TRAILER ANTI-LOCK BRAKING SYSTEM APPROVAL REPORT

Approval Report No: EB 128.3E

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1. Identification.

1.1	**Manufacturer:**	**Haldex Brake Products Ltd** Redditch, Worcestershire B98 9HA United Kingdom
1.2	**System name/model:**	**E B +**

2. System and installation

2.1	**Configurations and performance:**	2S/1M - 2S/2M* - 2S/2M_SL* - 4S/2M* - 4S/3M * with integrated and non-integrated versions See also paragraph 2.1.1.4 and Appendix 1 of the Manufacturer's Information Document
2.1.1	**Category A anti-lock performance:**	All anti-lock system configurations "2M" and "3M" contained in Appendix 1 of the Manufacturer's Information Document comply with the prescribed split friction requirements defined in paragraph 6.3.2 of Annex X.
2.1.2	**Category B anti-lock performance:**	The anti-lock system configurations 2S/1M contained in Appendix 1 of the Manufacturer's Information Document do not comply with the prescribed split friction requirements defined in paragraph 6.3.2 of Annex X. However, all relevant provisions applicable to this ABS category are fulfilled.

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.

For specific applications refer to paragraph 2.1.2 and Appendix 1 of the Manufacturer's Information Document.

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

For more detailed system installation examples refer to paragraph 2.1.3.5 and Appendix 12 of the Manufacturer's Information Document.

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. Optionally, as a back up, 1M and 2M integrated systems can accept an intermittent power supply via the ISO 1185 (24N) or ISO 12098 (15 pin) connector (stop lamp circuit).

Permanent

To comply with the requirements of Directive 98/12/EC and ECE Regulation 13/09 Supplement 8 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 ISO 7638 electrical power, 1M and 2M integrated systems are able to receive electrical power from the ISO 1185 (24N) or ISO 12098 (15 pin) connector (stop lamp circuit). In this case the EBS function is disabled but the ABS function and (optionally) a dynamic load sensing function are retained. However, the 2M non integrated and 4S/3M configurations do not support this feature.

For more detailed information see Manufacturer's Information Document, paragraphs 2.1.1.5 and 2.1.3.4.

2.4. Identification of approved components

2.4.1 Wheel speed sensors: see Manufacturer's Information Document, paragraph 2.1.3.1

2.4.2 Controller (ECU): see paragraph 2.1.3.2 of the Manufacturer's Information Document

2.4.3 Modulators: see paragraph 2.1.3.3.2 and Appendix 13 of the Manufacturer's Information Document

2.5. Energy consumption

2.5.1 **Drum brakes :**

2.5.1.1 Equivalent static brake applications:

Semi-trailers:

n_{e_EC} = 10 applications

n_{e_ECE} = 12 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 of Directive 71/320/EEC.
- The values n_{e_ECE} above is to be used with the verification procedure defined within annex 20 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 Manufacturer's Information Document paragraph 2.6.1.3

Semi-trailers:

n_{e_EC} = 12 applications

n_{e_ECE} = 13 applications

Full trailers:

n_{e_EC} = 13 applications

n_{e_ECE} = 14 applications

Notes:

- The brake applications n_{e_EC} defined above already takes 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 of ECE-Regulation No. 13.

2.6 Additional features: The following additional features are provided as options by appropriate connection to the 5 auxiliary connectors (**not subject to the assessment of this report**).

Reset to Ride Height:	see Manufacturer's Information Document, paragraph 2.1.3.2.4.2.
Speed Lock:	see Manufacturer's Information Document, paragraph 2.1.3.2.4.2.
Lifting axle(s):	see Manufacturer's Information Document, paragraph 2.1.3.2.4.2 and paragraph 2.1.2.2.
Retarder Control	see Manufacturer's Information Document, paragraph 2.1.3.2.4.2.
Trailer mounted warning:	see Manufacturer's Information Document, paragraph 2.1.3.2.4.2.
Tacho:	see Manufacturer's Information Document, paragraph 2.1.3.2.4.2.
Lining wear:	see Manufacturer's Information Document, paragraph 2.1.3.2.4.2.
Power out:	see Manufacturer's Information Document, paragraph 2.1.3.2.4.2.
Steer lock:	see Manufacturer's Information Document, paragraph 2.1.3.2.4.2.
Trailer Roll Stability	see Manufacturer's Information Document, paragraph 2.1.3.2.4.2.and RWTÜV Report No. 144.0E

2.6.1 Diagnostics: Diagnostics is in accordance with KWP2000 but using CAN as the physical layer, see Manufacturer's Information Document, paragraph 2.1.3.2.5.

3. Test data and results

3.0 General: The software versions of the assessed EB+ system are:

B299	(2M ECU's - covers 1M and integrated 2M systems)
B300	(3M ECU's - covers 3M and non-integrated 2M systems)

Note: The first character (letter) in the software number of the EB+ system (see above letter "**B**") denotes the software version as far as ECE-Regulation No. 13 is concerned.

The following number is a sequential identifier and may vary although the function of the EB+ system as far as

ECE-Regulation No. 13 is concerned is unchanged (compare ECE-R13, paragraph 3.3.5.1 of Annex 18).

3.1.	Test vehicle data:	see Appendix 3 of this approval report.
3.2.	Test track data:	see Appendix 2 of this approval report.
3.3.	Test results:	
3.3.1.	Utilisation of adhesion:	see Appendix 4-1 of this approval report.
3.3.2.	Energy consumption:	
3.3.2.1	Worst case axle load:	see paragraph 2.1.2.7.1 and Appendix 6 of the Manufacturer's Information Document.
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 Additional checks applicable to all system configurations:

3.3.6.1.1	Transition from high to low-adhesion surfaces:	see Appendix 4-4, paragraph 3 of this approval report.
3.3.6.1.2	Transition from low to high-adhesion surfaces:	see Appendix 4-4, paragraph 4 of this approval report.

