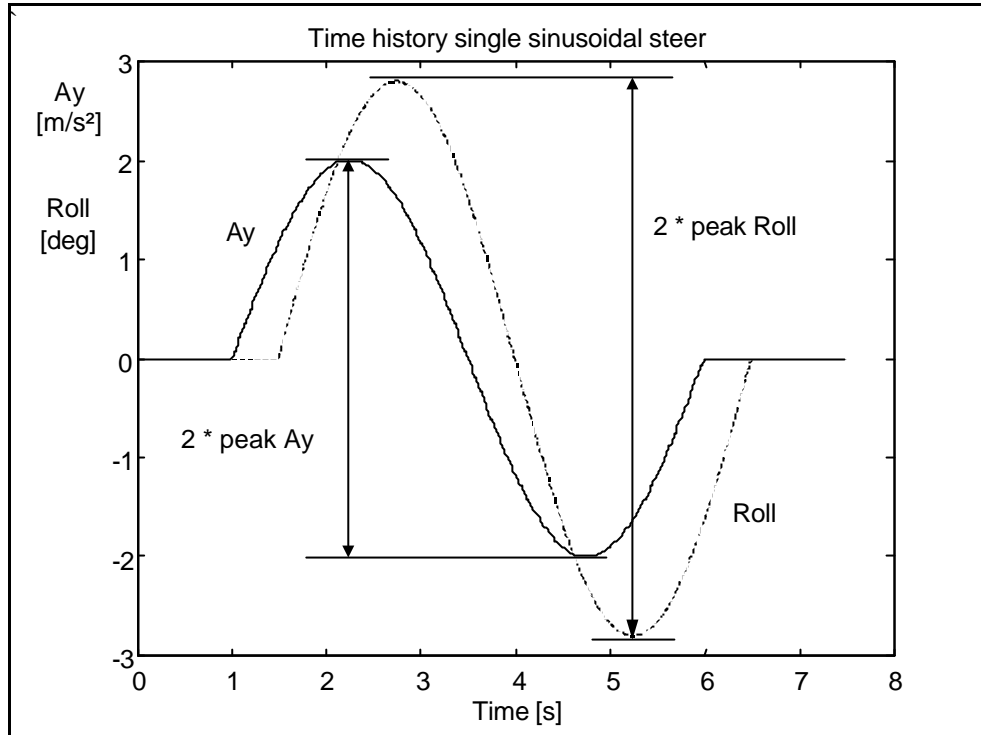


Figure 2: Peak values of lateral acceleration ( $A_y$ ) and body roll angle (Roll). The ratio is the peak Roll divided by the peak  $A_y$ .

#### 6.2. Single sinusoidal steer input test

The vehicle shall be driven at a speed of 80 km/h or at the maximum design speed if this is less than 80 km/h. The tolerance for the speed is  $\pm 2$  km/h. Starting with straight line driving, one full period sinusoidal steering-wheel angle input shall be applied at the frequency determined by the preliminary test (see paragraph 6.1 above). The amplitude error of the actual waveform compared to the true sine wave shall be within 10 per cent of the first peak value.

The steering-wheel angle amplitude shall be increased stepwise, using the same frequency determined by the preliminary test, with the aim of achieving the lateral acceleration level given in paragraph 5.3.1.3. of this Regulation.

In case the steering-wheel angle amplitude exceeds 120 degrees, the steering frequency may be lowered to the frequency of which the ratio of the peak lateral acceleration to the peak steering-wheel angle is 80 per cent of the value at 0.2 Hz.

The signals as mentioned in paragraph 2.1 above shall be recorded whilst rotating the steering wheel initially both to the left and to the right. All the tests may be done in one direction followed by all the tests in the other direction. As an alternative, the tests may be done successively in each direction for each steering wheel angle amplitude level.

The test run at the steering wheel angle amplitude which produces the lateral acceleration level given in paragraph 5.3.1.3 of this Regulation shall be performed three times.

If the vehicle is equipped with any stability enhancement system other than purely mechanical, the test shall be repeated with the system deactivated (failure mode).

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Annex 6

DYNAMIC LATERAL STABILITY SIMULATION

The dynamic lateral stability of motor vehicles, trailers and semi-trailers of categories M, N and O having a maximum permissible mass greater than 3.5t, shall be determined by a single sinusoidal steer input test simulation. In the case of any trailer, a typical powered towing vehicle shall be used for the simulation test runs.

