TRAILER ANTI-LOCK BRAKING SYSTEM APPROVAL REPORT

Approval Report No: EB 123.8E

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0. General

The purpose of this report is to add the variant E to the Trailer EBS (in addition to the variant D).

For the sake of clarity the two different variants are covered by separate reports.

Variant D is covered by the TÜV NORD System Approval Report EB123.7E and variant E by this report.

Thus, all tests which are related to the variant D are eliminated in this report.

For the sake of simplicity the Manufacturer's Information Document "ID_EB123.8E" of the Trailer EBS E system is abbreviated to **ID_TEBS**.

1. Identification

1.1 Manufacturer: WABCO Vehicle Control Systems
Am Lindener Hafen 21
D - 30453 Hannover

1.2 System name/model: **Trailer EBS**

1.3 System variant: **E** (see also paragraph 1.3 of ID_TEBS)

Versions:
- **Trailer EBS E**
- **Trailer EBS E with TCE***

* TCE: Trailer Central Electronic

Note: Regarding the description of the above mentioned different versions see paragraph 2.1.3 of **ID_TEBS**.

2. System and installation

2.1 Configurations: **2S/2M - 2S/2M+SLV - 4S/2M - 4S/2M+1M - 4S/3M**

See also paragraph 2.1 and Appendix 1 of ID_TEBS

2.1.1 Category A performance: All anti-lock system configurations and installations defined in Appendix 1 of ID_TEBS comply with the prescribed split friction requirements defined in paragraph 6.3.2 of annex X to Directive 71/320/EEC and annex 13 to ECE-Regulation No. 13.

2.2. Range of application: All system configurations as defined in 2.1 above may be used on semi- or centre-axle trailers having up to 3 axles.

4S/3M configurations may be used on full trailers with either 2 or 3 axles.

For specific applications refer to section 2 and Appendix 1 of ID_TEBS.

For more detailed system installation examples refer to paragraph 3.5 and Appendix 4 of ID_TEBS.

2.3 Methods of powering: All system configurations have the ability to accept a continuous power supply via the prescribed special connector conforming to ISO 7638 and - as a back up - an intermittent power supply via the ISO 1185 (24N) or ISO 12098 connector (stop lamp circuit).

Permanent To comply with the requirements of Directive 71/320/EEC and ECE Regulation 13 full functionality of the system can only be obtained when connected to an interface conforming to the following standards:

ISO 7638:1985	5 Pin
ISO 7638:1997 Part 1 (24 V)	5 Pin
ISO 7638:1997 Part 1 (24 V)	7 Pin

Intermittent: As a safety function in the event of a failure of the permanent ISO 7638 electrical power supply the system is able to receive intermittently electrical power from the ISO 1185 (24N) or ISO 12098 connector (stop lamp circuit). In this case only the anti-lock braking and the load-dependent brake force controls are available.

For more detailed information see ID_TEBS, paragraphs 1.5 and 3.4.

2.4 Identification of approved components

2.4.1 Wheel speed sensors: see paragraph 3.1 of ID_TEBS

2.4.2 Controller: see paragraph 3.2 of ID_TEBS

2.4.3 Modulators: see paragraph 3.3 of ID_TEBS

The part numbers not fully specified in ID_TEBS indicate that deviations from the listed equipment/components are possible. These, however, have no influence on the functions and effect with regard to the inspection performed.

2.5 Energy consumption

2.5.1 Drum brakes

2.5.1.1 Equivalent static brake applications:

Semi-trailers:

n_{e_EC} = 11 applications

n_{e_ECE} = 13 applications

Full trailers:

n_{e_EC} = 11 applications

n_{e_ECE} = 13 applications

Notes:

- The values n_{e_EC} above is to be used with the verification procedure defined within annex XIV, paragraph 6.2 of Directive 71/320/EEC.
- The values n_{e_ECE} above is to be used with the verification procedure defined within annex 20, paragraph 7.3 of ECE-Regulation No. 13.

2.5.1.2 Ratio of actuator stroke against brake lever length: **R =** s_T / l_T **= 0.2** (in all cases)

2.5.2 Disc brakes:

Annex XIV of Directive 71/320/EEC only defines a test procedure for trailers with drum brakes but states that alternative designs may be taken into consideration. In the case of disc brakes it is not possible to manipulate the stroke/pressure relationship due to the integration of automatic wear adjustment. To establish an alternative procedure, comparative testing was carried out with an unmodified installation and an installation with a 20 % increase in

delivery volume. This simulated a condition of R x 1,2 so that the equivalent number of static brake applications could be defined for the increased volume condition. This value is defined below as n_{e_EC}.

2.5.2.1 Equivalent static brake applications: see also ID_TEBS, paragraph 2.6.1.3

Semi-trailers:

n_{e_EC} = 11 applications

n_{e_ECE} = 12 applications

Full trailers:

n_{e_EC} = 11 applications

n_{e_ECE} = 12 applications

Notes:

- The brake applications n_{e_EC} defined above already take account of an increase in delivery volume of 20 %. Therefore, only in the case of trailers equipped with disc brakes, the procedure defined in paragraph 6.2.1.2 of annex XIV of Directive 71/320/EEC is to be carried out without any increase in actuator stroke as defined in paragraph 6.2.1.1 of annex XIV.
- The values n_{e_ECE} above is to be used with the verification procedure defined within annex 20, paragraph 7.3 of ECE-Regulation No. 13.

2.6 Additional features: The following additional features are provided as options. They are not subject to the assessment of this report.