3.3.6.2 Additional checks applicable to 4S/2M **A x A** system configurations only:

3.3.6.2.1	Transition from split to low-adhesion surfaces:	see Appendix 5, paragraph 4 of this approval report.
3.3.6.2.2	Transition from split to high-adhesion surfaces:	see Appendix 5, paragraph 4 of this approval report.
3.3.6.2.3	Transition from high to split-adhesion surfaces:	see Appendix 5, paragraph 4 of this approval report.
3.3.6.2.4	Transition from low to split-adhesion surfaces:	see Appendix 5, 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 RWTÜV "Electronic Function & Safety Assessment Test Report" No. EB 132.3E.

3.3.7.2 Functional checks of optional power connections: A failure of the ISO7638 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 ISO7638 power supply in service and is not a primary means of powering the braking system (see also paragraph 2.3 of this report).

* The load dependent pressure control under stop light back-up is a customer option.

3.3.7.3 Electro magnetic compatibility: The system has been tested and verified to conform to the requirements of Directive 72/245/EEC as last amended by Directive 95/54/EC - a copy of the approval report is included in the Manufacturer's Information Document (see also paragraph 2.1.4 and Appendix 17 that document).

3.3.7.4 ADR regulations: Within this test procedure no assessment was performed against ADR (Regulation governing Road Transport of Hazardous Goods). For information, see Haldex statement in the Manufacturer's Information Document, paragraph 2.1.2.1.

Limitations of installation

4.1. Tyre to exciter relationship: The relationship of tyre circumference to the resolution of the exciter is defined in the Manufacturer's Information Document, paragraph 2.1.2.3 and Appendix 16 and is applicable to all system configurations. - see also Appendix 5, paragraph 1 to this approval report

4.2.	Tyre size tolerance:	The tolerance on tyre circumference between one axle and another fitted with the same exciter is defined in the Manufacturer's Information Document, paragraph 2.1.2.4 and is applicable to all system configurations.
4.3.	Suspension type:	System performance was verified on semi-trailers with balanced pneumatic suspensions. Paragraph 2.1.2.5 and Appendix 4 of the Manufacturer's Information Document defines approved suspensions for the purpose of the application of this approval.
4.4.	Differential(s) in brake input torque within a trailer bogie:	see paragraph 2.1.2.6 and Appendix 5 of the Manufacturer's Information Document and Appendix 5, paragraph 2 to this approval report
4.5.	Wheelbase of full trailer	
4.5.1	Two axle full trailers:	The wheelbase is defined as the distance between centre line of axle 1 and the centre line of axle 2. The minimum approved wheelbase being 3,21 m.
4.5.2	Three axle full trailers:	The wheelbase 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 wheelbase being 3,84 m.
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 2.1.2.2 and Appendix 2 of the Manufacturer's Information Document and Appendix 5, paragraph 3 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.	Electronic load sensing (ELS):	All configurations were evaluated with the ELS operating. Performance of the respective system configurations fulfilled the prescribed requirements; for more detailed information see Manufacturer's Information Document, paragraph 2.1.2.8.

4.9. Warning signal sequence: All configurations have the option of two discrete warning signal sequences - see paragraph 2.1.3.4.3 and Appendix 11 of the Manufacturer's Information Document - both of which fulfil the prescribed requirements of paragraphs 4.1.1 and 4.1.2 (including footnote 3) of Annex X of Directive 71/320/EEC.

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 paragraph 2.1.2.2. and Appendix 1 of the Manufacturer's Information Document.

Note: This report does not cover an assessment of the reaction of any steering systems to the anti-lock braking control of the E B $^{+}$ system.

5. Date of tests: 2000 - 2002 - 2003 - 2004

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 09 series of amendments including Supplement 8 and Annex XIV of Directive 71/320/EEC as last amended by Directive 2002/78/EC.

6 Appendices

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7 Annex

Annex	Manufacturer's Information Document - GS 0285 - Issue 4 of 17th May 2004

Technical Service

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Appendix 1 - Abbreviations & Codes

A x A	Axle by Axle Configuration
"ABS"	measurement of "z" with the anti-lock braking system in operation
ASC	Adaptive Surface Control
BC	brake cylinder
ELS	Electronic Load Sensing
EPRV	Electro Pneumatic Relay Valve
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_D	height of drawbar (hinge point on trailer)
h_R	height of centre of gravity
h_K	height of fifth wheel coupling (king pin)
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.
n_e	number of equivalent static brake applications
n_{e_EC}	see paragraphs 2.5.1.1 and 2.5.2.1 of this approval report
n_{e_ECE}	see paragraphs 2.5.1.1 and 2.5.2.1 of this approval report
P or PA	mass of the 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 air reservoir
p_{15s}	pressure after 15 s
p_5	5th static pressure
$p_{5+20\%}$	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 (bogie) 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 71/320/EEC)
$R_I \equiv R_1$	$R_1 = \frac{S_T}{l_T}$ ratio of actuator stroke against brake lever length
RV	relay valve
S x S	Side by Side Configuration
SLV	select-low valve
t_{zRAL}	40 to 20 km/h ABS deceleration time of the trailer with the anti-lock braking system operative
V_0	capacity of the braking system air reservoir(s) in litres
s_T	brake chamber push rod travel in mm
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 good adhesion:

dry asphalt

This surface was used for the purposes of all tests with the exception of split friction and surface transition tests.

wet asphalt

This surface was used for the purposes of split friction and surface transition tests.

1.2 Road surface with low adhesion:

(updated "Engineering Report")

wet basalt

The characteristics of the surface were obtained from an "Engineering Report" from the manufacturer as of 20th August 2002 in accordance with the requirements of footnote 1 of Appendix 4 of Annex X to Directive 71/320/EEC as follows:

The full adhesion curve was obtained from a suitably equipped passenger car to produce a relationship of wheel slip against surface adhesion. The ratio **R** (k_{peak}/k_{lock}) obtained with this vehicle was 1.54.

