Prüfbericht / Test Report
Trailer EBS D mit/with RSS

Technischer Bericht Nr. EB 134.1 für
Trailer EBS D Generation mit
Roll Stability support (RSS)

Technical Report No. EB 134.1E for
Trailer EBS D generation with
Roll Stability support (RSS)

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Vehicle Control Systems
An American Standard Company

Version 001/11.02

Technical Report

No. EB134.1E

on an electronic stability system for trailers

RWTÜV Fahrzeug GmbH

A RWTÜV Group Company

Institute for Vehicle Technology
Adlerstraße 7
D-45307 Essen
Telephone: +49(0)201825-0
Fax: +49(0)201825-4150

Corporate seat: Essen
Commercial Register section
B 9975
Chairman of the Supervisory Board:
Elmar Legge

Management:
Prof. Dr. Claus Wolff (Chairm.)
Friedo Schäfer

This Technical Report (TR) serves as a working document for the officially authorised expert or examiner of the accredited testing laboratory in the assessment of trailers according to §§ 20 and 21 StVZO or Directive 71/320/EEC as amended by 98/12/EC (27 January 1998) and ECE Regulation No. 13 / 09 (Supplement 6).

The present report describes the more extensively developed Roll Stability Support (RSS) of the TR EB134.0E, including an additional, integrated lateral acceleration sensor.

1. Identification

1.1 Manufacturer:	WABCO Vehicle Control Systems Am Lindener Hafen 21 D - 30453 Hannover
1.2 Applicant:	s. 1.1
1.3 System:	**Trailer EBS**
1.3.1 Version:	**- Trailer EBS D plus** **- Trailer EBS D plus with TCE***
	* TCE: Trailer Central Electronic
1.3.2 System function:	**Roll Stability Support (RSS)**

2 Scope of application

Semi-trailers and centre-axle trailers of the classes O_3 and O_4 according to the Framework Directive 70/156/EEC and according to annex 7 of the "Consolidated Resolution on the Construction of Vehicles (R.E.3)" respectively with system configurations: 2S/2M - 2S/2M+SLV - 4S/2M - 4S/3M.

For vehicles with adhesion-controlled steering axle RSS is only permissible in connection with a 2S/2M+SLV (steering axle controlled via a **S**elect-**L**ow-**V**alve) or 4S/3M EBS/ABS system (steering axle MAR controlled).

Note:
The tests set out in Annexes 1 to 5 were carried out with the articulated vehicle described in Annex 1.

This report also applies for centre-axle trailers. The suitability of the RSS system for centre-axle trailers was verified by tests conducted by the manufacturer as part of the initial assessment (see Technical Report EB134.0 by RWTÜV).

2.2 Installation position:

The system must be installed in accordance with the manufacturer's installation specification as shown in Appendix 1.

3 Technical Data

3.1 General functional description:

A vehicle can overturn if the critical lateral acceleration for overturning is lower than the adhesion utilisation of tyres and road. Trailers in particular have a tendency to overturn during fast cornering because of their often relatively high centre of gravity. In the case of semi-trailers the critical lateral acceleration for overturning can be relatively low compared to that of the towing vehicle.

Unlike with the towing vehicle the driver often notices the overturning tendency of the trailer too late to be able to take appropriate countermeasures (e.g. braking).

The Roll Stability Support (RSS) system recognises the imminent overturning hazard in the trailer and initiates if necessary automatic braking of the trailer. This reduces the speed of the semi-trailer unit and hence also the overturning hazard.

