ABS-System : **VCS II**
Manufacturer : **WABCO**

TRAILER ANTI-LOCK BRAKING SYSTEM APPROVAL REPORT

Approval Report No: EB140.5E

ECE Regulation No. 13 - Annex 19
Directive 71/320/EEC - Annex XIV

0. General

With respect to the previous TÜV NORD Report EB140.4E this report covers the following additions:

- Confirm compliance with ECE Regulation No. 13 as last amended by supplement 5 to the 10 series of amendments
- Confirm compliance with ECE Regulation No. 10 as last amended by the 3 series of amendments
- Additional suspension types (see Appendix 2 of ID_VCS)
- Editorial amendments

For the sake of simplicity the Manufacturer's Information Document "ID_EB140.5E" of the Trailer Anti-Lock Braking System Vario Compact Trailer ABS 2nd Generation is abbreviated to **ID_VCS**.

1. Identification

1.1 Manufacturer: **WABCO Vehicle Control Systems**

Am Lindener Hafen 21

D - 30453 Hannover

1.2 System name/model: **Vario Compact Trailer ABS 2nd Generation** (VCS II)

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2. System and installation

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

See also para 1.4 and Appendix 1 of ID_VCS.

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 para. 2.1 and Appendix 1 of ID_VCS.

For more detailed system installation examples refer to section 2 and Appendices 7 and 8 of ID_VCS.

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 (for exceptions see ID_VCS, para. 3.4), 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 the system shall be connected to an interface conforming to the following standards:

ISO 7638:1985	5 Pin (71/320/EEC)
ISO 7638:1997 Part 1 (24 V)	5 or 7 Pin
ISO 7638:1997 Part 2 (12 V)	5 or 7 Pin

Intermittent: As a safety function in the case 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).

2.4. Identification of approved components

2.4.1 Sensors/exciters: see ID_VCS, paragraph. 3.1

2.4.2 Controller: see ID_VCS, paragraph. 3.2

2.4.3 Modulators: see ID_VCS, paragraph. 3.3

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

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2.5. Energy consumption

2.5.1 Drum brakes :

2.5.1.1 Equivalent static brake applications: see also ID_VCS, paragraph 2.6.1.3

Semi-trailers:

n_{e_EC} **= 12 applications**

n_{e_ECE} **= 14 applications**

Full trailers:

n_{e_EC} **= 12 applications**

n_{e_ECE} **= 15 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 = 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_VCS, paragraph 2.6.1.3

Semi-trailers: n_{e_EC} **= 13 applications**

n_{e_ECE} **= 15 applications**

Full trailers: n_{e_EC} **= 12 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: **see also ID_VCS, paragraph 3.2**

2.6.1 Generic Input/Output functionality

2.6.2 Tractor/trailer communication interface according ISO 11992

2.6.3 Diagnostic interface according to ISO 14230 (KWP2000)

2.6.4 Blink code

2.6.5 Automatic recognition of lift axles

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

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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 2.6.1 of ID_VCS.
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	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 “Electronic Function & Safety Assessment Test Report” No. EB 141.2E.
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 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 paragraph 3.4 of ID_VCS).
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 and to ECE Regulation No. 10 as last amended by 03 series of amendments. A copy of the approval documents is included in ID_VCS (see paragraph 3.6 and Appendix 5 and 6 of that document).

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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 ID_VCS, 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_VCS, 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 the Manufacturer's Information Document, para. 2.4, see also Appendix 5, para. 1 to this Approval Report.
4.3.	Suspension type:	System performance was verified on trailers with balanced mechanical, air or rubber suspensions. Paragraph 2.5 and Appendix 2 of ID_VCS defines approved suspensions for the purpose of the application of this approval. In the case of 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:	see paragraph 2.6 of ID_VCS 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 3755 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_VCS and Appendix 5, section 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:	This report is only applicable to trailers fitted **with a load sensing device**.
4.9.	Warning signal sequence:	All configurations have the option of two discrete warning signal sequences - see para. 3.4 of ID_VCS - both of which fulfil the prescribed requirements of Directive 71/320/EEC and ECE-Regulation No. 13. The anti-lock system doesn't utilize an electrical control line. Thus; only the yellow warning signal specified in paragraph 5.2.1.29.2. is used for the warning signal sequence.
4.10	Category A performance:	All anti-lock system configurations and installations defined in Appendix 1 of ID_VCS comply with the prescribed split friction requirements defined in para. 6.3.2 of annex X to Directive 71/320/EEC and annex 13 to ECE-Regulation No. 13.
4.11	Other recommendations/limitations	
4.11.1	Installation limitations:	For approved installation options with respect to sensor/modulator locations and recommendations for the use of lifting and steering axles see paragraph 2.2 and Appendix 1 of ID_VCS. **Note:** This report does not cover an assessment of the reaction of the available steering systems to the anti-lock braking control of the Vario Compact Trailer ABS II.