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

Test vehicle:	single axle semi-trailer
Axle weight:	5966 kg
Tyre type:	Michelin XZA 385/65 R22.5
k_{peak}	0.117
k_{lock}	0.108
Ratio „R“:	1.08

Appendix 3 - Test vehicle data

1 Vehicle data

1.1 General

	Manufacturer	Type	Suspension	Brake	Brake-man.
S21	Montracon	one axle semi-trailer (front & rear axle lifted)	air	drum	BPW
S22	Montracon	two axle semi-trailer (front axle lifted)	air	drum	BPW
S23	Montracon	three axle semi-trailer	air	drum	BPW
S31	General Trailers	single axle semi-trailer (front & rear axle lifted)	air	disc	Haldex
S32	General Trailers	two axle semi-trailer (front axle lifted)	air	disc	Haldex
S33	General Trailers	three axle semi-trailer	air	disc	Haldex
SF41*	Abel	two axle full trailer (first rear axle lifted) - first axle unbraked - simulated as an one axle semi-trailer	air	disc	Knorr
F42S	Abel	two axle full trailer (rear axle removed)	air	disc	Knorr
F42L	Abel	two axle full trailer (first rear axle lifted)	air	disc	Knorr
F43	Abel	three axle full trailer	air	disc	Knorr
SF51*	Abel	two axle full trailer (first rear axle lifted) - first axle unbraked - simulated as an one axle semi-trailer	air	drum	Knorr
F52S	Abel	two axle full trailer (rear axle removed)	air	drum	BPW
F52L	Abel	two axle full trailer (first rear axle lifted)	air	drum	BPW
F53	Abel	three axle full trailer	air	drum	BPW

***** A full trailer was used to simulate a one axle semi-trailer for the energy consumption test (see also note to paragraph 1.3 of Appendix 3.

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.

	S21	S22	S23	S31	S32	S33
Number of Axles	1	2	3	1	2	3
axle lifted	1st & 3rd	1st	-	1st & 3rd	1st	-
PM [kg]	11380	11880	11420	10320	10820	10350
PMnd [kg]	5160	5180	5170	6320	6430	6330
PMd [kg]	6220	6700	6250	4000	4390	4020
P (Trailer) [kg]	7860	7860	7860	7910	7910	7910
PR [kg]	6040	5540	6000	5880	5380	5850
h_R mm]	1350	1350	1350	1200	1200	1200
h_K [mm]	1350	1350	1350	1300	1300	1300
ER [mm]	7350	8010	7350	7450	8100	7450

	F42S = 4S	F42L = 4L	F43	F52S = 5S	F52L = 5L	F53
Number of Axles	2	2	3	2	2	3
axle lifted / removed	3rd removed	2nd lifted wheels removed	-	3rd lifted	2nd lifted	-
comment	stripped trailer	stripped trailer	stripped trailer	stripped trailer	stripped trailer	stripped trailer
PM [kg]	9070	9070	9070	9560	9560	9560
PMnd [kg]	4670	4670	4670	5160	5160	5160
PMd [kg]	4400	4400	4400	4400	4400	4400
P (Trailer) [kg]	4780	5260	5500	5520	5430	5430
PR [kg]	4780	5260	5500	5520	5430	5430
Pf [kg]	2150	2660	2480	1780	2880	2470

Appendix 3

	F42S = 4S	F42L = 4L	F43	F52S = 5S	F52L = 5L	F53
Pr [kg]	**2630**	**2600**	**3020**	**3740**	**2550**	**2960**
PRnd-kf [kg]	**2630**	**2600**	**3020**	**3740**	**2550**	**2960**
PRnd-kr [kg]	**2150**	**2660**	**2480**	**1780**	**2880**	**2470**
$\mathbf{h_R}$ mm]	**1150**	**1000**	**950**	**1000**	**1000**	**950**
$\mathbf{h_D}$ [mm]	**770**	**770**	**770**	**770**	**770**	**770**
E [mm]	**3210**	**4570**	**3890**	**3190**	**4550**	**3870**

1.3 **Weights** (energy consumption tests)

Tables "Overview worst case loading (EEC - Directive Annex XIV)

EEC-worst case loading		S22	S23	S32	S33
P	[kg]	**11840**	**9690**	**7640**	**9850**
PR	**[kg]**	**5180**	**7890**	**5260**	**7850**
PR_1	[kg]	**-**	**2600**	**-**	**2600**
PR_2	[kg]	**2620**	**2670**	**2650**	**2640**
PR_3	[kg]	**2560**	**2620**	**2610**	**2610**

EEC-worst case loading		SF41L	F42S	F42L	F43	SF51L	F52S	F52L	F53
P	[kg]	**5390**	**5190**	**5260**	**7870**	**5340**	**5190**	**5220**	**7920**
PR	**[kg]**	**5390**	**5190**	**5260**	**7870**	**5340**	**5190**	**5220**	**7920**
PR_1	**[kg]**	**(2790)***	**2590**	**2660**	**2600**	**(2740)***	**2610**	**2610**	**2620**
PR_2	**[kg]**	**-**	**2600**	**-**	**2650**	**-**	**2580**	**-**	**2670**
PR_3	**[kg]**	**2600**	**-**	**2600**	**2620**	**2600**	**-**	**2610**	**2630**

* First axle 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 **examples** of the locations and identification of sensors on test vehicles.

General notes in respect to the following table:

"a"	means ECU facing left side of combined modulators (EPRV's) 21/22
"b"	means ECU facing right side of combined modulators (EPRV's) 21/22
sensors "A"	always fitted on left side
sensors "B"	always fitted on right side
R	indirectly controlled axle via a SL-valve (SLV) and conventional relay valve (RV)
T	indirectly controlled axle via a conventional select-low valve (SLV)
„X"	denotes, no sensor fitted on given axle
4S/3M	modulator "2" (EPRV) is always in select low control

System configuration _S number of sensors (directly controlled wheels) _M number of pressure modulators	sensing-identifier sensor reference and position within the bogie	General notes see above
2 S / 1 M	**1** - one axle trailer - equipped with sensor **1 A** and **1 B** connected to modulator **"2"**	
2 S / 2 M S x S **Side by Side configurations ("integrated")**	**1 a** - one axle trailer - equipped with sensor **1 A** connected to modulator **2.1** - equipped with sensor **1 B** connected to modulator **2.2**	**1 b** - one axle trailer - equipped with sensor **1 B** connected to modulator **2.1** - equipped with sensor **1 A** connected to modulator **2.2**
	X **1 a** - two axle trailer - axle one without a sensor - equipped with sensor **1 A** connected to modulator **2.1** on second axle - equipped with sensor **1 B** connected to modulator **2.2** on second axle	X **1 b** - two axle trailer - axle one without a sensor - equipped with sensor **1 B** connected to modulator **2.1** on second axle - equipped with sensor **1 A** connected to modulator **2.2** on second axle
2 S / 2 M S x S ("non integrated")	**see above "integrated" sensing-identifiers**	**see above "integrated" sensing-identifiers**

