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TRAILER ANTI-LOCK BRAKING SYSTEM APPROVAL REPORT

Approval Report No: EB 120.1E

1. Identification.

1.1 Manufacturer: **Haldex Brake Products Ltd**
Redditch, Worcestershire B98 9HA
England

1.2. System name/model: **Modal**

2. System and installation

2.1 Configurations: **2S/1M - 2S/2M - 4S/2M - 4S/3M - 6S/3M**

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 and 6S/3M configurations may be used on full trailers with either 2 or 3 axles.

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

For more detailed system installation examples refer to para. 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 connector conforming to ISO 7638 and an intermittent power supply. In addition some ECU configurations have an additional optional permanent power supply. The following table defines the possibilities available:

	12 V	24 V
Permanent	ISO 7638-2	ISO 7638-1
Intermittent	ISO 1724 (12N)	ISO 1185 (24N)
Permanent	ISO 3732 (12S)	ISO 3731 (24S)

For specific application see manufacturer's Information Document, para. 2.1.3.4.2.

2.4. Identification of approved components

2.4.1 Sensors: see manufacturer's Information Document, para. 2.1.3.1.1

2.4.2 Controller (ECU): see para. 2.1.3.2.3 and Appendix 7 of the manufacturer's Information Document for 12 V and 24 V applications

2.4.3 Modulators: see para. 2.1.3.3.2 and Appendix 10 of the manufacturer's Information Document for 12 V and 24 V applications

2.5. Energy consumption

2.5.1 Drum brakes:

2.5.1.1 Equivalent static brake applications

Full trailers [3M-systems]: n_e = 13 applications

Semi-trailers

1M- and 2M-systems: n_e = 15 applications

3M-systems: n_e = 16 applications

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

2.5.2 Disc brakes:

The procedure defined in Annex XIV only defines a procedure for trailers with drum brakes but states that alternative designs may be taken into considerations. 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 static brake applications could be defined for the increased volume condition.

2.5.2.1 Equivalent static brake applications

For all anti-lock configurations: n_e = 15 applications

The 15 brake applications [n_e] 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

		is to be carried out **without** any increase in actuator stroke as defined in paragraph 6.2.1.1 of Annex XIV.
2.6.	**Additional features**	
2.6.1	Automatic configuration:	see manufacturer's Information Document, para. 2.1.3.2.5
2.6.2	Retarder Control	see manufacturer's Information Document, para. 2.1.3.2.5
2.6.3	Lifting axle(s)	see manufacturer's Information Document, para. 2.1.2.2 and para. 2.1.3.2.5
2.6.4	Steering axle(s)	see manufacturer's Information Document, para. 2.1.2.2 and para. 2.1.3.2.5
2.6.5	Reset to Ride Height	see manufacturer's Information Document, para. 2.1.3.2.5
2.6.6	Variable Parameters	see manufacturer's Information Document, para. 2.1.3.2.5
2.6.7	Diagnostics	see manufacturer's Information Document, para. 2.1.3.2.5
3.	**Test data and results**	
3.0	General:	(e.g. test schedule, worst case cross referencing) see Appendix 4 of this Approval Report
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	
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 para. 2.1.2.7 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, para. 1 of this Approval Report

3.3.5. High speed performance:	see Appendix 4-4, para. 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, para. 3 of this Approval Report
3.3.6.2 Transition from low to high-adhesion surfaces:	see Appendix 4-4, para. 4 of this Approval Report
3.3.7. Failure mode simulation:	see Appendix 5 of this Approval Report and para. 2.1.3.2.4 and appendices 8-1 to 8-4 of the manufacturer's Information Document
3.3.8. Functional checks of optional power connections:	Functional checks were carried out utilising the methods of powering as defined in paragraph 2.3 above.
3.3.9. 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 para. 2.1.4. of that document).
3.3.10. Performance of 12V-Systems:	The main application for the Modal systems is for trailers utilising 24V electrical systems. However performance comparisons were made with trailers installed with 12- and 24 Volt anti-lock systems, the results of which are defined in Appendix 5, para. 4 of this Approval Report and deemed to be satisfactory.