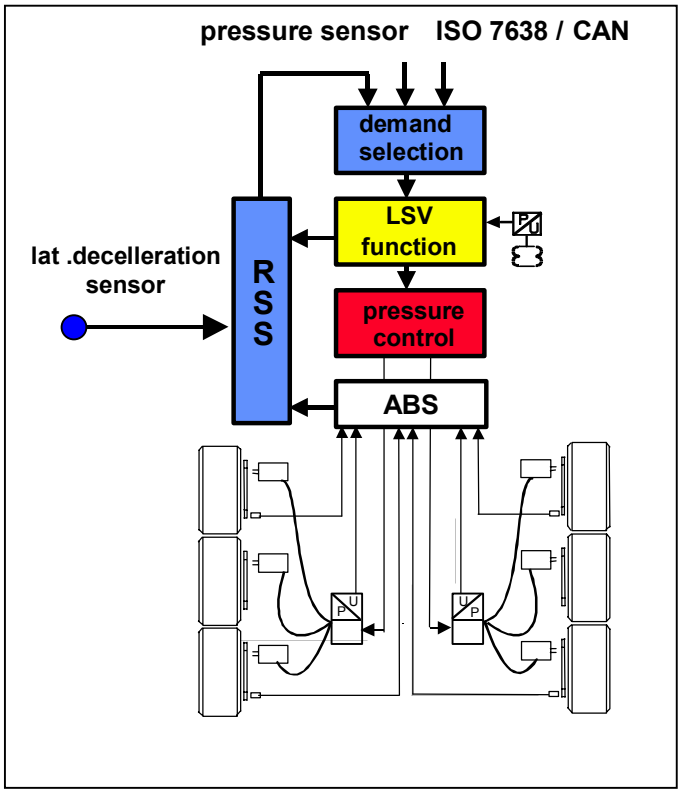

Figure 3.1 Brake management

The RSS function makes use of the known input variables of the trailer EBS, such as wheel speeds, load information, desired deceleration and the lateral acceleration measured by a sensor (see Figure 3.1).

3.1.1 Functional sequence:

Lateral acceleration: calculation:

The current lateral acceleration of the trailer is both measured continuously by a lateral acceleration sensor integrated in the trailer modulator and also calculated from the wheel speeds present. The influence of different tyre-tread circumference is eliminated by automatic tyre compensation.

Recognition of overturning hazard:

There is an overturning hazard if the load on the inside wheels is greatly reduced because of high lateral acceleration.

Overturning hazard is detected when the current lateral acceleration exceeds the lateral acceleration critical in terms of overturning (control threshold), which depends on the

load and the track width of the relevant trailer and is calculated by the system. A test pressure actuation is performed at low pressure to verify the overturning hazard detected.

The duration of this test actuation is limited in time. It is determined by the course of the current lateral acceleration (height and rate of increase) during the test actuation.

On the basis of the wheel response to the check braking the system decides if an overturning hazard actually exists or if it is not (yet) present. As long as the overturning hazard is not confirmed by the system on the basis of the wheel response (although the specified control threshold is exceeded) the control threshold is increased and the check braking continued.

Overturning hazard recognition is terminated as soon as the current lateral acceleration falls below the critical lateral acceleration for overturning.

Overturning prevention:

The system stores a certain portion of the difference between the critical lateral acceleration for overturning as adapted at the end of the check braking and the default value (value after system start), depending on the driving pattern up to that point. In a subsequent control operation (without load change) the increased control threshold, corrected by the stored adaptation value, is used.

Once the overturning hazard has been identified, the trailer is braked with high pressure in order to reduce vehicle speed and hence the lateral acceleration and the overturning hazard or to prevent overturning. The amount of the pressure applied depends on the possible adhesion utilisation and generally differs according to the type of vehicle used. In addition, the critical lateral acceleration for overturning which was increased during test pressure control is reset to its default value (value after system start). Braking with high pressure is terminated as soon as the current lateral acceleration again falls below the critical lateral acceleration for overturning.

3.1.3 Activation / Deactivation:

A prerequisite for the RSS function is the performance of a tyre adjustment. If the dynamic tyre-tread circumferences differ by more than 5 % (in relation to the largest tyre) the RSS function is blocked until all tyres are adjusted and the correction parameters stored in the ECU.

At speeds of more than 7 km/h, the RSS function is immediately available if tyres differ less than 5 %. It only

reaches its optimum effect, however, when the tyre adjustment has been completed.

At speeds greater than 7 km/h, the RSS function is always immediately available if the tyres have already been adjusted.