System configuration _S number of sensors (directly controlled wheels) _M number of pressure modulators	sensing-identifier sensor reference and position within the bogie	General notes see above
2 S / 2 M _ S L	_1aT	the first axle is equipped with sensors „1“, the second axle is not fitted with sensors (indirectly controlled by axle 1 via the SL-valve)
	_1aR	the first axle is equipped with sensors „1“, the second axle is not fitted with sensors (indirectly controlled by axle 1 via a SL-valve and conventional relay valve
	_X1aT	- axle one without a sensor - indirectly controlled by axle 2 - the second axle is equipped with sensors „1“ - the third axle is not fitted with sensors (indirectly controlled by axle 2 via the SL-valve)
	_T1aX	- the first axle is not fitted with sensors (indirectly controlled by axle 2 via the SL-valve) - the second axle is equipped with sensors „1“ - third axle without a sensor - indirectly controlled by axle 2
4 S / 2 M S x S **Side by Side configurations**	X **1 a 2 a** - three axle trailer - axle one without a sensor - equipped with sensor **1 A** connected to modulator **2.1** on second axle - equipped with sensor **2 A** connected to modulator **2.1** on third axle	X **1 b 2 b** - three axle trailer - axle one without a sensor - equipped with sensor **1 B** connected to modulator **2.1** on second axle - equipped with sensor **2 B** connected to modulator **2.1** on third axle

System configuration _S number of sensors (directly controlled wheels) _M number of pressure modulators	sensing-identifier sensor reference and position within the bogie	General notes see above
4S/2M A x A **Axle by Axle configurations**	**1 H** X **2 L** - three axle trailer - first axle equipped with sensors **1 A** and **1 B** connected to modulator **2.1** or **2.2** ("ASC-channel") - axle two without a sensor - indirectly controlled by the first (H) axle - third axle equipped with sensors **2 A** and **2 B** connected to modulator **2.1** or **2.2** ("SL-channel")	**1 L 2 H** X - three axle trailer - first axle equipped with sensors **1 A** and **1 B** connected to modulator **2.1** or **2.2** ("SL-channel") - second axle equipped with sensors **2 A** and **2 B** connected to modulator **2.1** or **2.2** ("ASC-channel") - axle three without a sensor - indirectly controlled by the second (H) axle
4S/3M **(2-axle semi-trailer)**	**a M S** - equipped with sensor **S 1 A** controlling modulator **"21"** on first axle - equipped with sensor **S 1 B** controlling modulator **"22"** on first axle - equipped with sensors **S 2 A** and **S 2 B** controlling modulator **"2"** on second axle	**M b S** - equipped with sensor **S 1 A** controlling modulator **"22"** on first axle - equipped with sensor **S 1 B** controlling modulator **"21"** on first axle - equipped with sensors **S 2 A** and **S 2 B** controlling modulator **"2"** on second axle
4S/3M **(3-axle semi-trailer)**	**a M** X **S** - equipped with sensor **S 1 A** controlling modulator **"21"** on first axle - equipped with sensor **S 1 B** controlling modulator **"22"** on first axle - axle two without a sensor - indirectly controlled by axle one side by side - equipped with sensors **S 2 A** and **S 2 B** controlling modulator **"2"** on third axle	**b M** X **S** - equipped with sensor **S 1 A** controlling modulator **"22"** on first axle - equipped with sensor **S 1 B** controlling modulator **"21"** on first axle - axle two without a sensor - indirectly controlled by axle one side by side - equipped with sensors **S 2 A** and **S 2 B** controlling modulator **"2"** on third axle
	S X **a M** - equipped with sensors **S 1 A** and **S 1 B** controlling modulator **"2"** on first axle - axle two without a sensor - indirectly controlled by axle three side by side - equipped with sensor **S 2 B** controlling modulator **"22"** on third axle - equipped with sensor **S 2 A** controlling modulator **"21"** on third axle	**b S** X **b M** - equipped with sensors **S 1 A** and **S 1 B** controlling modulator **"2"** on first axle - axle two without a sensor - indirectly controlled by axle three side by side - equipped with sensor **S 2 B** controlling modulator **"21"** on third axle - equipped with sensor **S 2 A** controlling modulator **"22"** on third axle

2 Test schedule

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

Semi- & centre axle trailer Sensing identifiers & location of directly controlled wheels										
no of axles	**1**	**1**	**2**	**2**	**2**	**2**	**3**	**3**	**3**	**3**
2S/1M [1]	**1**		**1X**	**X1**	**-**	**-**	**X1X**		**-**	**-**
2S/2M - SxS "integrated" [2a]	**1a**	**1b**	**1aX**	**X1a**	**1bX**	**X1b**	**X1aX**	**X1bX**	**-**	**-**
2S/2M - SxS "non integrated" - [2a]	**sensing identifier identical with the above specified integrated system 2S/2M - SxS - see also installation diagrams in Appendix 1**									
2S/2M_SL [2a]	**-**	**-**	**1aT**	**1aR**	**1bT**	**1bR**	**T1aX R1aX**	**T1bX R1bX**	**X1aT X1aR**	**X1bT X1bR**
4S/2M - SxS "integrated" [2a]	**-**	**-**	**1a2a**	**1b2b**	**-**	**-**	**X1a2a X1b2b**	**1a2aX 1b2bX**	**1aX2a 1bX2b**	**-**
4S/2M - SxS "non integrated" - [2a]	**sensing identifier identical with the above specified integrated system 4S/2M - SxS - see also installation diagrams in Appendix 1**									
4S/2M - AxA - ASC front	**-**	**-**	**-**	**1H2L**	**-**	**-**	**-**	**1HX2L**	**-**	**X1H2L**
4S/2M - AxA - ASC rear	**-**	**-**	**1L2H**	**-**	**-**	**-**	**1LX2H**	**-**	**1L2HX**	**-**
4S/3M [2b]	**-**	**-**	**aMS**	**bMS**	**SaM**	**SbM**	**SaMX SbMX**	**SXaM SXbM**	**aMXS bMXS**	**XaMS XbMS**

Full axle trailer Sensing identifiers & location of directly controlled wheels			
no of axles	**2**	**3**	**3**
4S/3M [2b]	**SaM / SbM**	**SaMX / SbMX**	**SXaM / SXbM**

3 Worst case cross referencing

In accordance with the provisions of paragraph 4.1 of Annex XIV the following worst case cross references were considered appropriate.