4. 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, para. 2.1.2.3 and is applicable to all system configurations. - see also Appendix 5, para. 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, para. 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 and balanced mechanical 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 para. 2.1.2.6 and Appendix 5 of the manufacturer's Information Document and Appendix 5, para. 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 3.2 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 3.93 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 para. 2.1.2.2 and para. 2.1.3.5.2 of the manufacturer's Information Document and Appendix 5, para. 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.	Load sensing device application:	All configurations were evaluated with the load sensing device set to the laden condition **and** with a delivery pressure equivalent to 1 bar above anti-lock cycling pressure. Performance of the respective system configurations fulfilled the prescribed requirements in both conditions. Therefore all systems may be used on trailers with or without a load apportioning device.
4.9.	Warning lamp sequence:	All configurations have the option of two discrete warning lamp sequences - see para. 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 98/12/EC.
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 para 2.1.2.2. and Appendix 1 of the manufacturer's Information Document.
4.10.2	Category A performance:	Anti-lock system configurations 2S/2M, 4S/2M, 4S/3M and 6S/3M comply with the prescribed split friction requirements defined in para. 6.3.2 of Annex X, provided the location of sensors and modulators are in accordance with the recommendations defined in para. 2.1.2.2 and Appendix 1 of the manufacturer's Information Document.

5. Date of test: October 1998

The anti-lock braking system described above complies with the requirements of Annex XIV of Directive 71/320/EEC as last amended by Directive 98/12/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

Appendix 4-2	Energy consumption
Appendix 4-3	Split-friction test
Appendix 4-4	Additional checks
Appendix 5	Further test results
Appendix 6	Safety assessment

7 Annex

Annex	Manufacturer's Information Document - GS 0244 - Issue 2 dated 17 February 1999

Technical Service

25 February 1999
TDB/Gaupp
200 041 09

LABORATORY FOR VEHICLE TECHNOLOGY
Testing Laboratory for Braking Systems according to Directive 71/320/EEC in the version of Directive 98/12/EC

Institute for Vehicle Technology
Technical Services for Braking Systems

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Approval Authority

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Flensburg, den 02.03.1999

Im Auftrag

(Artz)

Kraftfahrt-Bundesamt 58

Appendix 1 - Abbreviations & Codes

BC	brake cylinder
E	wheelbase
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)
ε_1:1	ε-value ascertained without load apportioning device
ε_LAD	ε-value ascertained with load apportioning device set at 1 bar above the maximum anti-lock cycling pressure
h_R	height of centre of gravity
h_D	height of drawbar (hinge point on trailer)
h_K	height of fifth wheel coupling (king pin)
l_T	brake lever length in mm.
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 air reservoir
p_{15s}	pressure after 15 s
p_5	5th static pressure
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 during the determination of k for a front axle
PRnd-kr	static reaction of the road surface of the unbraked axles 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)
V_0	capacity of the braking system air reservoir(s) in litres

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
$z_{RALS\_1:1}$	z_{RAL} on the split surface without load apportioning device
z_{RALS_LAD}	z_{RAL} on the split surface with load apportioning device set at 1 bar above the maximum anti-lock cycling pressure

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:

wet basalt

The characteristics of the surface were obtained in accordance with the requirements of footnote 1 of Appendix 4 of Annex X to Directive 98/12/EC 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 1.5.

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:	3110 kg
Tyre type:	Michelin XZA 385/65R22.5
k_{peak}	0.1504
k_{lock}	0.141
Ratio „R“:	1.066

Appendix 3 - Test vehicle data

1 Vehicle data

1.1 General

The following table defines the fixed parameters of the trailers used for the purpose of this approval.