2.6.1 Load-dependent brake force control (LSV): see ID_TEBS, paragraph 1.5.1.1.2

2.6.2 Monitoring of brake air pressure: see ID_TEBS, paragraph 1.5.1.1.7

2.6.3 Lifting axle control: see ID_TEBS, paragraph 1.5.1.1.8

2.6.4 Integrated speed switch: see ID_TEBS, paragraph 1.5.1.1.9

2.6.5 Standstill function: see ID_TEBS, paragraph 1.5.1.1.5

2.6.6 Emergency braking function: see ID_TEBS, paragraph 1.5.1.1.6

2.6.7 Roll Stability Support : see ID_TEBS, paragraph 1.5.1.1.11

2.6.8 ECAS: see ID_TEBS, paragraph 1.5.1.1.12

2.6.9 Parameter setting: see ID_TEBS, paragraph 1.5.1.1.13

3. Test data and results

3.0 General: (e.g. test schedule, worst case cross referencing) see Appendix 4 of this approval report

This System Approval Report covers only the Trailer **EBS "E"** variant.

All tests for the Trailer **EBS "D"** variant which have been carried out are described in the System Approval Report EB123.7E of TÜV NORD.

To differentiate between the various tests for the variants D and E (new modulator design) the following distinguishing symbol is used:

".8" Tests carried out for this System Approval Report EB123.8E of TÜV NORD

3.1. Test vehicle data:	see Appendix 3 of this approval report
3.2. Test surface information:	see Appendix 2 of this approval report
3.3. Test results	
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3.3.2.2 Test results:	see Appendix 4-2 of this approval report
3.3.3. Split-friction test:	see Appendix 4-3 of this approval report
3.3.4. Low speed performance:	see Appendix 4-4, paragraph 1 of this approval report
3.3.5. High speed performance:	see Appendix 4-4, paragraph 2 of this approval report
3.3.6. Additional checks	
3.3.6.1 Transition from high to low-adhesion surfaces:	see Appendix 4-4, paragraph 3 of this approval report
3.3.6.2 Transition from low to high-adhesion surfaces:	see Appendix 4-4, paragraph 4 of this approval report

3.3.7 System safety assessment/ failure mode simulation:

The assessment and simulation was carried out following the procedure defined within Annex 18 to ECE-Regulation No. 13. The results from this assessment are reported in TÜV NORD Test Report EB 124.4E (see Annex 1 "Electronic Function & Safety").

3.3.8. Functional checks of optional power connections:

A failure of the ISO 7638 power supply was simulated by disconnecting the connector. In this case the anti-lock braking function and load dependent pressure control remains operational when the system is wired to the stop lamp supply of either the ISO 1185 or ISO 12098 connections. This mode of operation is intended to enhance the failure modes of the braking system in the event of a failure of the ISO 7638 power supply occurs in service and is not a means of powering the braking system when no power supply failure exists (see also paragraph 2.3 of this report and paragraphs 1.5.1 c) and 3.4 of ID_TEBS).

3.3.9 Electromagnetic compatibility:

The system has been tested and verified to conform to the requirements of Directive 72/245/EEC as last amended by Directive 2006/28/EC*. A copy of the approval report is included in ID_TEBS (see paragraph 3.6 and Appendix 6 of that document).

* **Note:** This approval does not make reference to ECE-Regulation 10. However, the performance requirements of Directive 72/245/EEC as last amended by Directive 2006/28/EC are more extensive than those of ECE-Regulation 10/02. Since Directive 72/245/EEC contains also all technical requirements of ECE-Regulation 10/02 compliance with ECE-Regulation 10/02 is assured as well.

3.3.10 ADR regulations:

Within the test procedure according to Annex XIV and Annex 19 resp. no assessment was performed against ADR (Regulation governing Road Transport of Hazardous Goods). For information, see WABCO statement in the Manufacturer's Information Document, paragraph 3.4.

4. Limitations of installation

4.1. Tyre to exciter relationship:

The relationship of tyre circumference to the resolution of the exciter is defined in ID_TEBS, paragraph 2.3.

4.2. Tyre size tolerance:

The permissible tolerance on tyre circumference between one axle and another fitted with the same exciter is defined in ID_TEBS, paragraph 2.4, see also Appendix 5, paragraph 1 to this approval report.

4.3. Suspension type:

System performance was verified on trailers with balanced pneumatic and mechanical suspensions. Paragraph 2.5 and Appendix 2 of ID_TEBS defines approved suspensions for the purpose of the application of this approval.

In the case semi-trailers the measured braking performances refer to vehicle combinations where the coupling heights (fifth wheel) of the tractor and trailer where of a similar height, thus leading to equal static loads among the trailer axles (no or almost no longitudinal inclination of the trailer chassis).

4.4. Differential(s) in brake input torque within a trailer bogie:

- permissible on all system configurations

  see also paragraph 2.6 of ID_TEBS and Appendix 5, paragraph 2 to this approval report

4.5. Wheel base of full trailer

4.5.1 Two axle full trailers:

The wheel base is defined as the distance between centre line of axle 1 and the centre line of axle 2. The minimum approved wheel base being 3000 mm.

4.5.2 Three axle full trailers:

The wheel base is defined as the distance between centre line of axle 1 and the centre between the wheels of axles 2 and 3. The minimum approved wheel base being 3745 mm.

4.6.	Brake type:	The anti-lock system configurations covered by this approval are deemed to be satisfactory for trailers equipped with either air operated drum or disc brakes.
4.7.	Tube sizes and lengths:	see paragraph 3.5 of ID_TEBS and Appendix 5, paragraph 2 to this approval report **Note:** The use of the tube sizes recommended does not guarantee that the prescribed brake system response time can be fulfilled, therefore it shall be demonstrated that this requirement is fulfilled for each installation.
4.8.	Load sensing device application:	not applicable (LSV function - see paragraph 1.5.1.1.2 of ID_TEBS)
4.9.	Warning signal sequence:	All configurations have the option of two discrete warning signal sequences - see paragraph 3.4 of ID_TEBS - both of which fulfil the prescribed requirements of Directive 71/320/EEC and ECE-Regulation No. 13.
4.10	Other recommendations/limitations	
4.10.1	Installation limitations:	For approved installation options with respect to sensor/modulator locations and recommendations for the use of lifting and steering axles see Appendix 1 of ID_TEBS. **Note:** This report does not cover an assessment of the reaction of the available steering systems to the anti-lock braking control of the “Trailer EBS”.