1 2S/1M configurations: The ECU may be mounted facing in different directions as shown in Appendix 1 of the Manufacturer's Information Document

2a The side by side configurations "1a" are identical with the corresponding configurations "1b" in respect of functionality and performance. The same applies for the configurations 1a2a and 1b2b.

2b The 4S/3M configurations "**a** M" are identical with the corresponding configurations "**b** M" in respect of functionality and performance.

3 Paragraph 3.1.4 of annex XIV of Directive 98/12EC requires the utilisation of adhesion to be carried out with the load sensing device set for the laden and unladen conditions. The EB$^+$ system apportions the brake chamber pressure for the respective vehicle load condition during non-anti-lock operation. When the brake chamber pressure is such that a brake force is produced that exceeds the specified tyre to wheel adhesion limits then the anti-lock system takes control. During anti-lock operation reservoir pressure (≥ fully laden worst case demand) is applied on the input to each relay modulator valve. This pressure is modulated by the anti-lock and is not influenced by suspension behaviour. Therefore all tests were carried out with the electronic load sensing (ELS) in operation.

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Appendix 4-1 - Utilisation of adhesion

Trailer	System Configuration & sensing identifier	No. of axles	k_R	ε
S21	2S/1M_1	1	0,927	**0,77**
S22	2S/1M_1X	2	0,927	**0,92**
S22	2S/1M_X1	2	0,927	**0,87**
S23	2S/1M_X1X	3	0,927	**0,93**
S23	2S/1M_X1X*	3	0,927	**0,94**
S31	2S/1M_1	1	0,880	**0,77**
S32	2S/1M_1X	2	0,880	**0,87**
S32	2S/1M_X1	2	0,880	**0,87**
S33	2S/1M_X1X	3	0,880	**0,87**
S31	2S/2M_1	1	0,880	**0,89**
S32	2S/2M_1X	2	0,880	**0,89**
S32	2S/2M_X1	2	0,880	**0,88**
S33	2S/2M_X1X	3	0,880	**0,84**
S33	2S/2M_X1X*	3	0,880	**0,76**
S22	2S/2M_X1	2	0,927	**0,85**
S22	2S/2M_SL_1T	2	0,927	**0,84**
S22	2S/2M_SL_1R	2	0,927	**0,85**
S23	2S/2M_SL_T1X	3	0,927	**0,88**
S23	2S/2M_SL_R1X	3	0,927	**0,82**
S23	2S/2M_SL_X1T	3	0,927	**0,84**
S23	2S/2M_SL_X1R	3	0,927	**0,83**
S32	2S/2M_SL_1T	2	0,880	**0,85**
S32	2S/2M_SL_1R	2	0,880	**0,82**

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Trailer	System Configuration & sensing identifier	No. of axles	k_R	ε
S33	2S/2M_SL_T1X	3	0,880	**0,84**
S33	2S/2M_SL_R1X	3	0,880	**0,81**
S33	2S/2M_SL_X1T	3	0,880	**0,86**
S33	2S/2M_SL_X1R	3	0,880	**0,81**
S32	4S/2M_12	2	0,880	**0,90**
S33	4S/2M_X12	3	0,880	**0,86**
S33	4S/2M_12X	3	0,880	**0,81**
S33	4S/2M_1X2	3	0,880	**0,77**
S22	4S/2M_12	2	0,927	**0,87**
S23	4S/2M_X12	3	0,927	**0,90**
S22	4S/2M_ASC front HL	2	0,927	**0,89**
S23	4S/2M_ASC front HXL	3	0,927	**0,79**
S23	4S/2M_ASC front XHL	3	0,927	**0,90**
S32	4S/2M_ASC front HL	2	0,880	**0,86**
S33	4S/2M_ASC front HXL	3	0,880	**0,87**
S33	4S/2M_ASC front XHL	3	0,880	**0,86**
S32	4S/3M_MS	2	0,890	**0,86**
S32	4S/3M_SM	2	0,890	**0,87**
S33	4S/3M_SMX	3	0,890	**0,89**
S33	4S/3M_SXM	3	0,890	**0,88**
S33	4S/3M_MXS	3	0,890	**0,88**
S33	4S/3M_XMS	3	0,890	**0,87**
S22	4S/3M_MS	2	0,927	**0,91**
S22	4S/3M_MS*	2	0,927	**0,92**
S22	4S/3M_SM	2	0,927	**0,91**

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Trailer	System Configuration & sensing identifier	No. of axles	k_R	ε
S23	4S/3M_SMX	3	0,927	**0,96**
S23	4S/3M_SXM	3	0,927	**0,93**
S23	4S/3M_MXS	3	0,927	**0,92**
S23	4S/3M_XMS	3	0,927	**0,91**
S23	4S/3M_XMS*	3	0,927	**0,91**
F42S	4S/3M_SM	2	0,889	**0,81**
F42L	4S/3M_SM	2	0,888	**0,78**
F43	4S/3M_SMX	3	0,889	**0,84**
F43	4S/3M_SXM	3	0,889	**0,78**
F52S	4S/3M_SM	2	0,878	**0,89**
F52L	4S/3M_SM	2	0,863	**0,86**
F53	4S/3M_SMX	3	0,868	**0,96**
F53	4S/3M_SXM	3	0,869	**0,83**

Note: Tests marked with an ***** were carried out with a reduction in the brake lever length on axle „1“.