A self-adjustment of the lateral acceleration sensor takes place constantly during vehicle operation.

An RSS control takes place both in the partly braked and in the unbraked driving condition. If, during an ongoing RSS control, the towing vehicle sets a pneumatic or electric brake control pressure for the trailer which is higher than the pressure calculated by the RSS control, the RSS control is interrupted and the trailer is braked according to the control pressure of the towing vehicle.

3.1.4 Functional monitoring: The test pressure control is terminated when the lateral acceleration threshold, which is continuously increased during test pressure control, reaches physically implausible values.

3.2 Components

3.2.1 EBS trailer brake valve: WABCO No. 971 002 ... 0

3.2.2 Trailer modulator: WABCO No. 480 102 ... 0

3.2.3 TCE: WABCO No. 446 122 ... 0

3.2.4 EBS relay valve: WABCO No. 480 207 ... 0

3.2.5 ABS relay valve: WABCO No. 472 195 0.. 0

3.2.6 Sensors / pole wheels

3.2.6.1 ABS sensors: inductive speed sensors - WABCO No. 441 032 ... 0

Fastening in clamping bushes WABCO No. 899 760 510 4

3.2.6.2 Pole wheels: Pole wheels according to WABCO specification 895 905 000 4 with, for example, 60, 80, 90 100 and 120 teeth.

3.2.7. Axle load sensors (pressure sensors): WABCO Nos. 441 040 07 0 to 441 040 15 0 or axle load sensor integrated in the trailer modulator

3.3	**Electric plug connectors to trailer:**	Through the plug connector according to ISO 7638-1997 (7-pin) Part 1 (24 V) **or** according to ISO 7638-1985 (5-pin) (24 V)
3.4	**Warning device:**	The "Roll Stability Support" function is integrated in the trailer EBS. Malfunctions in any of the RSS components, including the integrated lateral acceleration sensor, are indicated by the yellow warning signal according to para. 5.2.1.29.2 of ECE-R13 via pin 5 of the ISO connector 7638 (see also note in para. 4.2 below).
3.5	**Tests:**	The proper functioning of the Roll Stability Support was tested on a semi-trailer unit with a 3-axle semi-trailer. Details of the test vehicles are provided in Annex 1.
3.5.1	**"Increasing curvature test"**	This test shows the system behaviour during cornering with decreasing bend radius (e.g. at a motorway exit). The test conditions and results are shown in Annex 2.
3.5.2	**"Constant circle test"**	This test shows the system behaviour during acceleration while cornering. The test conditions and results are shown in Annex 3.
3.5.3	**"J-turn test"**	This test shows the system behaviour during tangential turning into a circular track (e.g. at the transition from the deceleration lane to a motorway exit). The test conditions and results are shown in Annex 4.
3.5.4	**"Lane Change Test"**	This test shows the system behaviour during a sudden lane change (e.g. avoiding an obstacle) The test conditions and results are shown in Annex 5.
3.5.5	**Measurement data acquisition:**	The following measured variables, among others, were recorded to evaluate and document the tests: - Brake pressures - Wheel speeds - Lateral acceleration - Reference measure (height above roadway, measured in the centre of the semi-trailer's third axle) to roadway using an optical sensor ("lift sensor") as a criterion for the lift of the inside wheels

3.6 Safety assessment:

The safety assessment of the trailer EBS was conducted within the framework of the RWTÜV Technical Report EB 124.0E.
If function-impairing errors are detected the RSS function is permanently or temporarily switched off.

3.7 Electromagnetic compatibility (EMC):

To fulfil the statutory requirements regarding EMC the electronics itemised in paragraph 3.2 have been tested to Directive 72/245/EEC as amended by Directive 95/54/EC and approved under the approval marks

- e1-72/245/*95/54*1206*00
- e1-72/245/*95/54*1665*00

3.8 Test documents

The following documents were available for the test:

- Product specification
- System FMEAs

4. Statutory Regulations

4.2 Par. 5.2.1.21 of ECE-R13:

In ECE Regulation No. 13 (Supplement 4 to the 09 series of amendments) and Directive 98/12/EC (see Annex I, paragraph 2.2.1.24) it is required that, for a motor vehicle authorized to tow a trailer of category O_3 or O_4 the service braking system of the trailer may only be operated in conjunction with the service, secondary or parking braking system of the towing vehicle. This is intended to ensure that there is no danger of the trailer brakes' overheating when travelling on public roads and also that the compatibility requirements are fulfilled (see ECE-R13, Annex 10).