5. Date of test:

1997 - 1999 - 2002 – 2004 - 2006

The tests have been carried out and the results reported in accordance with Annex 19 to ECE Regulation No. 13 as last amended by the 10 series of amendments including Supplement 2 and Annex XIV of Directive 71/320/EEC as last amended by Directive 2002/78/EC.

6 Appendices

Appendix 1	Abbreviations & Codes
Appendix 2	Test track data
Appendix 3	Test vehicle data

Appendix 4	Test results
Appendix 4-1	Utilisation of adhesion
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7 Annex — **Manufacturer's Information Document - ID_EB123.7E of 15.01.2007**

Essen, 24th January 2007
TDB/Gaupp
Order-No. 06.1216

TÜV NORD Mobilität GmbH & Co. KG
Institute for Vehicle Technology and Mobility (IFM)

Technical Service for Braking Systems

Accredited by the accreditation authority of the Kraftfahrt-Bundesamt Bundesrepublik Deutschland - Federal Republic of Germany - DAR-registration-number KBA-P 00004-96

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Flensburg, 09.03.2007

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Beglaubigt:
Verw.-Angestellte:

Appendix 1 - Abbreviations & Codes

.8	Distinguishing symbols to denote tests carried out with the test vehicles used for the System Approval Report EB123.8E.
A14	Energy consumption tests according to the procedure defined within annex XIV of Directive 71/320/EEC
A19	Energy consumption tests according to the procedure defined within annex 19 of ECE-Regulation No. 13
"ABS"	measurement of "z" with the anti-lock braking system in operation
BC	brake cylinder
E	wheel base
ER	distance between king-pin and centre of axle or axles of semi-trailer.
ε	the adhesion utilised by the vehicle: quotient of the maximum braking rate with the anti-lock braking system operative (z_{AL}) and the coefficient of adhesion (k)
f	$f = z_{RALH} / z_{RALL}$
h_R	height of centre of gravity of trailer
h_D	height of drawbar (hinge point on trailer)
h_K	height of fifth wheel coupling (king pin)
ID_TEBS	Manufacturer's Information Document of the Trailer EBS E system
INR	indirectly control
INSR	indirectly sidewise control
IR	individual control
k	coefficient of adhesion between tyre and road
"K"	measurement of "k" with the anti-lock braking system inoperative between 40 km/h and 20 km/h
l_T	brake lever length in mm
LSV	load sensing valve (LSV function: load-dependent brake force control)
MAR	modified axle control
MSR	modified sidewise control
n_e	number of equivalent static brake applications
PA	mass of the trailer
Pf	mass of the front axle of the full trailer
PM	mass of the motor vehicle (including imposed king pin load if applicable)

PMd	total normal static reaction of road surface on the unbraked and driven axles of the motor vehicle
PMnd	total normal static reaction of road surface on the unbraked and non-driven axles of the motor vehicle
p_0	initial pressure in the air reservoir
p_{15s}	pressure after 15 s
p_5	air reservoir pressure after 5th static brake application
$p_{5+20\%}$	in the case of disc brakes: air reservoir pressure after 5th static brake application with a 20 % increase in delivery volume; see paragraph 2.5.2 of this approval report
Pr	static reaction of the road of the rear axle of the full trailer
PR	total normal static reaction of road surface on all wheels of the trailer
PRnd-kf	static reaction of the road surface of the unbraked axles of the full trailer during the determination of k for a front axle
PRnd-kr	static reaction of the road surface of the unbraked axles of the full trailer during the determination of k for a rear axle
R	ratio of k_{peak} to k_{lock}.(according to Appendix 4 of Directive 98/12/EC and Appendix 4 of Annex 13 to ECE-Regulation No. 13)
TCE	Trailer Central Electronic
V_0	capacity of the braking system air reservoir(s) in litres
s_T	brake chamber push rod travel in mm
t_{zRAL}	deceleration time for the calculation for z_R
z	braking rate
z_R	braking rate z of the trailer with the anti-lock braking system inoperative
z_{RAL}	braking rate z of the trailer with the anti-lock braking system operative
z_{RALH}	z_{RAL} on the surface with the high coefficient of adhesion
z_{RALL}	z_{RAL} on the surface with the low coefficient of adhesion
z_{RALS}	z_{RAL} on the split surface

Appendix 2 - Test track data

1 Test surface information

1.1 Road surface with high adhesion:

dry asphalt

This surface was used for the purposes of all tests with the exception the surface transition tests (see Appendix 4-4)

wet/damp asphalt

This surface was used for the purposes of the surface transition tests.

1.2 Road surface with low adhesion:

- µ-split measurements:

Wet blue basalt

The characteristics of the wet basalt surface were obtained in accordance with the requirements defined in Directive 71/320/EEC and ECE-Regulation No. 13 as follows:

The relationship of surface adhesion against wheel slip for the full adhesion curve was determined with a commercial vehicle measuring wheel.

The vehicle from which the ratio R for a commercial vehicle was determined had the following characteristics:

Test vehicle:	Special test trailer
Axle weight	7000 kg*
Tyre type:	Michelin XZA1 295/80 R22.5
k_{peak}	0.16
k_{lock}	0.14
Ratio „R“:	1.14

* Weight of measuring wheel = 3500 kg

- Surface transition tests (see Appendix4-4): :

Wet steel plates

Appendix 3 - Test vehicle data

1 Vehicle data

To distinguish the different test vehicles the following symbols are used for the various tables below:

".8" Trailers which were used for the tests of amendment **8** (variant E) of the TÜV NORD System Approval Report EB123.8E.