Appendix 4-2 - Energy consumption tests

Note: The energy consumption tests of the following table were all carried out with the "EEC worst case loading" (see table "Weights (energy consumption tests)" in paragraph 1.3 of Appendix 3 of this report). Comparative tests with the prescribed lower ECE axle loads were carried out with each type of trailer (covering **all** different types of configurations, brakes and suspensions). All comparative tests (EEC / ECE axle loading) have shown that the energy consumption with the ECE axle loads were less or equal than the energy consumption with the "EEC worst case loading".

The "**worst case**" energy consumption test results of the following table were taken also for the energy consumption test results according to Annex 19 of ECE-Regulation No. 13

Trailer	System Configuration	sens.-identif.	No. of axles	V_0 l	p_0 bar	p_{15s} bar	p_5 bar	n_{e_EC} n_{er_ECE}	n_{e_ECE}	$p_{5\ EC\ +20\%}$ bar	$n_{e\ EC\ +20\%}$	R_l R_1
S22	2S/1M	1X	2	80	8,1	6,64	5,22	**8,4**	**11**	-	-	0,2
S23	2S/1M	X1X	3	100	8,1	6,63	5,10	**8,0**	**10**	-	-	0,2
S32	2S/1M	1X	3	80	8,0	7,13	5,7	**7,2**	**9**	5,5	**7,9**	disc
S32	2S/1M	X1	2	80	8,0	7,17	5,7	**7,1**	**9**	5,5	**7,9**	disc
S33	2S/1M	X1X	3	100	8,0	7,01	5,5	**7,3**	**9**	5,3	**8,2**	disc
S32	2S/2M	1X	2	80	8,0	6,72	5,4	**8,7**	**11**	5,2	**9,9**	disc
S32	2S/2M	X1	2	80	8,0	6,93	5,6	**8**	**10**	5,4	**9,0**	disc
S33	2S/2M	X1X	3	100	8,1	6,71	5,3	**8,2**	**10**	5,0	**9,3**	disc
S22	2S/2M	X1	2	80	8,0	6,74	5,4	**8,6**	**11**	-	-	0,2
S22	2S/2M_SL	1T	2	80	8,0	7,07	5,6	**7,6**	**10**	-	-	0,2
S23	2S/2M_SL	T1X	3	100	8,0	6,60	5,1	**8,0**	**10**	-	-	0,2
S23	2S/2M_SL	X1R	3	100	8,0	6,26	4,9	**9,0**	**11**	-	-	0,2
S32	2S/2M_SL	1R	3	80	8,1	7,18	5,8	**7,3**	**9**	5,5	**8,2**	disc
S33	2S/2M_SL	R1X	3	100	8,1	6,30	4,8	**10,4**	**13**	4,5	**11,8**	disc
S33	2S/2M_SL	X1T	3	100	8,0	6,42	4,8	**10,1**	**13**	4,6	**11,3**	disc
S32	4S/2M_12	12	2	80	8,0	7,11	5,7	**7,5**	**9**	5,5	**8,4**	disc
S23	4S/2M	X12	3	100	8,0	6,50	5,0	**8,3**	**10**	-	-	0,2
S22	4S/2M _ASC front	HL	2	80	8,0	6,97	5,6	**7,9**	**10**	-	-	0,2

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Trailer	System Configuration	sens.-identif.	No. of axles	V_0 l	p_0 bar	p_{15s} bar	p_5 bar	n_{e_EC} n_{er_ECE}	n_{e_ECE}	p_{5_EC} +20% bar	$n_{e\ EC}$ +20%	R_l R_1
S23	4S/2M _ASC front	HXL	3	100	8,0	6,67	5,1	**7,9**	**10**	-	-	0,2
S23	4S/2M _ASC front	XHL	3	100	8,0	6,50	5,0	**8,3**	**10**	-	-	0,2
S32	4S/2M _ASC front	HL	2	80	8,1	7,15	5,7	**7,4**	**9**	5,5	**8,2**	disc
S33	4S/2M _ASC front	HXL	3	100	8,1	6,57	5,2	**8,6**	**11**	4,9	**9,8**	disc
S32	4S/3M	MS	2	80	8,0	6,68	5,4	**8,6**	**11**	5,2	**9,6**	disc
S33	4S/3M	SMX	3	100	8,0	6,51	5,1	**8,8**	**11**	4,9	**9,9**	disc
S33	4S/3M	XMS	3	100	8,0	6,80	5,3	**7,8**	**10**	5,1	**8,9**	disc
S22	4S/3M	SM	2	80	8,1	6,84	5,3	**7,8**	**10**	-	-	0,2
S23	4S/3M	SMX	3	100	8,1	6,46	5,0	**8,6**	**11**	-	-	0,2
S23	4S/3M	MXS	3	100	8,1	6,61	5,1	**8,2**	**10**	-	-	0,2
SF41	2S/1M	1	1	40	8,0	6,67	5,2	**8,1**	**10**	5,0	**8,9**	disc
SF41	2S/2M	1	1	40	8,0	6,77	5,4	**8,1**	**10**	5,1	**9,3**	disc
F42S	4S/3M	SM	2	80	8,0	6,79	5,8	**9,9**	**12**	5,6	**11,4**	disc
F42L	4S/3M	SM	2	80	8,040	6,76	5,7	**10,6**	**13**	5,3	**12,0**	disc
F43	4S/3M	SMX	3	120	8,0	6,92	5,7	**10,2**	**13**	5,5	**11,2**	disc
F43	4S/3M	SXM	3	120	8,0	6,91	5,7	**10,3**	**13**	5,5	**11,3**	disc
SF51	2S/1M	1	1	40	8,0	6,80	5,4	**8,0**	**10**	-	-	0,2
SF51	2S/2M	1	1	40	8,0	6,86	5,5	**8,4**	**11**	-	-	0,2
F52S	4S/3M	SM	2	80	8,1	7,05	6,0	**8,9**	**11**	-	-	0,2
F52L	4S/3M	SM	2	80	8,1	7,04	5,9	**8,5**	**11**	-	-	0,2
F53	4S/3M	SMX	3	120	8,0	6,64	5,4	**9,3**	**12**	-	-	0,2
F53	4S/3M	SXM	3	120	8,0	6,61	5,4	**9,4**	**12**	-	-	0,2