5. Date of test: **September 2003 - 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 5 and Annex XIV of Directive 71/320/EEC as last amended by Directive 2002/78/EC.

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6 Appendices

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Appendix 4-4	Additional checks
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7 Annex

Manufacturer's Information Document - ID_EB140.5E of 04.01.2012

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Appendix 1 - Abbreviations & Codes

"ABS"	measurement of "z" with the anti-lock braking system in operation
BC	brake cylinder
DAR	diagonal axle control
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** = $\mathbf{z}_{RALH}$ / $\mathbf{z}_{RALL}$
$\mathbf{h_R}$	height of centre of gravity of trailer
$\mathbf{h_D}$	height of drawbar (hinge point on trailer)
$\mathbf{h_K}$	height of fifth wheel coupling (king pin)
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
$\mathbf{l_T}$	brake lever length in mm
LSV	load sensing valve (LSV function: load-dependent brake force control)
MAR	modified axle control
MSR	modified sidewise control
$\mathbf{n_e}$	number of equivalent static brake applications
$\mathbf{n_{e\_EC}}$	see paragraphs 2.5.1.1 and 2.5.2.1 of this approval report
$\mathbf{n_{e\_ECE}}$	see paragraphs 2.5.1.1 and 2.5.2.1 of this approval report
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

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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)
$R_I \equiv R_1$	$R_1 = \frac{s_T}{l_T}$ ratio of actuator stroke against brake lever length
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

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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 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 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 passenger car measuring wheel. The ratio **R** (k_{peak}/k_{lock}) obtained was 1,8.

The ratio $R = k_{peak}/k_{lock}$ for a commercial vehicle tyre was established using a value of k_{peak} determined according to the procedure as defined in Appendix 2 to Annex X to Directive 98/12/EC and Annex 13 to ECE-Regulation No. 13 respectively.

Several tests with different commercial vehicles (in the “laden” and “unladen” state) and with different tyres showed R values between 1,02 and 1,37.

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Appendix 3 - Test vehicle data

1 Vehicle data

1.1 General

Table "Overview test vehicles

Ref.	Manufacturer	Type	Susp.	Brake	Brake-man.	BC/ l_T [mm]
S11	**Benalu**	one axle semi-trailer (front & rear axle lifted)	air	disc	WABCO	2x16"/86
S12	**Benalu**	two axle semi-trailer (front axle lifted)	air	disc	WABCO	4x16"/86
S13	**Benalu**	three axle semi-trailer	air	disc	WABCO	6x16"/86
S21	**Kögel**	one axle semi-trailer (1st & 3rd axle - wheels removed)	leaf	drum	BPW	2x20"/180
S22	**Kögel**	two axle semi-trailer (3rd axle - wheels removed)	leaf	drum	BPW	4x20"/180
S23	**Kögel**	three axle semi-trailer	leaf	drum	BPW	6x20"/180
C31	**Al-Ko**	one axle centre-trailer (1st axle - wheels removed)	rubber	drum	Al-Ko	2x9"/60
C32	**Al-Ko**	two axle centre-trailer	rubber	drum	Al-Ko	4x9"/60
S41	**Sommer**	"converted semi-trailer" (first axle unbraked, used as a dolly axle)	air	disc	WABCO	2x20"/69
F42 ≡ F42_L	**Sommer**	two axle full trailer **(2nd axle lifted)**	air	disc	WABCO	2x24"/69 2x20"/69
F42_K	**Sommer**	two axle full trailer **(3nd axle lifted)**	air	disc	WABCO	2x24"/69 2x20"/69
F43	**Sommer**	three axle full trailer	air	disc	WABCO	2x24"/69 4x20"/69
F52	**Krone**	two axle full trailer	leaf	drum	BPW	2x16"/165 2x16"/120

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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.