In Supplement 5 to the 09 series of amendments of the ECE-R13 this requirement is stated more precisely and application of the trailer brakes alone (without actuation of the towing vehicle's braking systems) is expressly permitted, provided this is used for the purpose of vehicle stabilisation.

In para. 5.2.2.17.1 of Supplement 7* to the 09 series of amendments of ECE-R13 permission is given for the trailer also to signal a fault in the electrical part of the transmission of the stability system to the towing vehicle by means of the yellow warning signal in accordance with para. 5.2.1.29.2 of ECE-R13 via pin 5 of the ISO connector 7638.

***Note:** Has not yet come into effect

5. Concluding certification

The "Roll Stability Support" function is integrated in the trailer EBS, which counteracts the tendency of the trailer to roll over. With the RSS the signals of the individual wheel speeds and the lateral acceleration sensor are determined and evaluated by the system. Automatic braking of the trailer is triggered if certain pre-specified limit values or limit values calculated by the system are exceeded.

In the present technical report the aspects regarding compliance and operating behaviour of this special function were assessed.

In the tests performed it was shown that the "Roll Stability Support" function enhances driving safety.

The special requirements for "EBS trailers" as stated in the ECE Regulation No. 13 Supplement 6 to the 09 series of amendments were positively reviewed.

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Institute for Vehicle Technology
Technical Service for Braking Systems

W. Gaupp

Dipl.-Ing. Gaupp

RWTÜV · KBA P-00009-95 0/5041 · Labor für Fahrzeugtechnik

1 Articulated vehicle

1.1 Semi-trailer tractor

Manufacturer:	RVI
Model:	Premium
Type:	4 x 2
Axle / chassis	
- Front axle:	5400 kg
- Rear axle:	8600 kg
Wheel base:	3640 mm
- Distance between rear axle and fifth wheel kingpin:	600 mm
- Suspension:	air suspension

1.2 Semi-trailer

Manufacturer:	Renders
Number of axles:	3
Vehicle category:	O_4
Load:	Tank container with 22 000 l water
Axle load:	7500 kg each
Fifth wheel load:	7500 kg
Suspension:	air suspension
Type of brakes:	drum
Height of centre-of-gravity:	approx. 2100 mm
Wheel base:	6800/1300/1300 mm
Width of vehicle without outrigger wheels:	2500 mm
Width of vehicle with outrigger wheels:	4500 mm
EBS/ABS configuration:	2S/2M

1.3 Vehicle combination

Total combination weight	36 500 kg

1. Test conditions

The test was performed on a roadway with the following course.