	S1	S2	S3	S4	S5	F1	F2	F3
no axles	1	2	3	3	2	2	2	3
brake	drum	drum	drum	disc	disc	drum	drum	drum
suspension	air	mechanical (balanced)	mechanical (balanced)	air	air	air	air	air
air res. V_0 in l	40	80	120	120	80	80	80	120
axle 1 BC/ l_T	24/130	24/130	24/105	16/--	16/-- (lifted)	30/135	30/135	30/135
axle 2 BC/ l_T	--	24/130	24/130	16/--	16/--	24/135	24/135	24/135
axle 3 BC/ l_T	--	--	24/130	16/--	16/--	(3. axle removed)	(2. axle lifted)	24/135

1.2 Weights and dimensions (z_{RAL}-measurements)

	S1	S2	S3	S4	S5	F1	F2	F3
no axles	1	2	3	3	2	2	2	3
PM [kg]	9680	9170	9810	11200	11600	8120	8200	8200
PMnd [kg]	5460	5570	5870	7890	8100	5340	5410	5410
PMd [kg]	4220	3600	3940	3310	3500	2780	2790	2790
PA [kg]	4570	5010	6710	7650	7650	5740	5580	5580
PR [kg]	3110	4090	5150	5750	5350	5740	5580	5580
PRnd-kf [kg]	-	-	-	-	-	3420	2740	3220
PRnd-kr [kg]	-	-	-	-	-	2320	2840	2360

	S1	S2	S3	S4	S5	F1	F2	F3
Pf [kg]	-	-	-	-	-	2320	2840	2360
Pr [kg]	-	-	-	-	-	3420	2740	3220
hR [mm]	900	900	900	900	900	900	900	900
hK / hD [mm]	1350	1400	1400	1400	1400	750	750	750
ER / E [mm]	7750	8665	7600	7750	8420	3200	4610	3930

1.3 Weights and dimensions (k-measurements)

	S1	S2	S3	S4	S5	F1	F2	F3
no axles	1	2	3	3	2	2	2	3
PM [kg]	9680	8690	9450	11260	11260	8120	8200	8200
PMnd [kg]	5460	5460	5730	7930	7930	5340	5410	5410
PMd [kg]	4220	3230	3720	3330	3330	2780	2790	2790
PA [kg]	4570	4070	5040	7650	7650	5740	5580	5580
PR [kg]	3110	3630	3840	5690	5690	5740	5580	5580
PRnd-kf [kg]	-	-	-	-	-	3420	2740	2740
PRnd-kr [kg]	-	-	-	-	-	2320	2840	2840
Pf [kg]	-	-	-	-	-	2320	2840	2840
Pr [kg]	-	-	-	-	-	3420	2740	2740
hR [mm]	900	900	900	900	900	900	900	900
hK / hD [mm]	1350	1400	1400	1400	1400	750	750	750
ER / E [mm]	7750	7750	7600	7750	7750	3200	4610	4610

1.4 Weights (energy consumption tests)

	S1	S2	S3	S4	S5	F1	F2	F3
PR [kg]	3550	7040	10560	10510	7170	7110	7020	10620
PA [kg]	4870	7920	13710	12480	9810	7110	7020	10620

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.

System configuration _S number of sensors (directly controlled wheels) _M number of pressure modulators	sensing-identifier sensor reference and position within the bogie	Notes „X" denotes, no sensor is fitted on given axle
2S/1M	_1	the number of characters after the under score „_" denote the number of axles: here the „1" denotes that the 1-axle trailer is fitted with sensors „1"
2S/2M	_2X	the first axle is equipped with sensors „2", the second axle is not fitted with sensors (indirectly controlled axle)
4S/2M-SxS	_23	side by side control with sensor „2" on first axle and with sensor „3" on second axle
6S/3M	_321	sensor „3" on first axle - sensor „2" on second axle - sensor „2" on third axle fitted

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.

Location of directly controlled wheels - Semi-trailer							
	1 axle	2 axles	2 axles	3 axles	3 axles	3 axles	3 axles
2S/1M	1 [1]	1X [2]	X1 [2]	X1X [3]			
2S/2M	2 [1]	2X [2]	X2 [2]	X2X [3]			
4S/2M - SxS		23 [5]	32 [5]	X23 [3,4,5]	X32 [3,4,5]		
4S/3M		12	21 [6]	2X1 [6]	12X	X21 [3,4,5]	1X2
6S/3M				321 [6]	123 [5]	132 [5]	

Location of directly controlled wheels - Full trailer			
	2 axles	3 axles	3 axles
4S/3M	12	12X	1X2
6S/3M		123 [5]	132 [5]

Note: The figures in brackets relate to worst case cross referencing as defined below.