Appendix 4-3 - Split-friction test

Road surface: wet blue basalt/ wet asphalt

Test speeds: 50 km/h

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

Trailer	System Configuration & sensing identifier	No. of Axles	z_{RALH}	z_{RALL}	f	z_{RALS}	$z_{RALS\_requ.}$
S23	2S/1M_X1X	3	0,467	0,090	5,2	0,115	- **
S23	2S/1M_X1X*	3	0,489	0,099	4,9	0,113	- **
S33	2S/1M_X1X	3	0,464	0,077	6,0	0,081	- **
S31	2S/2M_1	1	0,466	0,076	6,1	0,273	0,130
S32	2S/2M_X1	2	0,513	0,087	5,9	0,311	0,146
S33	2S/2M_X1X	3	0,521	0,080	6,5	0,304	0,149
S33	2S/2M_X1X*	3	0,463	0,086	5,4	0,289	0,159
S22	2S/2M_X1	2	0,522	0,095	5,5	0,273	0,159
S22	2S/2M_SL_1R	2	0,475	0,054	8,7	0,149	0,122
S23	2S/2M_SL_R1X	3	0,422	0,075	5,6	0,199	0,132
S32	2S/2M_SL_1T	2	0,500	0,045	11,1	0,170	0,120
S33	2S/2M_SL_X1T	3	0,480	0,064	7,5	0,198	0,128
S32	4S/2M_12	2	0,461	0,079	5,9	0,288	0,130
S33	4S/2M_X12	3	0,432	0,082	5,3	0,286	0,135
S33	4S/2M_12X	3	0,416	0,080	5,2	0,303	0,137
S33	4S/2M_1X2	3	0,433	0,079	5,4	0,295	0,146
S22	4S/2M_12	2	0,543	0,067	8,1	0,253	0,140
S22	4S/2M_ASC front HL	2	0,507	0,082	6,2	0,195	0,141
S23	4S/2M_ASC front HXL	3	0,487	0,089	5,5	0,235	0,160
S32	4S/2M_ASC front HL	2	0,493	0,086	5,7	0,219	0,147

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Trailer	System Configuration & sensing identifier	No. of Axles	z_{RALH}	z_{RALL}	f	z_{RALS}	$z_{RALS\_requ.}$
S33	4S/2M_ASC front XHL	3	0,510	0,089	5,8	0,261	0,150
S32	4S/3M_MS	2	0,596	0,099	6,0	0,221	0,173
S33	4S/3M_SXM	3	0,619	0,108	5,7	0,272	0,180
S33	4S/3M_XMS	3	0,630	0,096	6,6	0,249	0,174
S22	4S/3M_MS	2	0,504	0,081	6,2	0,185	0,137
S22	4S/3M_MS*	2	0,540	0,083	6,5	0,175	0,143
S23	4S/3M_SXM	3	0,473	0,099	4,8	0,223	0,140
S23	4S/3M_MXS	3	0,494	0,094	5,3	0,219	0,142
S23	4S/3M_XMS	3	0,477	0,103	4,6	0,195	0,146
S23	4S/3M_XMS*	3	0,483	0,094	5,1	0,215	0,142
F42S	4S/3M_SM	2	0,615	0,108	5,7	0,234	0,194
F43	4S/3M_SXM	3	0,571	0,108	5,3	0,235	0,193
F52L	4S/3M_SM	2	0,607	0,112	5,4	0,217	0,184
F53	4S/3M_SMX	3	0,621	0,126	4,9	0,236	0,178

Note: Tests marked with an ***** were carried out with a reduction in the brake lever length on axle „1“.

Tests marked with two ****** were carried out to check the stability behaviour of these vehicles (fitted with a category B anti-lock braking system) when the brakes were suddenly actuated when the right and left wheels of the vehicles were situated on surfaces with differing coefficients of adhesion

Appendix 4-4 - Additional checks

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 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 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 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 blue basalt
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 blue basalt/ dry asphalt
Test speeds:	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 1,6 s.

Appendix 5 - Further test results

The following tests results were obtained with the test vehicles fitted with the previous software version. Comparative testing with vehicles equipped with the new and old software had shown that the old testing results are also applicable for the ABS with the current software version. In particular, the spread of the test results regarding the deviation of the 40 to 20 km/h deceleration times t in % in respect to the various simulated tyre rolling circumference and the various tube lengths were less or equal than of the test results obtained with the previous software.

1 Tyre to exciter relationship

Paragraph 4.1.4.2 of Annex XIV requires that the functional checks defined in paragraph 6.3 of Annex X be carried out with the extremes of tolerance of the recommended range of tyre size for an exciter with a given number of teeth. To assess the influence on system performance at the extremes defined in the Manufacturer's Information Document, assessments of performance were carried out with exciters having 100 (optimum design, equating to 306 revs/km), 75 and 120 teeth which represent a variation on the optimum of - 25 % to + 20 % which is greater than the tolerance defined in the Manufacturer's Information Document (compare paragraph 2.1.2.3).

Test results and observations:

The following table contains the respective 40 to 20 km/h deceleration times for the optimum and tolerance extremes.

Simulated tyre rolling circumference	**3268 mm**	**3921 mm**	**2450 mm**
Circumference variation	**0 %**	**+20 %**	**-25 %**
Test order	1st measurement	2nd measurement	3rd measurement
Revolutions/km	306	255	408
Asphalt dry	2,14	2,20	2,14
2S/2M - S33_X1aX	2,20	2,19	2,05
40 to 20 km/h time (t)	2,22	2,23	2,03
average (time t)	**2,19 s**	**2,21 s**	**2,07 s**
deviation of t in %	**0 %**	**+ 0,9 %**	**- 5,5 %**