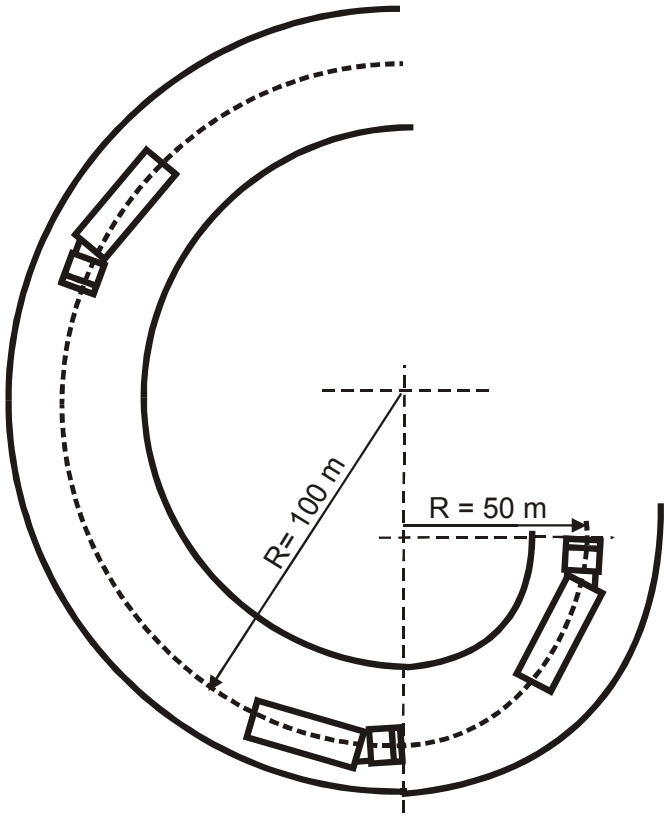


Figure 1

Roadway surface: dry asphalt

R_o = 100 m (radius of circular track at the speed of v_o)

R_{min} = 50 m (radius of circular track at maximum lateral acceleration)

The course was followed at constant speed v_0 on a circular track with approx. 100 m radius up to the beginning of bend. At the beginning of the bend the curvature increases continuously and the radius of bend (in relation to the instantaneous centre) decreases until it reaches approx. 50 m, then the curvature decreases again.

2. Test results

	without RSS			with RSS				
v_o [km/h] Speed at beginning of bend	< 50	**50**	> 50	58	**59**	60	61	63
v_K [km/h] Speed of the inside wheels at overturning limit angle	-	**50**	**= v_o**	-	**50**	52	53	55
Touchdown of outrigger wheel	no	**no**	yes	no	**no**	yes	yes	yes
v_G [km/h] Limit speed at beginning of bend	**50**			**59**				

Tests without RSS

- Without RSS the bend was taken at constant speed. At v < 50 km/h the inside wheels had road contact during the entire turn.

  At v_G = 50 km/h the wheels lifted slightly in the area of the greatest curvature, the outrigger wheel did not yet touch down (the vehicle would not have overturned even without outrigger wheels). The given test conditions resulted in an overturning limit speed of 50 km/h.

  When the speed was increased to more than 50 km/h, the outer outrigger wheel always touched down, i.e. the semi-trailer unit would always overturn at the respective speed at the beginning of the bend.

Tests with RSS

- In these tests it was possible to choose higher speeds at the beginning of the bend than without RSS, since the trailer was automatically braked as it reached the RSS control threshold so that the vehicle combination was decelerated.

  At a speed of v_0 = 58 km/h at the beginning of the bend the deceleration caused by RSS was sufficient to reduce the vehicle speed in the area of the biggest curvature to such a level that the inside wheels did not lift off the roadway.

  At a speed of v_0 = 59 km/h (= v_G) at the beginning of the bend the inside wheels lifted slightly even with the RSS activated, since the overall deceleration gained by the brake intervention of the RSS function could not sufficiently reduce vehicle speed. Touchdown of the outrigger wheel was still avoided at such a speed, however (the vehicle would not have overturned even without outrigger wheels).

  When the speed v_0 at the beginning of the bend was increased to more than 59 km/h, the outer outrigger wheel touched down (the semi-trailer unit would have overturned without outrigger wheels).

Touchdown of the outrigger wheel (overturning location) shifted forward to the less curved area (critical lateral acceleration for overturning $a_q = v^2/R$) by further increasing the speed at the beginning of the bend. The outrigger wheel thus touched down at higher speeds (52 to 55 km/h).

v_o without and with RSS

- Without RSS the highest possible speed at the beginning of the bend v_0 (= v_G), at which the outer outrigger wheel does not yet touch down during the turn is 50 km/h under the test conditions given above. In the tests with RSS function the speed v_0 at the beginning of the bend was increased to 59 km/h without a critical driving condition occurring during the turn.

1. Test conditions

The test was performed on a roadway with the following course.