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 **Single axle semi-trailer:** The suspension type is not considered important and therefore for the purposes of this approval all tests were carried out on a trailer with air suspension and the results applied to single axle trailers with mechanical suspension.

2 **Two axle semi-trailer:** In the case of systems with only two sensors it is considered that due to suspension reactivity that this test condition represents a worst case, this was verified by a single comparative test.

3 **Three axle semi-trailer with mechanical suspension:** In the case of all two sensor installations and some four sensor installations the tests were carried out with the cam lever length on axle 1 reduced by 25 mm/1" (see also Appendix 5, para. 2 of this report).

4 **Three axle semi-trailer with pneumatic suspension:** Tests to be repeated with the cam lever length reduced by 25 mm/1".

5 These configurations are considered to have the same performance and was verified by a comparative test.

6 „Select Low" control channel is installed on the heaviest axle during dynamic braking and represents a worst case for utilisation of adhesion, split friction and energy consumption testing, this was verified by a comparative test.

General

Test results within the following appendices that have a smaller type face are from tests that were conducted on an anti-lock system [Modular] that utilises the same software and pressure modulators and are reported in Approval Report EB 121.1E. These tests were carried out on the same test trailers and at the same time.

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Appendix 4-1 - Utilisation of adhesion

1 Semi-trailer

Trailer	Test ref.	Configuration	Axle no.	k_R	c_1:1	c_LAD
S1	A01	2S/1M_1	1	0.848	0.85	0.82
S1	A02	2S/1M_1	1	0.848	0.80	0.77
S1	A03	2S/2M_2	1	0.848	0.82	0.80
S1	A04	2S/2M_2	1	0.848	0.85	081
S2	A05	2S/1M_1X	2	0.850	0.81	0.85
S2	A06	2S/1M_1X	2	0.850	0.80	0.85
S2	A07	2S/2M_2X	2	0.850	0.79	0.82
S2	A08	2S/2M_2X	2	0.850	0.80	0.83
S2	A09	4S/2M-SxS_23	2	0.850	0.78	0.80
S2	A10	4S/2M-SxS_23	2	0.850	0.80	0.84
S2	A12	4S/3M_21	2	0.850	0.82	0.87
S3	A26*	2S/1M_X1X	3	0.857	0.83	0.85
S3	A27*	2S/1M_X1X	3	0.857	0.82	0.82
S3	A28*	2S/2M_X2X	3	0.857	0.82	0.84
S3	A29*	2S/2M_X2X	3	0.857	0.80	0.82
S3	A30*	4S/2M-SxS_X23	3	0.857	0.82	0.80
S3	A31*	4S/2M-SxS_X23	3	0.857	0.80	0.84
S3	A34	4S/3M_2X1	3	0.857	0.81	0.82
S3	A35	4S/3M_12X	3	0.857	0.83	0.80
S3	A36	6S/3M_321	3	0.857	0.82	0.85

Trailer	Test ref.	Configuration	Axle no.	k_R	ε_1:1	ε_LAD
S4	A37*	2S/1M_X1X	3	0.816	0.85	0.87
S4	A38*	2S/1M_X1X	3	0.816	0.83	0.85
S4	A39*	2S/2M_X2X	3	0.816	0.84	0.86
S4	A40*	2S/2M_X2X	3	0.816	0.86	0.88
S4	A41*	4S/2M-SxS_X23	3	0.816	0.84	0.87
S4	A42*	4S/2M-SxS_X23	3	0.816	0.83	0.84
S4	A43	4S/2M-SxS_X32	3	0.816	0.87	0.87
S4	A48	4S/3M_2X1	3	0.816	0.79	0.82
S4	A49*	4S/3M_X21	3	0.816	0.87	0.90
S4	A50	4S/3M_12X	3	0.816	0.85	0.88
S4	A51	4S/3M_1X2	3	0.816	0.87	0.88
S4	A52	6S/3M_321	3	0.816	0.87	0.88
S4	A53	6S/3M_123	3	0.816	0.81	0.88
S4	A54	6S/3M_132	3	0.816	0.86	0.90
S5	A13	2S/1M_1X	2	0.816	0.89	0.91
S5	A14	2S/1M_1X	2	0.816	0.87	0.86
S5	A15	2S/1M_X1	2	0.816	0.89	0.86
S5	A16	2S/2M_2X	2	0.816	0.93	0.95
S5	A17	2S/2M_2X	2	0.816	0.92	0.95
S5	A18	2S/2M_X2	2	0.816	0.86	0.90
S5	A19	4S/2M-SxS_23	2	0.816	0.89	0.90
S5	A20	4S/2M-SxS_23	2	0.816	0.90	0.97
S5	A21	4S/2M-SxS_32	2	0.816	0.89	0.92
S5	A24	4S/3M_21	2	0.816	0.92	0.89
S5	A25	4S/3M_12	2	0.816	0.92	0.91