Tables "Weights and dimensions"

	S11	S12	S13	S21	S22	S23
Number of Axles	1	2	3	1	2	3
PM [kg]	9640	10250	9790	10910	10390	10970
PMnd [kg]	5840	6050	6270	5920	5860	5940
PMd [kg]	3800	4200	3520	4990	4530	5030
P (Trailer) [kg]	6940	6940	6940	7950	8170	8390
PR [kg]	5640	5030	5490	5750	6490	6130
h_R mm]	1480	1480	1480	1050	1050	1050
h_K [mm]	1260	1260	1260	1270	1270	1270
ER [mm]	5580	6235	5580	8000	7340	8000

	C31	C32
Number of Axles	1	2
PM [kg]	4570	4290
PMnd [kg]	1950	2150
PMd [kg]	2620	2140
P (Trailer) [kg]	2490	2570
PR [kg]	2070	2430
h_R mm]	800	800
h_K [mm]	680	680
ER [mm]	4275	3850

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	F42_L	F42_K	F43	F52
Number of Axles	2	2	3	2
axle lifted	2nd	3nd	-	-
PM [kg]	6210	6210	6210	6 210
PMnd [kg]	3250	3250	3250	3 270
PMd [kg]	2960	2960	2960	2 940
P (Trailer) [kg]	6150	6150	6150	4 690
PR [kg]	6150	6150	6150	4 690
Pf [kg]	3090	1590	2460	2 540
Pr [kg]	3060	4560	3690	2 150
PRnd-kf [kg]	3060	4560	3690	2150
PRnd-kr [kg]	3090	1590	2460	2540
h_R mm]	1050	1050	1050	1100
h_D [mm]	880	880	880	740
E [mm]	4510	3000	3755	4680

1.3 **Weights** (energy consumption tests)

See also the note in Appendix 4-2 of this report.

EEC **worst case** loading	S12	S13	S22	S23	C32	S41	F42	F43	F52
P [kg]	7300	8940	8390	10890	2570	4980*	4970	8660	5130
PR [kg]	5320	7530	5320	7600	2430	2900	4970	8660	4690
PR_1 [kg]	-	2380	-	2510	1330	*	2280	3010	2540
PR_2 [kg]	2660	2560	1750	2500	1100	2900	2690	2810	2150
PR_3 [kg]	2660	2590	3570	2590	-	-	-	2840	-

* First axle used only as an unbraked dolly axle to simulate an one axle semi-trailer

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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 “** denotes 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+DR	HH	**Axle 1**: sensor d (IR-controlled wheel on right vehicle side) **Axle 2**: sensor c (IR-controlled wheel on left vehicle side)	The trailer modulator controls the left and right side separately (diagonal axle control)
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

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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 “** denotes 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.

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2 Test schedule

The following tables define the test schedules by system configurations and trailer types that were considered for the purpose of an approval according to annex XIV of Directive 71/320/EEC or annex 19 of ECE-Regulation No. 13.

Semi- & centre axle trailer Sensing identifiers & location of directly controlled wheels								
no of axles	**1**	**2**	**2**	**3**	**3**	**3**	**3**	**3**
2S/2M_B	**H**	**HX**	**XH**	**XHX**	**XXH**	**HXX**	**-**	**-**
2S/2M_M	**H**	**HX**	**XH**	**-**	**-**	**-**	**-**	**-**
2S/2M_R	**H**	**HX**	**XH**	**XHX**	**XXH**	**HXX**	**-**	**-**
2S/2M_DR_M	-	**-**	**HH**	**-**	**-**	**-**	**-**	**-**
2S/2M+SLV_B	-	**-**	**-**	**XHS**	**-**	**-**	**-**	**-**
4S/2M_B	-	**HZ**	**ZH**	**XHZ**	**ZHX**	**XZH**	**HZX**	**ZXH**
4S/2M_M	-	**HZ**	**ZH**	**-**	**-**	**-**	**-**	**-**
4S/2M_R	-	**HZ**	**ZH**	**XHZ**	**ZHX**	**XZH**	**HZX**	**ZXH**
4S/3M_B	-	**HL**	**LH**	**XHL**	**LHX**	**LXH**	**HXL**	-
4S/3M_M	-	**HL**	**LH**	**XHL**	**LHX**	**LXH**	**HXL**	-
4S/3M_R	-	**HL**	**LH**	**XHL**	**LHX**	**LXH**	**HXL**	-