Note: The test trailers up to the distinguish symbol "7" (variant D) are covered by TÜV NORD System Approval Report EB123.7E.

1.1 General

Table "Overview test vehicles ".8"

Ref.	Manufacturer	Type	Susp.	Brake	Brake-man.	BC/ l_T [mm]
S11.8	Schmitz Gotha	one axle semi-trailer (wheels of 1st and 3rd axle lifted)	**air**	**disc**	**WABCO**	2x20"/69
S12.8	Schmitz Gotha	two axle semi-trailer (wheels of 1st axle lifted)	**air**	**disc**	**WABCO**	4x20"/69
S13.8	Schmitz Gotha	**three axle semi-trailer**	**air**	**disc**	**WABCO**	6x20"/69
S21.8	Kögel	one axle semi-trailer (wheels of 1st and 3rd axle removed)	**mech.**	**drum**	**BPW**	2x24"/150
S22.8	Kögel	two axle semi-trailer (wheels of 1st axle removed)	**mech.**	**drum**	**BPW**	4x24"/150
S23.8	Kögel	**three axle semi-trailer**	**mech.**	**drum**	**BPW**	6x24"/150
Z32.8	Schmitz Gotha	**two axle centre-axle trailer**	**air**	**drum**	**BPW**	4x24"/150
FS41.8	Sommer	"converted semi-trailer" (first axle unbraked - used only as a dolly axle, second axle lifted)	air	disc	WABCO	2x20"/69
F42S.8	Sommer	two axle full trailer (3nd axle lifted)	air	disc	WABCO	2x24"/69 2x20"/69
F42L.8	Sommer	two axle full trailer (wheels of 2nd axle	air	disc	WABCO	2x24"/69 2x20"/69

Ref.	Manufacturer	Type	Susp.	Brake	Brake-man.	BC/ l_T [mm]
		removed)				
F43.8	Sommer	**three axle full trailer**	air	disc	WABCO	2 x 2 4 ” / 6 9 4 x 2 0 ” / 6 9
F52.8	Schmitz	**two axle full trailer**	air	drum	BPW	4x24’’/150

1.2 Weights and dimensions (“K” and “ABS” measurements)

The tables below define the fixed parameters of the trailers used for the purpose of this approval.

Table “Weights and dimensions of test vehicles “.8”

	S11	S12	S13	S21	S23
Number of Axles	**1**	**2**	**3**	**1**	**3**
	1st & 3rd lifted	**1st lifted**	**-**	**1st & 3rd lifted**	**-**
P Truck [kg]	**7120**	**7120**	**7120**	**7010**	**7010**
PM [kg]	**8230**	**12255**	**10310**	**9330**	**9410**
PMnd [kg]	**4930**	**5510**	**5290**	**5080**	**5070**
PMd [kg]	**3300**	**6745**	**5020**	**4250**	**4340**
P (Trailer) [kg]	**5810**	**10310**	**10840**	**8060**	**9960**
PR [kg]	**4700**	**5176**	**7650**	**5740**	**7560**
h_R mm]	**1000**	**1250**	**1250**	**1050**	**1050**
h_K [mm]	**1200**	**1200**	**1200**	**1200**	**1200**
ER [mm]	**7530**	**8185**	**7530**	**7250**	**7250**

	Z31	Z32
Number of Axles	**1**	**2**
	2nd lifted	**-**
P Truck [kg]	**8400**	**8400**

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	Z31	Z32
PM [kg]	**8590**	**9060**
PMnd [kg]	**3910**	**3710**
PMd [kg]	**4980**	**5350**
P (Trailer) [kg]	**3460**	**5430**
PR [kg]	**3270**	**4770**
h_R mm]	**720**	**870**
h_K [mm]	**375**	**375**
ER [mm]	**5850**	**6525**

	F42S.8	F42L.8	F43.8
Number of Axles	**2**	**2**	**3**
axle lifted / removed	**3rd wheels removed**	**2nd lifted wheels removed**	**-**
PM [kg]	**5910**	**5910**	**5910**
PMnd [kg]	**3220**	**3220**	**3220**
PMd [kg]	**2690**	**2690**	**2690**
P (Trailer) [kg]	**5120**	**5080**	**7770**
PR [kg]	**5120**	**5080**	**7770**
Pf [kg]	**2410**	**2510**	**2710**
Pr [kg]	**2710**	**2570**	**5060**
PRnd-kf [kg]	**2710**	**2570**	**5060**
PRnd-kr [kg]	**2410**	**2510**	**2710**
h_R mm]	**1200**	**1200**	**1350**
h_D [mm]	**820**	**820**	**820**
E [mm]	**3000**	**4490**	**3745**

1.3 **Weights** (energy consumption tests)

Table "Weights (energy consumption tests) - test vehicles ".8"

	EEC Annex XIV worst case loading			ECE Annex 19 loading		
Trailer	**P** (Trailer) **[kg]**	**PR [kg]**	**Axle load (average) [kg]**	**P** (Trailer) **[kg]**	**PR [kg]**	**Axle load (average) [kg]**
FS41.8*	5180	5180	2590	4710	4710	2355
S12.8	10310	5176	2588	9510	4500	2250
S13.8	10840	7650	2550	8525	6635	2210
S23.8	9960	7560	2520	9340	6980	2330
Z32.8	5870	5350	2675	5430	4770	2385
F42S.8	5180	5180	2590	4710	4710	2355
F42L.8	5080	5080	2540	4550	4550	2275
F43.8	7770	7770	2590	7060	7060	2355
F52.8	5310	5310	2655	4660	4660	2330

* First axle (of 2-axle full trailer F42) used only as an unbraked dolly axle to simulate a one axle semi-trailer.