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

2 Full trailer

Trailer	Test ref.	Configuration	Axle no.	k_f	k_r	k_R	e_1:1	e_LAD
F1	A60	4S/3M_12	2	0.895	0.899	0.897	0.82	0.77
F2	A55	4S/3M_12	3	0.803	0.846	0.822	0.79	0.76
F3	A56	4S/3M_12X	3	0.803	0.846	0.822	0.82	0.80
F3	A57	4S/3M_1X2	3	0.803	0.846	0.822	0.76	0.79
F3	A58	6S/3M_123	3	0.803	0.846	0.822	0.82	0.78
F3	A59	6S/3M_132	3	0.803	0.846	0.822	0.80	0.78

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Appendix 4-2

Appendix 4-2 - Energy consumption

Trailer	Test ref.	Configuration	Axle no.	V_0 l	p_0 bar	p_{15s} bar	p_5 bar	n_e	BC brake chamber	R
F1	C60	4S/3M_12	2	80	8,0	5,35	4,2	13	30/24	0.2
F2	C23	4S/3M_12	3	80	8,0	5,7	4,2	13	30/24	0.2
F3	C24	4S/3M_12X	3	120	8,0	5,7	4,6	12	30/24/24	0.2
F3	C25	6S/3M_123	3	120	8,0	5,75	4,7	12	30/24/24	0.2
S1	C01	2S/1M_1	1	40	8,0	5,5	4,25	15	24	0.2
S1	C02	2S/2M_2	1	40	8,0	5,3	4,1	14	24	0.2
S2	C03	2S/1M_1X	2	80	8,0	5,5	4,25	14	24/24	0.2
S2	C04	2S/2M_2X	2	80	8,0	5,45	4,2	15	24/24	0.2
S2	C05	4S/2M-SxS_23	2	80	8,0	5,5	4,3	14	24/24	0.2
S2	C07	4S/3M_21	2	80	8,0	5,3	4,2	15	24/24	0.2
S3	C12	2S/2M_X2X	3	120	8,0	5,4	4,45	14,5	24/24/24	0.2
S3	C13	4S/2M-SxS_X23	3	120	8,0	5,4	4,35	15	24/24/24	0.2
S3	C15	4S/3M_2X1	3	120	8,0	5,05	4,1	16	24/24/24	0.2
S3	C16	6S/3M_321	3	120	8,0	5,15	4,15	16	24/24/24	0.2
S4	C17	2S/2M_X1X	3	120	8,0	6,0	5,0	13,5	16/16/16	-
S4	C18	2S/2M_X2X	3	120	8,0	5,9	4,9	14	16/16/16	-
S4	C19	4S/2M-SxS_X23	3	120	8,0	5,7	4,7	15	16/16/16	-
S4	C21	4S/3M_2X1	3	120	8,0	6,0	4,8	14	16/16/16	-
S4	C22	6S/3M_321	3	120	8,0	6,0	4,7	14,5	16/16/16	-
S5	C08	2S/2M_2X	2	80	8,0	5,4	4,4	13	16/16	-
S5	C09	4S/2M-SxS_X23	2	80	8,0	5,4	4,35	13	16/16	-
S5	C11	4S/3M_21	2	80	8,0	5,4	4,4	13	16/16	-

Appendix 4-3 - Split-friction test

Road surface: wet blue basalt/ wet asphalt

Test speeds: 50 km/h

Ratio $f = z_{RALH} / z_{RALL}$ in the μ-split tests: ≈ 4 to 5

No inadmissible locking or inadmissible course deviation was established with the following split-friction tests.