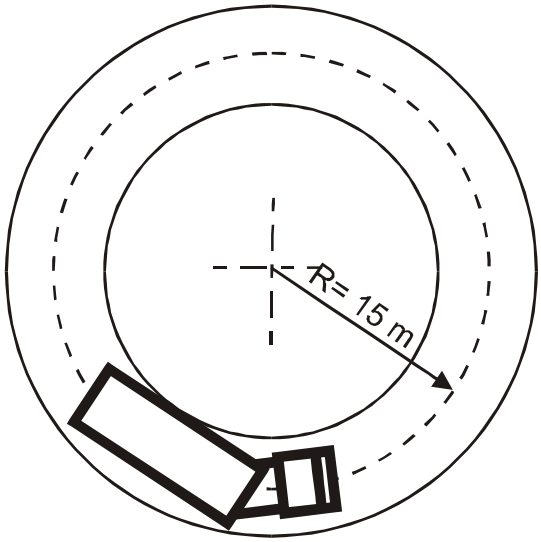


Figure 2

Roadway surface: dry asphalt

R = approx. 15 m

This test was performed with and without the RSS function:

- Without RSS the test vehicle was accelerated up to the speed at which the outer outrigger wheel touched down.
- With RSS the test vehicle was accelerated up to the speed at which the trailer was automatically braked.

2. Test results

	Mean values **without RSS**	Mean values **with RSS**
v_1 [km/h] Speed at the first RSS control brake actuation (at which the control threshold was reached)	-	23
v_2 [km/h] Speed at which braking was performed with high pressure	-	25
v_K [km/h] Speed of the inside wheels at overturning limit angle	28	-

Tests without RSS

The vehicle combination was accelerated until it reached a speed where the trailer started to overturn. The different driving tests yielded an average overturning limit speed of 28 km/h.

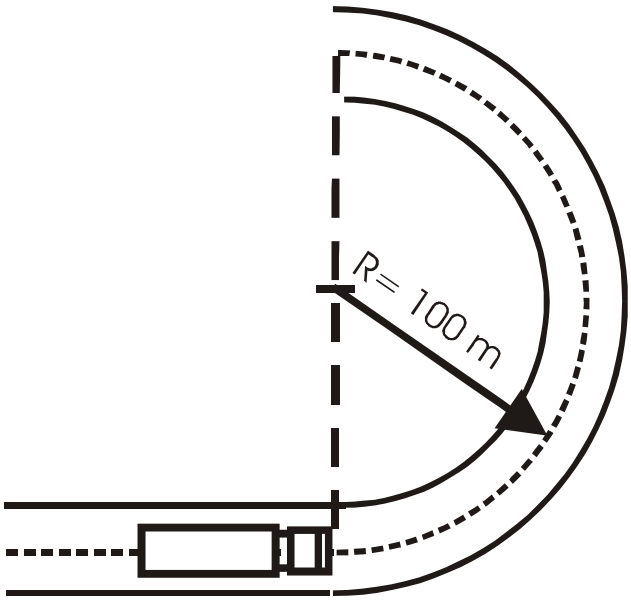
Tests with RSS

With RSS the automatic braking of the trailer was initiated before the critical speed for overturning was reached. The speed critical for overturning was thus not reached.

1. Test conditions

The test was performed on a roadway with the following course.

Figure 3



Roadway surface: Blue basalt wet

R = approx. 100 m

The limit speed v_G at which the trailer starts to jackknife on a circular track because its cornering stability is no longer sufficient was determined. The critical lateral acceleration for overturning could not be reached because of the low coefficient of friction (μ = approx. 0.2). In this test the vehicle speed was kept constant within one measurement. The initial speed before entering the circle was gradually increased until it reached a level at which the trailer became unstable because of insufficient cornering forces and the rear end of the trailer jackknifed out of the bend.

2. Test results

	without RSS [mean values]	with RSS [mean values]
v_G [km/h] Limit speed at which the trailer became unstable (jackknifed)	approx. 47	approx. 47

Tests without RSS

Without RSS the highest possible cornering speed at which the trailer could still be guided in the lane was approx. 47 km/h. Above that speed the rear part of the trailer jackknifed, since it was not possible to transfer sufficiently high cornering forces because of the relatively low adhesion utilisation conditions between wheels and roadway.
It was therefore not possible to induce overturning of the trailer. The coefficient of friction was too low to reach the critical lateral acceleration for overturning.