Full axle trailer Sensing identifiers & location of directly controlled wheels				
no of axles	**2**	**2**	**3**	**3**
4S/3M_B	**LH**	**HL**	**LXH**	**LHX**
4S/3M_M	**LH**	**HL**	**-**	**-**
4S/3M_R	**LH**	**HL**	**LXH**	**LHX**

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Note:

"H" means sensors "c" and "d" (or in the case of "HH" "c" or "d" ⇐ 2S/2M-DAR)

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

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

"B" Double relay valve ("Boxer valve")

"M" ABS Solenoid Control Valve

"R" ABS Relay Valve

3 Worst case cross referencing

In accordance with the provisions of paragraph 4.1 of Annex XIV to Directive 71/320/EEC and paragraph 5.4.1 of annex 19 to ECE-Regulation No. 13 the following worst case cross references were considered appropriate.

1 In the case of a one axle vehicle air and leaf suspension are seen as equivalent.

2. Comparison test have shown that trailers fitted with relay ("R") and solenoid ("M") valve is best case. As worst case - in the case of 1-axle semi-trailer - the tests were carried out with the double relay valve ("B").

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Appendix 4-1 - Utilisation of adhesion

The test results recorded below were obtained with trailers fitted with a load sensing device set to the unladen condition (compare also paragraph 4.8 of this report).

Trailer	System Configuration	sensing-identifier	No. of axles	k_R	ε
S11	2S/2M_B	H	1	0,697	**0,85**
S12	2S/2M_B	H X	2	0,697	**0,78**
	2S/2M_B	X H	2	0,697	**0,84**
S13	2S/2M_B	X H X	3	0,697	**0,87**
	2S/2M_B	X X H	3	0,697	**0,77**
	2S/2M_B	H X X	3	0,697	**0,82**
C32	2S/2M_M	H X	2	0,705	**0,98**
	2S/2M_M	X H	2	0,705	**0,86**
S22	2S/2M_R	H X	2	0,641	**0,80**
	2S/2M_R	X H	2	0,641	**0,78**
S23	2S/2M_R	X H X	3	0,641	**0,88**
	2S/2M_R	X H X *****	3	0,641	**0,76**
	2S/2M_R	X X H	3	0,641	**0,87**
	2S/2M_R	H X X	3	0,641	**0,80**
C32	2S/2M_DR_M	H H	2	0,705	**0,89**
S13	2S/2M_SLV_B	X H S	3	0,697	**0,76**
S12	4S/2M_B	H Z	2	0,697	**0,90**
	4S/2M_B	Z H	2	0,697	**0,81**
S13	4S/2M_B	X H Z	3	0,697	**0,84**
	4S/2M_B	Z H X	3	0,697	**0,83**
	4S/2M_B	X Z H	3	0,697	**0,88**
	4S/2M_B	H Z X	3	0,697	**0,86**
	4S/2M_B	Z X H	3	0,697	**0,82**
C32	4S/2M_M	H Z	2	0,705	**0,80**
	4S/2M_M	Z H	2	0,705	**0,80**