Trailer	Test ref.	Configuration	Axle no.	$z_{RALS\_1:1}$	z_{RALS_LAD}	$z_{RALS\_requ.}$
F1	S60	4S/3M_12	2	0,226	0,239	0,196
F2	S19	4S/3M_12	3	0,205	0,197	0,190
F3	S20	4S/3M_12X	3	0,214	0,221	0,187
F3	S21	6S/3M_123	3	0,211	0,196	0,168
S1	S01	2S/2M_2	1	0,338	0,346	0,194
S2	S02	2S/2M_2X	3	0,285	0,284	0,178
S2	S03	4S/2M-SxS_23	3	0,260	0,253	0,166
S2	S05	4S/3M_21	2	0,226	0,216	0,157
S3	S10	2S/2M_X2X	3	0,298	0,298	0,185
S3	S11	4S/2M-SxS_X23	3	0,273	0,265	0,173
S3	S13	4S/3M_2X1	3	0,243	0,223	0,179
S3	S14	6S/3M_321	3	0,239	0,254	0,170
S4	S15	4S/2M-SxS_X32	3	0,327	0,307	0,170
S4	S17	4S/3M_12X	3	0,241	0,237	0,174
S4	S18	6S/3M_123	3	0,248	0,242	0,179
S5	S06	2S/2M_2X	2	0,327	0,323	0,163
S5	S07	4S/2M-SxS_32	2	0,325	0,317	0,162
S5	S09	4S/3M_12	2	0,222	0,228	0,164

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Appendix 4-4 - Additional checks

1 Low speed performance

The tests described in Section 6.3.1 of Annex X were carried out on all the above defined unladen test trailers with each anti-lock configuration (with and without the LAD).

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 were carried out on all the above defined unladen test trailers with each anti-lock configuration (with and without the LAD).

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 indended 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 indended course - in all cases the anti-lock systems reacted to the change in tyre to road surface adhesion within a time of 0.4 s to 1.2 s:

Appendix 5 - Further test results

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 102 (optimum design equating to 504 revs/mile), 120 and 76 teeth which represent a variation on the optimum of - 25 % to + 17 % which is greater than the tolerance defined in the Information Document.

Test results and observations:

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

Number of exciter teeth	40 to 20 km/h time (t)	40 to 20 km/h time (t)	40 to 20 km/h time (t)	Average 40 to 20 time	%-Variation mean
102	3.08	3.01	2.92	**3**	
77	**3.01**	**3.1**	**3.07**	**3.06**	**- 0.02%**
120	**3.06**	**2.97**	**2.95**	**2.99**	**+ 0.003%**

Note: all tests conducted with a wet test track

The following table contains information supplied by the system manufacturer in support of worst case discussions. The above table being a verification of that declaration.

Ref	Exciter	Surface	Initial speed	Actual stopping distance	Corrected stopping distance	40 to 20 time
1	120	split	13.8 m/s	112.13 m	112.13 m	6.25 s
2	102	split	13.7 m/s	111.42 m	113.05 m	6.3 s
3	77	split	13.9 m/s	111.67 m	110.06 m	6.3 s
4	120	asphalt	22.2 m/s	127.4 m	127.4 m	2.75 s

Ref	Exciter	Surface	Initial speed	Actual stopping distance	Corrected stopping distance	40 to 20 time
5	102	asphalt	22.2 m/s	127.53 m	127.53	2.75 s
6	77	asphalt	22.2 m/s	128.87 m	128.87 m	2.75 s
7	102	asphalt	11.1 m/s	37.16 m	37.16 m	2.83 s*
8	102	asphalt	11.1 m/s	37.39 m	37.39 m	2.9 s*
9	77	asphalt	11.1 m/s	37.01 m	37.01 m	2.95 s*

* Times measured between 35 and 15 km/h.

It was verified that the high and low speed performance [80 and 40 km/h] was satisfactory and that the directly controlled wheels remained under control at all speeds v > 15 km/h without deviation from the intended course.

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 following time measurements 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:

Measurement obtained with an optimum installation:	0,33 s
Measurement obtained with a tube length increased to 3 m:	0,37 s
Measurement obtained with a tube length increased to 5 m:	0,39 s

Anti-lock performance

The following test results were obtained from a three axle semi-trailer installed with a 2S/2M-system 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.