Appendix 4 - Test results

1 Locations and identification of sensors on test vehicles

The following table provides codification examples of the locations and identification of sensors on test vehicles

System configuration _S number of sensors (of directly controlled wheels) _M number of pressure modulators	**Sensing-identifier** sensor reference and position within the bogie	**Notes** „X“ and “S” denote that no sensor is fitted on given axle “H” - “Z” - “L” ⇐ see explanation in the “**Note**” below	
		Sensors	**Modulators**
2S/2M	HX	**Axle 1**: sensors c, d (IR-controlled axle) **Axle 2**: not sensed (INR-controlled axle)	The trailer modulator controls the left and right side separately
2S/2M+SLV	XHS	**Axle 1**: not sensed (INR-controlled axle) **Axle 2**: sensors c, d (IR-controlled axle) **Axle 3**: not sensed (SL-controlled axle)	The trailer modulator controls the left and right side of axle 2 separately Axle “S” indirectly controlled by using a select-low valve
4S/2M	ZH	**Axle 1**: sensors e, f (MSR-controlled axle) **Axle 2**: sensors c, d (MSR-controlled axle)	The trailer modulator controls the left and right side separately
4S/2M+1M	XHL	**Axle 1**: not sensed (INR-controlled axle) **Axle 2**: sensors c, d (IR-controlled axle) **Axle 3**: sensors e, f (MAR-controlled axle)	At the first and second axle the trailer modulator controls the left and right side separately. At the third axle the ABS-relay valve controls the complete axle.

Appendix 4

System configuration _S number of sensors (of directly controlled wheels) _M number of pressure modulators	Sensing-identifier sensor reference and position within the bogie	Notes „X“ and “S” denote that no sensor is fitted on given axle “H” - “Z” - “L” ⇐ see explanation in the “Note” below	
		Sensors	**Modulators**
4S/3M semi-trailer	LXH	**Axle 1**: sensors e, f (MAR-controlled axle) **Axle 2** : not sensed (INR-controlled axle) **Axle 3**: sensors c, d (MSR-controlled axle)	At the first axle the ABS-relay valve controls the complete axle. At the second and third axle the trailer modulator controls the left and right side separately.
4S/3M full trailer	HL	**Axle 1**: sensors c, d (MSR-controlled axle) **Axle 2**: sensors e, f (MAR-controlled axle)	At the first axle the trailer modulator controls the left and right side separately. At the second axle the ABS-relay valve controls the complete axle.

Note:

“H” means sensors “c” and “d” (IR-controlled axle)

“Z” means sensors “e” and “f” (MSR-controlled axle)

“L” means sensors “e” and “f” (MAR-controlled axle)

“S” means an axle indirectly controlled by using a select-low valve

2 Test Schedule

The following table defines test schedules by system configuration and trailer types that were considered appropriate for the purpose of an Annex XIV approval.

Semi- & centre axle trailer	1 axle	2 axles	2 axles	3 axles	3 axles	3 axles	3 axles	3 axles
2S/2M	H	HX	XH	XHX	XXH			
2S/2M+SLV			HS	SHX	XHS			
4S/2M		HZ	ZH	XHZ	ZHX	XZH	HZX	ZXH
4S/3M		HL	LH	XHL	LHX	LXH	HXL	
4S/2M+1M ①				XHL	LHX	LXH	HXL	
Full trailer								
4S/3M		LH	HL	LXH	LHX		HXL	

Note: Meaning of the figure ① see paragraph 3 below.

3 Worst case cross referencing

① The 4S/2M+1M-system has the same performance as the 4S/3M-system with corresponding configuration.

Appendix 4-1 - Utilisation of adhesion

1 Test vehicles ".8"

Trailer	System config.	Sensor code	Axle No.	k_f	k_r	k_R	ε
S11.8	2S/2M	H	1	-		0,833	**0,90**
S13.8	2S/2M	X H X	3	-		0,833	**0,82**
		X X H				0,833	**0,81**
S21.8	2S/2M	H	1	-		0,763	**0,90**
S23.8	2S/2M	X H X	3	-		0,763	**0,78**
		X H X *				0,763	**0,77**
S23.8	2S/2M	S H X _ S L V	3	-		0,763	**0,81**
		X H S _ S L V				0,763	**0,84**
Z32.8	2S/2M	H X	2	-		0,825	**0,89**
		X H				0,825	**0,83**
		H S _ S L V				0,825	**0,79**
S12.8	4S/2M	H Z	2	-		0,833	**0,86**
		Z H				0,833	**0,87**
S13.8	4S/2M	X Z H	3	-		0,833	**0,83**
		H Z X				0,833	**0,84**
		Z X H				0,833	**0,88**
S23.8	4S/2M	X H Z	3	-		0,763	**0,79**
		X H Z *				0,763	**0,79**
		Z H X				0,763	**0,83**
Z32.8	4S/2M	H Z	2	-		0,825	**0,94**
		Z H				0,825	**0,93**

Appendix 4-1

Trailer	System config.	Sensor code	Axle No.	k_f	k_r	k_R	ε
S13.8	4S/3M	X H L	3	-		0,833	**0,83**
		L H X				0,833	**0,82**
		L X H				0,833	**0,82**
		H X L				0,833	**0,81**
		H X L (2 M + 1 M)				0,833	**0,84**
S23.8	4S/3M	X H L	3	-		0,763	**0,84**
		X H L *				0,763	**0,84**
Z32.8	4S/3M	H L	2	-		0,825	**0,85**
		L H				0,825	**0,94**
F42S.8	4S/3M	L H	3	0,745	0,760	0,752	**0,85**
		H L				0,752	**0,82**
F42L.8	4S/3M	L H	3	0,812	0,719	0,772	**0,79**
		H L				0,773	**0,87**
F43.8	4S/3M	L X H	3	0,812	0,719	0,763	**0,79**
		L H X				0,763	**0,79**
		H X L				0,764	**0.83**

Note: Tests marked with an * were carried out with a reduction in the brake lever length on axle .