Typ / *Type* : **VCS II**
Hersteller / *Manufacturer* : **WABCO**

Trailer	System Configuration	sensing-identifier	No. of axles	k_R	ε
S22	4S/2M_R	H Z	2	0,641	**0,84**
	4S/2M_R	Z H	2	0,641	**0,84**
S23	4S/2M_R	X H Z	3	0,641	**0,78**
	4S/2M_R	Z H X	3	0,641	**0,82**
	4S/2M_R	X Z H	3	0,641	**0,78**
	4S/2M_R	X Z H *****	3	0,641	**0,79**
	4S/2M_R	H Z X	3	0,641	**0,77**
	4S/2M_R	Z X H	3	0,641	**0,78**
S12	4S/3M_B	H L	2	0,697	**0,85**
	4S/3M_B	L H	2	0,697	**0,95**
S13	4S/3M_B	X H L	3	0,697	**0,88**
	4S/3M_B	L H X	3	0,697	**0,85**
	4S/3M_B	L X H	3	0,697	**0,85**
	4S/3M_B	H X L	3	0,697	**0,82**
C32	4S/3M_M	H L	2	0,705	**0,89**
	4S/3M_M	L H	2	0,705	**0,96**
S23	4S/3M_R	X H L	3	0,641	**0,93**
	4S/3M_R	L H X	3	0,641	**0,91**
	4S/3M_R	L X H	3	0,641	**0,92**
	4S/3M_R	L X H *****	3	0,641	**0,90**
	4S/3M_R	H X L	3	0,641	**0,86**
F52	4S/3M_B	L H	2	0,658	**0,96**
	4S/3M_B	H L	2	0,656	**0,96**
F43	4S/3M_B	L X H	3	0,778	**0,78**
	4S/3M_B	L H X	3	0,778	**0,89**
F52	4S/3M_M	L H	2	0,656	**0,99**
	4S/3M_M	H L	2	0,656	**0,98**
F42	4S/3M_R	L H	2	0,777	**0,89**
	4S/3M_R	H L	2	0,777	**0,87**

Typ / *Type* : **VCS II**
Hersteller / *Manufacturer* : **WABCO**

Trailer	System Configuration	sensing-identifier	No. of axles	k_R	ε
F43	4S/3M_R	L X H	3	0,778	**0,83**
	4S/3M_R	L H X	3	0,778	**0,96**

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

Typ / *Type* : **VCS II**
Hersteller / *Manufacturer* : **WABCO**

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 he 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
S12	2S/2M_B	**X H**	2	80	8,0	5,5	4,2	**10,5**	**13**	3,8	12,5	disc
S13	2S/2M_B	**X X H**	3	80	8,0	4,6	3,5	**11,5**	**14**	3,2	13,0	disc
	2S/2M_B	**H X X**	3	80	8,0	4,6	3,5	**11,5**	**14**	3,2	13,0	disc
C32	2S/2M_M	**H X**	2	30	8,0	5,6	4,1	**9,5**	**12**	-	-	0,2
S22	2S/2M_R	**H X**	2	80	8,0	5,9	4,5	**9,5**	**12**			0,2
S22	2S/2M_R	**H X**	2	80	8,0	5,4	4,2	**11,0**	**14**			0,2
S23	2S/2M_R	**X H X**	3	80	8,0	4,6	3,2	**11,0**	**14**			0,2
S23	2S/2M_R	**X H X**	3	80	8,0	4,9	3,4	**10,3**	**13**			0,2
C32	2S/2M_DR_M	**H H**	2	30	8,0	5,5	4,0	**9,8**	**12**			0,2
S13	2S/2M_SLV_B	**X H S**	3	80	8,0	4,6	3,5	**11,5**	**14**	3,2	13,0	disc
S12	4S/2M_B	**Z H**	2	80	8,1	5,6	4,2	**10,5**	**13**	3,9	12,0	disc
S13	4S/2M_B	**Z H X**	3	80	8,0	4,6	3,5	**11,5**	**14**	3,2	13,0	disc
C32	4S/2M_M	**H Z**	2	30	8,0	5,7	4,1	**9,3**	**12**	-	-	0,2
S23	4S/2M_R	**X H Z**	3	80	8,0	5,5	3,7	**8,8**	**11**	-	-	0,2
	4S/2M_R	**Z X H**	3	80	8,0	5,5	3,7	**8,8**	**11**	-	-	0,2
S12	4S/3M_B	**H L**	2	80	8,0	5,6	4,4	**11,5**	**14**	3,9	14,0	disc
S13	4S/3M_B	**L X H**	3	100	8,0	5,3	4,0	**12,0**	**15**	3,6	15	disc
C32	4S/3M_M	**L H**	2	30	2	5,4	3,8	**10,0**	**12**			0,2
S23	4S/3M_R	**H X L**	3	80	8,0	5,5	3,9	**9,3**	**12**	-	-	0,2