Tests conducted with front and rear axle raised (simulated laden condition):

S4_1	ABS times [s]	Average time[s]
Optimal length	2.9 - 2.79 - 2.72	2.80
3 m tube length	2.76 - 2.64 - 2.79	2.73
"Laden" Variation = -2.5%		

Tests conducted with all three axles braked:

S4_3	ABS times [s]	Average time [s]
Optimal length	2.99 - 2.9 - 3.07	2.98
3 m tube length	3.15 - 2.99 - 3.01	3.05
"Unladen" Variation = +2.3%		

The following test results were obtained from a three axle semi-trailer installed with a 2S/2M-system where the tube length to the rear indirectly controlled axle represented an optimum installation and one where the delivery tube length to that axle was increased to 5 m.

Optimum tube length		5 m to rear axle only	
6.5 bar demand	3.8 bar demand	6.5 bar demand	3.8 bar demand
3.02	2.88	3.05	2.85
2.88	3.02	2.84	2.98
2.99	3.06	2.75	2.91
Average = 2.96 s	**Average = 2.99 s**	**Average = 2.88 s**	**Average = 2.91 s**

From the above results it is considered that the performance with the increased tube length to an indirectly controlled axle is satisfactory.

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4 Performance of 12V-Systems

To evaluate the performance of the system 12V-variant comparison tests were carried out relative to the previously evaluated 24V-systems. The results of which are as follows:

Results obtained from a 3-axle semi-trailer installed with a 2S/2M-system.

Operating Voltage	Demand Pressure	40 to 20 time	40 to 20 time	40 to 20 time	Average Time	ABS Efficiency
24 V	6.5	2.68	2.63	2.63	2.64	0.769
	3.8	2.52	2.69	2.5	2.57	0.795
12 V	6.5	2.72	2.48	2.5	2.56	0.796
	3.8	2.63	2.55	2.62	2.6	0.785

From the above results it is concluded that there is no difference in the performance between the performanceof 12V and 24V systems.

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Appendix 6 - Safety assessment

1 Safety assessment

1.1 Assessment of the development systematic and the safety concept

1.1.1 Documentation and evaluation of the system concept

For evaluation of the safety concept, the manufacturer presented documentation in which the configurations of the ABS systems "Modal" with its functions and the safety philosophy are described.

1.1.2 Safety assessment

An audit with respect to the safety philosophy of the system was carried out which included the following:

- Project management
- Course of development
- Safety concept
- System specification
- Development methods and tools
- Block diagrams
- Circuit diagrams
- Monitoring functions
- System FMEA
- Design FMEA

Overall the documents examined were satisfactory. It is anticipated that the measures taken are sufficient to attain the desired level of safety.

1.1.3 Analysis regarding possible failures

It was evident in a documented analysis regarding possible failures (FMEA) that the safety concept presented had been realised.

Practical tests of the efficiency of the failure monitoring at the periphery were carried out during driving and bench tests (see para. 1.2 below). The specified safety and failure concept was confirmed.

1.2 Peripheral fault detection and system reaction

The following failures outside of the controller were simulated and analysed:

- Open circuits

- Short circuits
- Sensor failures
- Undervoltage/overvoltage in supply power (electronics)

Measures have been taken within the controller (ECU), that enable detection of corrupted input signals. Depending on the type of failure and system configuration, the controller passes into a defined state in which partial functions are maintained, or the system is switched-off completely. In all cases the controller is able to detect failures external to the controller and provide a failure warning.

1.3 Operational and environmental influences

1.3.1 The manufacturer demonstrated that the electronic controller was specified and developed for those service and environmental influences (climatic test, protection class test, vibration and shock test) that would be appropriate to a vehicle mounted electronic system.

1.3.2 Electro-Magnetic Compatibility (EMC)

Appropriate action has been taken within the design of the system to take account of adverse electromagnetic fields or disturbances and has been validated as follows:

In order to fulfil the requirements with respect to EMC, the systems have been certified according to Directive 72/245/EEC as last amended by Directive 95/54/EC under the Approval No: e11*72/245/*95/54*0122*03.