Appendix 5

Simulated tyre rolling circumference	3268 mm	3921 mm	2450 mm
Circumference variation	**0 %**	**+20 %**	**-25 %**
Test order	1st measurement	2nd measurement	3rd measurement
Revolutions/km	306	255	408
Asphalt dry	3,62	3,72	3,71
2S/1M - S11_1	3,82	3,59	3,74
40 to 20 km/h time (t)	3,53	3,54	3,78
average (time t)	**3,66 s**	**3,62 s**	**3,74 s**
deviation of t in %	**0 %**	**- 1,1 %**	**+ 2,4 %**
Asphalt dry	2,42	2,20	2,25
4S/3M - S23_SaMX ("2")	2,36	2,17	2,34
40 to 20 km/h time (t)	2,25	2,21	2,32
average (time t)	**2,34 s**	**2,19 s**	**2,30 s**
deviation of t in %	**0 %**	**- 6,4 %**	**- 1, 7 %**
split	4,12	4,05	3,95
2S/2M - S33_X1aX	3,98	4,07	3,77
40 to 20 km/h time (t)	4,15	4,13	4,01
average (time t)	**4,08 s**	**4,08 s**	**3,91 s**
deviation of t in %	**0 %**	**0 %**	**- 4,2 %**
split	5,91	5,85	5,95
4S/3M - S23_SaMX ("2")	5,66	5,94	5,82
40 to 20 km/h time (t)	5,74	6,01	5,73
average (time t)	**5,77 s**	**5,93 s**	**5,83 s**
deviation of t in %	**0 %**	**+2,8 %**	**+ 1,0 %**

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

Within Appendix 4-1 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 the Manufacturer's Information Document, response tests were carried out with the delivery tubes specified. Anti-lock performance was then verified at the extremes of tube size recommended.

Time measurement

The Manufacturer's Information Document states that the maximum length of tube for a directly controlled wheel shall be limited to 3 m and in the case of an indirectly controlled wheel this may be increased to 5 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 length of the modulator to brake chamber tube length.

The response time measurements (pneumatic control signal) given in the table below represent those obtained from a 3-axle semi-trailer where the tube length to either a directly controlled axle or indirectly controlled axle was increased as follows:

Anti-lock performance

The following test results were obtained from a three axle semi-trailer installed with a 2S/2M-system, configured as X1aX (Table A) and with a 2S/1M-system, configured as X1X (Table B) where the tube length to the **directly** controlled axle represented an optimum installation and one where the delivery tube length to that axle was increased to 3 m. The tube length to the indirectly controlled axle was increased up to 5 m.

The tests "S4_1" and "S3_1" (see following tables) carried out with front and rear axle raised represent a simulated laden condition.

Appendix 5

Table A

	S4_3 ⇒ "unladen" S4_1 ⇒ "laden"	t_{zRAL} [s]	axle 1	axle 2	axle 3	time [ms]
A	**S4_3** **standard** tube length	2,39 2,33 2,45	2,75 m indirectly controlled	1,20 m directly controlled	1,55 m indirectly controlled	**300**
	Average	**2,39**				
B	**S4_3** increased tube length	2,38 2,40 2,44	2,75 m indirectly controlled	3,00 m directly controlled	1,55 m indirectly controlled	**305**
	Average	**2,41**				
C	**S4_3** increased tube length	2,35 2,33 2,51	2,75 m indirectly controlled	3,00 m directly controlled	5,00 m indirectly controlled	**327**
	Average	**2,40**				
D	**S4_1** **standard** tube length	2,44 2,40 2,43	2,75 m indirectly controlled **lifted**	1,2 m directly controlled	1,55 m indirectly controlled **lifted**	**300**
	Average	**2,42**				
E	**S4_1** increased tube length	2,43 2,38 2,39	2,75 m indirectly controlled **lifted**	3,00 m directly controlled	5,00 m indirectly controlled **lifted**	**327**
	Average	**2,40**				

Table B

S3_3 ⇒ "unladen" S3_1 ⇒ "laden"	t_{zRAL} [s]	axle 1	axle 2	axle 3
S3_3 **standard** tube length	2,39 2,64 2,55	2,75 m indirectly controlled	1,20 m directly controlled	1,55 m indirectly controlled
Average	**2,53**			
S3_3 increased tube length	2,68 2,6 2,56	2,75 m indirectly controlled	3,00 m directly controlled	5,00 m indirectly controlled
Average	**2,61**			
S3_1 increased tube length	2,64 2,49 2,63	2,75 m indirectly controlled **lifted**	3,00 m directly controlled	5,00 m indirectly controlled **lifted**
Average	**2,59**			

4 Specific tests for „Adaptive Surface Control“ configuration

It was considered to be appropriate that for trailers equipped with a **4S/2M axle by axle installation** utilising Adaptive Surface Control on either channel (but only one at any time) should be subject to additional tests although no procedures or requirements exist within the EEC Directive 71/320/EEC or ECE Regulation 13. The tests considered appropriate were those that verified that the system was capable of reacting to changes in tyre to road adhesion e.g. „low to split“ etc.

The following tests were carried out.

4.1 Transition assessment tests - test procedure

The trailer only was braked on either a homogeneous surface or split surface and with the anti lock cycling and the appropriate control logic operational a transition to split friction or homogeneous surface was made.

4.2 Observations

4.2.1 Split to **low:**

Following application of the brakes the system recognised the differences in adhesion and changed logic to Select High. On traversing onto the low adhesion surface the controlling high adhesion wheel reacted to the change in surface adhesion which provoked a reaction from the opposite side directly controlled wheel. A comparison of wheel reactions was then made and the system reverted to Select Low as appropriate for the low adhesion homogenous surface.

4.2.2 Split to **high:**

Following application of the brakes the system recognised the differences in adhesion and changed logic to Select High. On traversing onto the high adhesion surface the locked low adhesion wheel reacted to the change in surface adhesion. A comparison of wheel reactions was then made and the system reverted to Select Low as appropriate for the high adhesion homogenous surface.

4.2.3 **High** to split:

Following application of the brakes the system recognised the homogeneous surface and remained in Select Low. On traversing onto the split adhesion surface a difference in wheel reaction was recognised with a change to Select High being made.

4.2.4 **Low** to split:

Following application of the brakes the system recognised the homogeneous surface and remained in Select Low. On traversing onto the split adhesion surface a difference in wheel reaction was recognised with a change to Select High being made.

4.2.5 In all of the above test conditions trailer stability was maintained throughout.