Typ / *Type* : **VCS II**
Hersteller / *Manufacturer* : **WABCO**

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
S41	2S/2M_R	**H**	1	100	8,0	6,9	5,9	**9,5**	**12**	5,5	12	disc
F42	4S/3M_R	**H L**	2	100	8,0	6,4	4,9	**9,0**	**11**	4,5	11	disc
F43	4S/3M_R	**L X H**	2	100	8,0	5,8	4,1	**9,0**	**11**	3,6	11	disc
F52	4S/3M_B	**H L**	2	60	8,0	4,8	3,6	**12,0**	**15**	-	-	0,2
F52	4S/3M_M	**L H**	2	60	8,0	5,7	4,2	**9,3**	**12**	-	-	0,2
F52	4S/3M_M	**H L**	2	60	8,0	5,8	4,3	**9,1**	**11**	-	-	0,2

Typ / *Type* : **VCS II**
Hersteller / *Manufacturer* : **WABCO**

Appendix 4-3 - Split-friction test

Road surface: wet blue basalt / damp asphalt
Test speed: 50 km/h
No inadmissible locking or inadmissible course deviation was observed during any of the following split-friction tests.

Ratio **f** = z_{RALH} / z_{RALL}

Trailer	System Configuration	Sensing-Identifier	No. of Axles	z_{RALH}	z_{RALL}	f	z_{RALS}	$z_{RALS\_requ.}$
S11	2S/2M_B	H	1	0,538	0,120	4,5	0,288	0,179
S12	2S/2M_B	X H	2	0,576	0,098	5,8	0,238	0,174
S13	2S/2M_B	X H X	3	0,478	0,101	4,7	0,207	0,152
S22	2S/2M_R	X H	2	0,454	0,102	4,4	0,219	0,166
S23	2S/2M_R	X H X	3	0,509	0,089	5,8	0,210	0,165
	2S/2M_R	X H X *	3	0,428	0,088	4,9	0,208	0,153
	2S/2M_R	X X H	3	0,503	0,125	4,0	0,232	0,174
	2S/2M_R	H X X	3	0,462	0,078	5,9	0,157	0,144
C32	2S/2M_DR_M	H H	2	0,506	0,147	3,5	0,226	0,184
S13	2S/2M_SLV_B	X H S	3	0,435	0,078	5,6	0,152	0,147
S12	4S/2M_B	H Z	2	0,574	0,094	6,1	0,203	0,158
	4S/2M_B	Z H	2	0,576	0,094	6,1	0,200	0,176
S13	4S/2M_B	X H Z	3	0,483	0,099	4,9	0,201	0,156
	4S/2M_B	X Z H	3	0,533	0,096	5,5	0,208	0,158
C32	4S/2M_M	H Z	2	0,471	0,138	3,4	0,269	0,192
S23	4S/2M_R	Z H X	3	0,441	0,079	5,8	0,199	0,139
	4S/2M_R	X Z H	3	0,464	0,101	4,6	0,224	0,167
	4S/2M_R	X Z H *	3	0,410	0,096	4,3	0,208	0,150
	4S/2M_R	H Z X	3	0,435	0,083	5,3	0,202	0,150
	4S/2M_R	Z X H	3	0,392	0,078	5,0	0,225	0,136
S12	4S/3M_B	H L	2	0,510	0,095	5,4	0,182	0,157
S13	4S/3M_B	L H X	3	0,466	0,099	4,6	0,181	0,153

Typ / *Type* : **VCS II**
Hersteller / *Manufacturer* : **WABCO**

Trailer	System Con-figuration	Sensing-Identifier	No. of Axles	z_{RALH}	z_{RALL}	f	z_{RALS}	$z_{RALS\_requ.}$
	4S/3M_B	H X L	3	0,450	0,105	4,3	0,204	0,158
C32	4S/3M_M	L H	2	0,592	0,145	4,1	0,592	0,185
S23	4S/3M_R	X H L	3	0,478	0,099	4,8	0,195	0,140
	4S/3M_R	L X H	3	0,519	0,109	4,7	0,206	0,156
	4S/3M_R	L X H *****	3	0,509	0,089	5,7	0,210	0,165
F52	4S/3M_B	L H	2	0,485	0,118	4,1	0,163	0,151
F43	4S/3M_B	L X H	3	0,466	0,108	4,3	0,193	0,137
F52	4S/3M_M	H L	2	0,521	0,121	4,3	0,202	0,158
F42	4S/3M_R	H L	2	0,503	0,106	4,8	0,173	0,119
F43	4S/3M_R	L H X	3	0,497	0,109	4,6	0,193	0,115