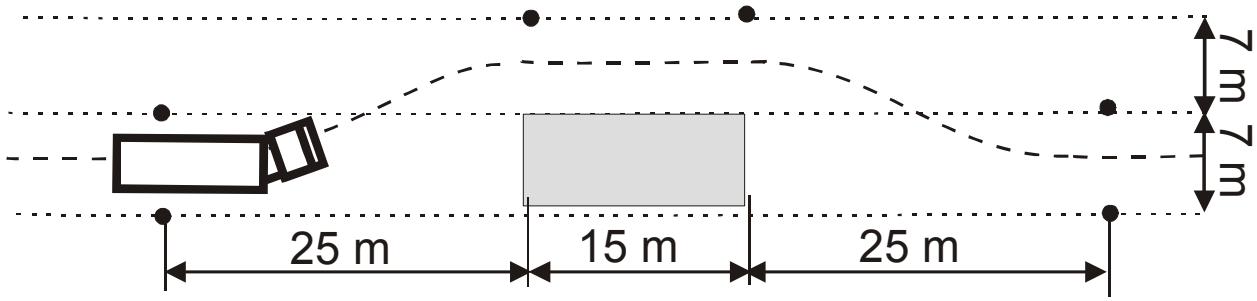
Tests with RSS

As in the tests without RSS, the highest possible cornering speed was again approx. 47 km/h because of the physical conditions. The trailer became unstable (tangential jackknifing of the rear end of the trailer out of the circular track) even before the RSS control thresholds were reached.

1. Test conditions

The test was performed on a roadway with the following course:

Figure 4



Roadway surface: moist-dry asphalt

The initial speed v_0 is the speed at the beginning of the avoidance manoeuvre.

It was established in pilot tests with what initial speed v_0 the limit speed v_G was reached at which the inside wheels lifted off during the lane-change manoeuvre.

This initial speed v_0 is taken in each case as the limit speed v_G at which the vehicle just does not yet overturn.

For safety reasons test drives above the limit speed v_G were not carried out, because with such a manoeuvre the outrigger wheel on the trailer can only prevent overturning up to a certain limit.

2 Test results

without RSS			
	measurement 1	**measurement 2**	**measurement 3**
v_o (= v_G)* [km/h] Initial speed before avoidance manoeuvre	50	51	52
v_o = v_G [km/h], Mean value from measurements 1, 2, 3	51		
v_K [km/h] Speed of the inside wheels at overturning limit angle	49	50	51
v_K [km/h], Mean value from measurements 1, 2, 3	50		

with RSS			
	measurement 4	**measurement 5**	**measurement 6**
v_o (= v_G)* [km/h] Initial speed before avoidance manoeuvre	67	67	68
v_o = v_G [km/h], Mean value from measurements 4, 5, 6	67		
v_K [km/h] Speed of the inside wheels at overturning limit angle	50	- (no lift yet)	- (no lift yet)

* The measurements given here show the initial speeds v_o, which at the same time are identical with the limit speeds v_G. During these tests the inside wheels did not lift or lifted only slightly during the lane change manoeuvre. With all tests the outer outrigger wheel did not yet touch down.

Tests without RSS

Without RSS, the double lane change was performed with an initial speed of max. 51 km/h (mean value). The inside wheels lifted off (beginning of overturning) at approx. 50 km/h in the rear area of the lane change (cutting back into the right lane).

Tests with RSS

The initial speeds in the driving tests with RSS were higher than those without RSS. In pilot tests they were chosen in such a way that the deceleration by RSS was sufficient to reduce the vehicle speed to the critical limit speed v_K.

With RSS the trailer was already braked with high pressure as the vehicle changed to the left lane. From this moment on the vehicle speed was reduced much more than in the driving tests without RSS, where the speed was merely reduced by slightly closing the throttle right during the lane change.