Appendix 4-2 - Energy consumption

1 Test trailers ".8"

Trailer	Test	System config.	Sensor-config..	Axle No.	V_0 [l]	p_0 bar	p_{15s} bar	p_5 $p_{5+20\%}$ bar	n_{e_EC} n_{er_ECE}	n_{e_ECE}	n_{e_int}	R_I R_1
FS41.8	**A14**	2S/2M	H	1	100	8,0	6,91	5,99	10,38	-	**11**	disc
	A19				100	8,0	6,94	6,07	9,83	11,80	**12**	disc
S13.8	**A14**	2S/2M	X H X	3	80	8,0	5,58	3,90	9,88	-	**10**	disc
	A19					8,0	5,72	4,11	8,93	10,72	**11**	disc
S13.8	**A14**	2S/2M	X X H	3	80	8,0	5,64	3,94	9,70	-	**10**	disc
	A19					8,0	5,65	4,07	9,10	10,92	**11**	disc
S23.8	**A14**	2S/2M	X H S S L V	3	80	8,0	5,39	3,77	9,32	-	**10**	0,2
	A19					8,0	5,40	3,78	9,30	11,16	**12**	0,2
Z32.8	**A14**	2S/2M	H X	2	80	8,0	5,76	4,59	10,93	-	**11**	0,2
	A19					8,0	6,04	4,83	10,04	12,04	**13**	0,2
Z32.8	**A14**	2S/2M	X H	2	80	8,0	6,04	4,83	10,04	-	**11**	0,2
	A19					8,0	6,42	5,07	8,89	10,67	**11**	0,2
S12.8	**A14**	4S/2M	H Z	3	80	8,0	6,87	4,74	9,92		**10**	disc
	A19					8,0	6,72	5,16	8,03	9,63	**10**	disc
S12.8	**A14**	4S/2M	Z H	3	80	8,0	6,67	4,75	9,85		**10**	disc
	A19					8,0	6,80	5,22	7,82	9,38	**10**	disc
S13.8	**A14**	4S/2M	X Z H	3	80	8,0	5,95	4,00	10,21	-	**11**	disc
	A19					8,0	6,13	4,45	8,36	10,04	**11**	disc
S13.8	**A14**	4S/2M	H Z X	3	80	8,0	5,95	4,00	10,21	-	**11**	disc
	A19					8,0	5,95	4,34	8,77	10,53	**11**	disc
S13.8	**A14**	4S/2M	Z X H	3	80	8,0	6,03	4,04	9,99	-	**10**	disc
	A19					8,0	6,01	4,37	8,64	10,36	**11**	disc
S23.8	**A14**	4S/2M	X H Z	3	80	8,0	5,42	3,79	9,24	-	**10**	0,2
	A19					8,0	5,67	3,93	8,70	10,44	**11**	0,2

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Trailer	Test	System config.	Sensor-config..	Axle No.	V_0 [l]	p_0 bar	p_{15s} bar	p_5 $p_{5+20\%}$ bar	n_{e_EC} n_{er_ECE}	n_{e_ECE}	n_{e_int}	R_l R_1
S23.8	**A14**	4S/2M	Z H X	3	80	8,0	5,31	3,72	9,54	-	**10**	0,2
	A19					8,0	5,49	3,84	9,05	10,86	**11**	0,2
Z32.8	**A14**	4S/2M	H Z	2	80	8,0	5,95	4,73	10,25	-	**11**	0,2
	A19					8,0	5,97	4,74	10,18	12,21	**13**	0,2
Z32.8	**A14**	4S/2M	Z H	2	80	8,0	5,77	4,60	10,89	-	**11**	0,2
	A19					8,0	5,79	4,62	10,82	12,99	**13**	0,2
S13.8	**A14**	4S/3M	X H L	3	80	8,0	5,60	3,79	10,19	-	**11**	disc
	A19					8,0	5,74	4,10	8,87	10,64	**11**	disc
S13.8	**A14**	4S/3M	L H X	3	80	8,0	5,61	3,79	10,16	-	**11**	disc
	A19					8,0	5,53	3,97	9,39	11,27	**12**	disc
S13.8	**A14**	4S/3M	L X H	3	80	8,0	5,73	3,87	9,83	-	**10**	disc
	A19					8,0	5,45	3,92	9,61	11,53	**12**	disc
S13.8	**A14**	4S/3M	H X L	3	80	8,0	5,48	3,71	10,55	-	**11**	disc
	A19					8,0	5,75	4,10	9,85	11,82	**12**	disc
S13.8	**A14**	4S/3M	H X L 2M+1M	3	80	8,0	5,67	3,78	9,95	-	**10**	0,2
	A19					8,0	6,19	4,32	8,83	10,60	**11**	0,2
Z32.8	**A14**	4S/3M	H L	2	80	8,0	5,80	4,62	10,79	-	**11**	0,2
	A19					8,0	6,04	4,79	9,93	11,91	**12**	0,2
Z32.8	**A14**	4S/3M	L H	2	80	8,0	5,82	4,64	10,71	-	**11**	0,2
	A19					8,0	5,80	4,62	10,79	12,94	**13**	0,2
F42S.8	**A14**	4S/3M	L H	2	80	8,0	6,25	0,00	10,36	-	**11**	disc
	A19				80	8,0	6,17	0,00	9,69	11,63	**12**	disc
F42S.8	**A14**	4S/3M	H L	2	80	8,0	6,17	0,00	10,57	-	**11**	disc
	A19				80	8,0	6,22	0,00	9,57	11,49	**12**	disc
F42L.8	**A14**	4S/3M	L H	2	80	8,0	5,73	4,14	10,70	-	**11**	disc
	A19				80	8,0	5,81	4,38	9,61	11,53	**12**	disc
F42L.8	**A14**	4S/3M	H L	2	80	8,0	6,15	4,31	9,59	-	**10**	disc
	A19				80	8,0	6,38	4,67	9,07	10,09	**11**	disc