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

Typ / *Type* : **VCS II**
Hersteller / *Manufacturer* : **WABCO**

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 0,6 s to 1,4 s:

Typ / *Type* : **VCS II**
Hersteller / *Manufacturer* : **WABCO**

Appendix 5 - Further test results

1 Tyre to pole wheel 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. To assess the influence on system performance at the extremes defined in the manufacturer's Anti-Lock Information Document (see para 2.4 and Appendix 3) of the manufacturer's Anti-Lock Information Document assessments of performance were carried out by modifying the number of pole wheel teeth parameterised within the ECU. This represented the equivalent changes in tyre sizes from minus 20 % to plus 15 % of the optimum value.

Test results and observations:

The following table contains the respective 40 to 20 km/h deceleration times for the optimum and tolerance extremes - ascertained on a high friction surface with the test trailer S23 (configuration 2S/2M_R_XHX).

Simulated tyre rolling circumference	**3250 mm**	**3737,5 mm**	**2600 mm**
Circumference variation	**0 %**	**+15 %**	**-20 %**
Test order	1st measurement	2nd measurement	3rd measurement
Revolutions/km	**307,7**	**267,6**	**384,6**
Asphalt dry 40 to 20 km/h time (t)	3,34	3,07	3,20
	3,17	3,25	3,29
	3,15	3,18	3,27
Average (time t)	**3,22**	**3,17**	**3,25**
Deviation of t in %	**0 %**	**- 1,6 %**	**+ 0,9 %**
split 40 to 20 km/h time (t)	5,97	6,18	6,01
	6,25	6,05	6,13
	6,01	6,31	6,94
Average (time t)	**6,08**	**6,18**	**6,36**
Deviation of t in %	**0 %**	**- 1,6 %**	**- 4,6 %**

Typ / *Type* : **VCS II**
Hersteller / *Manufacturer* : **WABCO**

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 manufacturer's recommendations defined within the Anti-Lock Information Document, response tests were carried out with the recommended delivery tube lengths. Anti-lock performance was then verified at the extremes of tube size recommended.

Time measurements

The manufacturer's Anti-Lock Information Document states that the maximum length of tube for a directly controlled wheel shall be limited to **3,00 m** and in the case of an indirectly controlled wheel this may be increased to **5,00 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 brake chamber.

The following test results were obtained from a three axle semi-trailer (S1x) installed with a **2S/2M_B**-system where the tube lengths to either a directly controlled axle or indirectly controlled axle were varied as indicated in the table below.

Typ / *Type* : **VCS II**
Hersteller / *Manufacturer* : **WABCO**

The tests **"S1_3"** (see following tables) were carried out with all **three** axles representing the **unladen** condition and the tests **"S1_2"** were carried out with **two** axles (rear axle lifted) to represent a **simulated partially laden condition.**

	asphalt - dry		**Delivery tube lengths**			
	S1_3 ⇒ "unladen" **S1_1 ⇒ "laden"**	**t_{zRAL} [s]**	**axle 1** indirectly controlled	**axle 2** directly controlled	**axle 3** indirectly controlled	**resp. time [ms]**
A	**S1_3** **standard** tube length	2,66 2,71 2,79	1,20 m	2,10 m	2,65 m	**0,38**
	Average	**2,72**				
B	**S1_3** increased tube length	2,76 2,79 2,78	1,20 m	**3,00 m**	**5,00 m**	**0,39**
	Average	**2,78**				
C	**S1_3** increased tube length	2,73 2,88 2,78	**5,00 m**	**3,00 m**	2,65 m	**0,40**
	Average	**2,80**				
D	**S1_2** **standard** tube length	2,63 2,64 2,55	1,20 m	2,10 m	2,65 m **lifted** (and brake cylinders isolated)	**0,37**
	Average	**2,61**				
E	**S1_2** increased tube length	2,76 2,68 2,77	**5,00 m**	**3,00 m**	2,65 m **lifted** (and brake cylinders isolated)	**0,40**
	Average	**2,74**				

The above tests with the various tube length variations show that the utilisation of adhesion times t_{zRAL} are within a tolerance band of ± 1,5% for the "unladen" and ± 2,5% for the "partially laden" condition.