The tests and requirements shall not apply to a towing vehicle specifically designed not to carry any load other than that imposed by a semi-trailer through a fifth wheel coupling device.

1. GENERAL CONDITIONS

1.1. Modelling and simulation tool

The simulation shall be carried out with a validated modelling and simulation tool which is either used by or has been agreed with the type approval authority or technical service.

1.1.1. The calculation method takes into account the main factors which influence the roll motion of the vehicle. The model should have at least the following vehicle parameters:

1.1.1.1. Vehicle parameters

wheel base;  
track width;  
wheel/axle geometry and wheel loads;  
centre of gravity positions of unsprung masses;  
inertia (mass,  $J_x$ ,  $J_y$  &  $J_z$ ) of unsprung masses;  
centre of gravity position(s) of sprung masses;  
inertia (mass,  $J_x$ ,  $J_y$  &  $J_z$ ) of sprung masses;  
chassis (torsional) stiffness;  
height of roll centre;  
stiffness of suspension (vertical, lateral, fore/aft and roll);  
damping characteristics of suspension systems;  
kinematics of suspension systems.

1.1.1.2. Tyre parameters

cornering stiffness;  
radial/vertical stiffness  
lateral stiffness;  
dynamic tyre/road side force friction coefficient;  
no tyre damping.

- 1.1.1.3. Other parameters
- No driver influence (a single sinusoidal steering-wheel input);
  - steering stiffness;
  - load sharing distribution between the axles of a bogie;
  - in the case of a fast height levelling system (see paragraph 1.2.1 below), the properties/characteristics of the height levelling system;
  - in the case of a stability enhancement system other than purely mechanical, the properties/characteristics of the system.

- 1.1.1.4. Pay load parameters
- centre of gravity position;
  - inertia (mass, Jx, Jy & Jz).

The vehicle parameter values represent the loaded condition.

- 1.2. Operating components

- 1.2.1. Height-levelling systems shall not be included in the simulation model unless the response time of the system is less than one second.
- 1.2.2. If the vehicle is equipped with a stability enhancement system other than purely mechanical, the simulation shall be carried out with and without the system in operation.

2. NON POWER-DRIVEN VEHICLES

In the case of a non-powered vehicle, it shall be simulated using the characteristics of a typical power-driven vehicle to be agreed by the type approval authority or technical service in consultation with the manufacturer of the non-powered vehicle.

3. VEHICLE LOADING CONDITION

The standard test condition shall be the maximum permissible mass distributed between the axles as declared by the vehicle manufacturer .

The standard type of load shall be considered to be a fixed load with properties (mass, mass distribution and maximum recommended height of the centre of gravity) specified by the manufacturer taking into account the type of body fitted or expected to be fitted to a vehicle in service.

In the case of a tank type vehicle the normally intended load shall be considered as an equivalent fixed load.

4. TEST SIMULATION

The test simulation to establish the dynamic rollover stability shall be a single sinusoidal steer input test:

The test shall simulate a vehicle being driven at a speed of 80 km/h or at the maximum design speed if this is less than 80 km/h. Starting with straight line driving, one full period sinusoidal steering input shall be applied to the steered wheels with a frequency corresponding to the roll eigen frequency and at the lateral acceleration level given in paragraph 5.3.1.3. of this Regulation.

The simulations shall be done whilst rotating the steered wheels initially both to the left and to the right.

If the vehicle is equipped with any stability enhancement system other than purely mechanical, the simulation shall be repeated with the system deactivated (failure mode).

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Annex 6 - Appendix

CALCULATION REPORT

1. Trade name or mark of the vehicle: .....
2. Vehicle type: .....
3. Manufacturer: .....
4. Modeling and simulation tool; make, model, version: .....
5. Parameters of vehicle model (see annex 6, paragraph 1.1.1.):
  - 5.1 data of vehicle parameters: .....
  - 5.2. data of tyre parameters: .....
  - 5.3. data of other parameters: .....
  - 5.4. data of pay load parameters: .....
6. Calculation:
  - 6.1. roll frequency: .....
  - 6.2. calculation results: .....
  - 6.3. in case of a vehicle equipped with a stability enhancement system which is not purely mechanical, calculation results without the stability enhancement system: .....
7. Calculation carried out by: Technical service/Manufacturer/Manufacturer's representative 1/
8. Technical service responsible for conducting approval tests: ...
9. Date: .....
10. Signature: ..... "

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1/ Strike out what does not apply.

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