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Trailer	Test	System config.	Sensor-config..	Axle No.	V_0 [l]	p_0 bar	p_{15s} bar	p_5 $p_{5+20\%}$ bar	n_{e_EC} n_{er_ECE}	n_{e_ECE}	n_{e_int}	R_I R_1
F43.8	**A14**	4S/3M	L X H	3	80	8,0	5,31	3,47	10,25	-	**11**	disc
	A19				80	8,0	5,38	3,74	9,14	10,97	**11**	disc
F43.8	**A14**	4S/3M	H X L	3	80	8,0	5,52	3,59	9,74	-	**10**	disc
	A19				80	8,0	5,47	3,79	8,94	10,73	**11**	disc

Appendix 4-3 - Split-friction test

1 Test trailers ".8"

Trailer	System config.	Sensor code	Axle No.	z_{RALH}	z_{RALL}	f	z_{RALS}	z_{RALS} - requ.
S11.8	2S/2M	H	1	0,670	0,107	6,3	0,319	0,182
S13.8	2S/2M	X H X	3	0,590	0,108	5,5	0,310	0,190
		X X H		0,624	0,109	5,7	0,305	0,194
S13.8	2S/2M	X H X	3	0,666	0,095	7,0	0,309	0,191
		X X H		0,572	0,113	5,0	0,341	0,190
S23.8	2S/2M	X H X	3	0,452	0,108	4,2	0,237	0,171
		X H X *	3	0,421	0,093	4,5	0,236	0,156
S23.8	2S/2M	S H X _ S L V	3	0,542	0,076	7,2	0,164	0,157
		X H S _ S L V		0,523	0,078	6,8	0,163	0,150
Z32.8	2S/2M	H X	2	0,505	0,095	5,3	0,219	0,149
		X H		0,524	0,111	4,7	0,248	0,176
		H S _ S L V		0,485	0,065	7,5	0,158	0,142
S12.8	4S/2M	H Z	2	0,646	0,132	4,9	0,273	0,206
		Z H		0,683	0,124	5,5	0,308	0,203
S13.8	4S/2M	H Z X	3	0,587	0,079	7,4	0,284	0,160
		Z X H		0,634	0,111	5,7	0,320	0,183
S23.8	4S/2M	X H Z	3	0,549	0,107	5,1	0,251	0,186
		X H Z *	3	0,557	0,117	4,8	0,216	0,194
Z32.8	4S/2M	Z H	2	0,482	0,091	5,3	0,251	0,136
S13.8	4S/3M	X H L	3	0,719	0,121	5,9	0,261	0,217
		L H X		0,489	0,085	5,8	0,199	0,151
		L X H		0,619	0,124	5,0	0,229	0,203
		H X L		0,708	0,118	6,0	0,259	0,219
		H X L (2 M + 1 M)		0,544	0,083	6,6	0,187	0,157

Appendix 4-3

Trailer	System config.	Sensor code	Axle No.	z_{RALH}	z_{RALL}	f	z_{RALS}	z_{RALS} - requ.
S23.8	4S/3M	X H L	3	**0,495**	**0,105**	**4,7**	**0,215**	**0,164**
		X H L *	3	**0,472**	**0,100**	**4,7**	**0,188**	**0,156**
Z32.8	4S/3M	L H	2	**0,473**	**0,100**	**4,7**	**0,194**	**0,140**
F42S.8	4S/3M	L H	2	**0,533**	**0,096**	**5,6**	**0,179**	**0,162**
		H L		**0,420**	**0,085**	**5,5**	**0,171**	**0,139**
F42L.8	4S/3M	L H	2	**0,601**	**0,104**	**5,8**	**0,197**	**0,194**
		H L		**0,626**	**0,107**	**5,8**	**0,229**	**0,181**
F43.8	4S/3M	L X H	3	0,519	0,093	5,6	0.191	0,170
		H X L		0,596	0,092	6,5	0,192	0,175

Road surface: wet blue basalt / d ry asphalt

Test speed: 50 km/h

No inadmissible locking or inadmissible course deviation was observed during any of the above listed split-friction tests.

Ratio $\mathbf{f} = z_{RALH} / z_{RALL}$

Appendix 4-4 - Additional checks

Test trailers ".8"

1 Low speed performance

The tests described in Section 6.3.1 of Annex X to Directive 71/320/EEC and Annex 13 to ECE-Regulation No. 13 respectively were carried out on all unladen test trailers defined in Appendix 3 of this report with each anti-lock configuration.

All tests were carried out on a dry asphalt surface from an initial speed of 40 km/h.

When the brakes were suddenly actuated there was no locking of any directly controlled wheel at speeds v > 15 km/h or course deviation at any speed.

2 High speed performance

The tests described in Section 6.3.1 of Annex X to Directive 71/320/EEC and Annex 13 to ECE-Regulation No. 13 respectively were carried out on all the above defined unladen test trailers with each anti-lock configuration.

All tests were carried out on a dry asphalt surface from an initial speed of 80 km/h.

When the brakes were suddenly actuated there was no locking of any directly controlled wheel at speeds v > 15 km/h or course deviation at any speed.