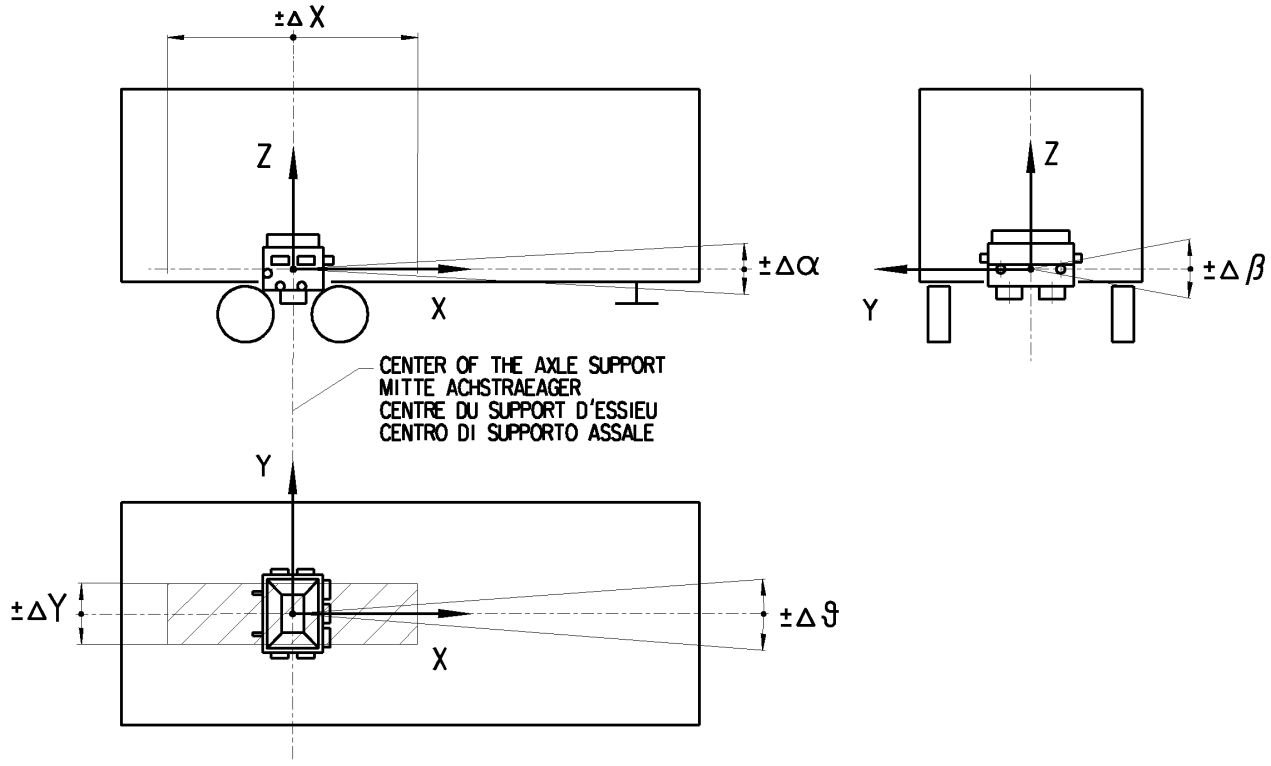
With RSS it was therefore possible to perform the lane-changing test with a higher initial speed v_o (67 km/h as against 51 km/h without RSS).

Because of the physical boundary conditions, however, the limit speed v_K of 50 km/h at which the inside wheels lifted off was approximately the same as in the driving tests without RSS.

RSS with Lateral Acceleration Sensor
Installation Specification

Admissible installation position of RSS modulator:

Δ X [mm]	Δ Y [mm]	Δ α	Δ β	Δ δ
±2000	±300	±15°	±3°	±3°



The brake cylinder and sensors of the respective trailer side must be connected only with the modulator side turned towards it.

It is to recommend to calibrate or check the modulator inclination by PC diagnosis. Where no calibration is conducted, self-calibration takes place during vehicle operation.