3 Transition from high to low adhesion surfaces

Road surface:	dry asphalt / wet steel plates
Test speeds:	40 km/h and 80 km/h
Observations:	- no locking of any directly controlled wheel at v > 15 km/h
	- vehicle stable with no deviation from the intended course
	- in all cases the anti-lock systems reacted rapidly to the change in tyre to road surface adhesion

4 Transition from low to high adhesion surfaces

Road surface:	wet steel plates / dry asphalt
Test speed:	50 km/h
Observations:	- no locking of any directly controlled wheel at v > 15 km/h
	- vehicle stable with no deviation from the intended course
	- in all cases the anti-lock system reacted to the change in tyre to road surface adhesion within a time of 0,4 s to 1,0 s

Appendix 5 - Further test results

1 Tyre to exciter relationship

Paragraph 4.1.4.2 of Annex XIV to Directive 71/320/EEC and paragraph 5.4.1.4.2 of annex 19 to ECE-Regulation No. 13 require that the functional checks defined in paragraph 6.3 of Annex X to Directive 71/320/EEC and of Annex 13 to ECE-Regulation No. 13 be carried out with the extremes of tolerance of the recommended range of tyre size for a pole wheel with a given number of teeth.

The "Trailer EBS" takes into account the actual tyre rolling circumference and the number of exciter teeth (which are stored in the ECU prior to entry into service) of the individual trailer.

Thus only the inter-wheel variations of the rolling circumference of 6,5 % permitted by the manufacturer (see paragraph 2.4 of ID_TEBS) were assessed.

The following tables contain the respective 40 to 20 km/h deceleration times for the optimum circumference variation of 0 % and the tolerances of ± 7 % ascertained on a high friction surface with the test trailers S13.8 and S23.8 with the configuration 2S/2M_XHX.

Tyre rolling circumference S13.8	**3200 mm**	**3425 mm**	**2975 mm**
Circumference variation	**0 %**	**+7,03 %**	**-7,03 %**
Test order	1st measurement	2nd measurement	3rd measurement
Number of exciter teeth	90	90	90
40 to 20 km/h time (t)	2,168	2,126	2,057
	2,052	2,123	2,141
	2,351	2,339	2,193
average (time t)	**2,190**	**2,196**	**2,130**
deviation of t in %	**0 %**	**+ 0,3 %**	**- 2,7 %**

Tyre rolling circumference S23.8	3200 mm	3425 mm	2975 mm
Circumference variation	**0 %**	**+7,03 %**	**-7,03 %**
Test order	1st measurement	2nd measurement	3rd measurement
Number of exciter teeth	100	100	100
40 to 20 km/h time (t)	2,496	2,506	2,542
	2,279	2,208	2,435
	2,490	2,427	2,278
average (time t)	**2,412**	**2,380**	**2,418**
deviation of t in %	**0 %**	**- 1,3 %**	**+ 0,3 %**

2 Differential(s) in brake input torque within a trailer bogie

Within Appendices 4-1 and 4-3 of this report reference is made to tests carried out where the brake input torque was reduced on axle 1 to take account of dynamic load transfer within the bogie during braking.

3 Tube sizes and lengths

To assess the influence of the recommendations contained within ID_TEBS response tests were carried out with the delivery tubes specified. Anti-lock performance was then verified at the extremes of tube size recommended.

3.1 Time measurement

The manufacturer's Information Document states that the maximum length of tube for a directly and a indirectly controlled wheel shall be limited to 6 m. However in all cases the prescribed system response times must be fulfilled. To verify this statement it was considered appropriate to compare differences in system response and anti-lock performance relative to the tube length from the modulator to the brake chamber.

The following time measurements were obtained from a 3-axle full trailer representing the testing conditions of the ABS-performances specified in the table of paragraph 3.2 below. The tube lengths to either a directly controlled axle or indirectly controlled axles were increased according to the maximum tube length of 6,0 m as specified by the manufacturer in paragraph 3.5 of ID_TEBS.

	Axle 1	Axle 2	Axle 3
Delivery tube lengths [Øi = 13 mm]:	**5,4 m**	**2,2 m**	**3,9 m**
Response time (pneumatic / CAN):	**0,39 / 0,35 s**	**0,34 / 0,27 s**	**0,35 / 0,28 s**
Delivery tube lengths [Øi = 13 mm]:	**6,0 m**	**6,0 m**	**6,0 m**
Response time (pneumatic / CAN):	**0,41 / 0,36 s**	**0,37 / 0,31 s**	**0,39 / 0,31 s**

3.2 Anti-lock performance

The following test results were obtained from a three axle full trailer installed with a **4S/3M_LXH** system where the tube lengths represented a "standard installation" and installations where the delivery tube lengths were **increased to 3 and 6 m** respectively (motor vehicle unbraked).

F43_unl ⇒ unladen trailer weight: 6395 kg

F43_lad ⇒ laden trailer weight: 16360 kg

ABS performance				
	t_{zRAL} [s]	axle 1 (directly controlled)	axle 2 (indirectly controlled)	axle 3 (directly controlled)
F43_unl standard tube length	2,638 2,641 2,702	**5,4 m**	**2,2 m**	**3,9 m**
Average	**2,660**			
F43_unl increased tube length	2,689 2,664 2,712	**6,0 m**	**6,0 m**	**6,0 m**
Average	**2,688**			
F43_lad standard tube length	1,912 1,989 1,996	**5,4 m**	**2,2 m**	**3,9 m**
Average	**1,966**			
F43_lad increased tube length	2,173 1,992 1,998	**6,0 m**	**6,0 m**	**6,0 m**
Average	**2,054**			

All comparison tests were carried out on a dry asphalt surface.

The above tests with the various tube length variations show that the utilisation of adhesion times t_{zRAL} are within the following tolerances:

a) <u>Comparison between the standard and increased tube length</u> condition in relation to the respective mean values for the unladen and laden state:

For the unladen state the deviation was **± 0.52 %** and for the laden state the deviation was **± 2.19 %**.

b) <u>Variation of the test results</u> in relation to the respective mean values for the unladen and laden state:

For the unladen state the measured utilisation of adhesion times lay in a tolerance band of **2.8 %** whereas for the laden state the tolerance band was **13 %**.