

E/ECE/324 }  
E/ECE/TRANS/505 } Rev.1/Add.12/Rev.4/Amend.3

18 March 2003

## **AGREEMENT**

### **CONCERNING THE ADOPTION OF UNIFORM TECHNICAL PRESCRIPTIONS FOR WHEELED VEHICLES, EQUIPMENT AND PARTS WHICH CAN BE FITTED AND/OR BE USED ON WHEELED VEHICLES AND THE CONDITIONS FOR RECIPROCAL RECOGNITION OF APPROVALS GRANTED ON THE BASIS OF THESE PRESCRIPTIONS \*/**

(Revision 2, including the amendments which entered into force on 16 October 1995)

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#### **Addendum 12: Regulation No. 13**

#### **Revision 4 - Amendment 3**

Supplement 7 to the 09 series of amendments - Date of entry into force: 30 January 2003

### **UNIFORM PROVISIONS CONCERNING THE APPROVAL OF VEHICLES OF CATEGORIES M, N AND O WITH REGARD TO BRAKING**



**UNITED NATIONS**

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\*/ Former title of the Agreement:

Agreement Concerning the Adoption of Uniform Conditions of Approval and Reciprocal Recognition of Approval for Motor Vehicle Equipment and Parts, done at Geneva on 20 March 1958.

GE.03-20991

Insert a new paragraph 2.30. to read:

“2.30.            “Reference braking forces” means the braking forces of one axle generated at the circumference of the tyre on a roller brake tester, relative to brake actuator pressure and declared at the time of type approval.”

Insert new paragraphs 5.1.4.6. to 5.1.4.7.1., including its corresponding footnote, to read:

"5.1.4.6.           Reference braking forces

5.1.4.6.1.           Reference braking forces shall be defined for vehicles with compressed air operated brakes using a roller brake tester.

5.1.4.6.2.           Reference braking forces are to be determined for a brake actuator pressure range from 1 bar to the pressure generated under Type-0 conditions for each axle. The applicant for type approval shall nominate reference-braking forces for a brake activator pressure range from 1 bar. These data shall be made available, by the vehicle manufacturer, according to paragraph 5.1.4.5.1. above.

5.1.4.6.3.           The reference braking forces shall be declared such that the vehicle is capable of generating a braking rate equivalent to that defined in annex 4 of this Regulation for the relevant vehicle (50 per cent in the case of vehicles of category M<sub>2</sub>, M<sub>3</sub>, N<sub>2</sub>, N<sub>3</sub>, O<sub>3</sub> and O<sub>4</sub> except semi-trailers, 45 per cent in the case of semi-trailers), whenever the measured roller braking force, for each axle irrespective of load, is not less than the reference braking force for a given brake actuator pressure within the declared operating pressure range \*/.

5.1.4.7.            It shall be possible to verify, in a simple way, the correct operational status of those complex electronic systems which have control over braking. If special information is needed, this shall be made freely available.

5.1.4.7.1.           At the time of type approval, the means implemented to protect against simple unauthorized modification of the operation to the verification means chosen by the manufacturer (e.g. warning signal) shall be confidentially outlined.

Alternatively, this protection requirement is fulfilled when a secondary means of checking the correct operational status is available.

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\*/ For the purpose of periodic technical inspection, the minimum limit braking rate values defined for the whole vehicle may need adjustment to reflect national or international in-service requirements.”

Insert a new paragraph 5.2.2.17.1., to read:

“5.2.2.17.1. Trailers that utilize selective braking as a means to enhance vehicle stability shall in the event of a failure within the electric control transmission of the stability system indicate the failure by the separate yellow warning signal specified in paragraph 5.2.1.29.2. above via pin 5 of the ISO 7638:1997 connector.

Note: This requirement shall be kept under review during subsequent amendments to Regulation No. 13 pending:

- (i) an amendment to the ISO 11992 data communication standard that includes a message to indicate a failure within the electric control transmission of the trailer stability control system; and
- (ii) vehicles equipped to that standard are in general use.”

Annex 2,

Insert a new item 14.10.4., to read

"14.10.4. Where an annex 19 test report has been utilised, the test report number(s) shall be stated:"

Insert new items 15. to 16., to read :

- "15. Additional information for use with the annex 20 alternative type approval procedure.
- 15.1. Description of suspension: .....
- 15.1.1. Manufacturer: .....
- 15.1.2. Make: .....
- 15.1.3. Type: .....
- 15.1.4. Model: .....
- 15.2. Wheelbase of vehicle tested: .....
- 15.3. Actuation differential (if any) within bogie: .....

16. Trailer approved utilising annex 20 procedure: .....Yes / No 2/  
(If yes, appendix 2 to this annex shall be completed)"

Items 15. to 24. (former), renumber as items 17. to 26.

Insert a new appendix 2, including the references to footnote 2/ and footnote 2/, to read: \*/

"Annex 2 - Appendix 2

TYPE APPROVAL CERTIFICATE CONCERNING THE  
VEHICLE BRAKING EQUIPMENT

1. General

The following additional items are to be recorded when the trailer has been approved utilising the alternative procedure defined in annex 21 to this Regulation.

2. Annex 19 test reports

- 2.1. Diaphragm brake chambers: Report No. ....
- 2.2. Spring Brakes: Report No. ....
- 2.3. Trailer brake cold performance characteristics: Report No. ....
- 2.4. Anti-lock braking system: Report No. ....

3. Performance checks

- 3.1. The trailer fulfils the requirements of annex 4, paragraphs 3.1.2. and 1.2.7 (service braking cold performance) Yes / No 2/
- 3.2. The trailer fulfils the requirements of annex 4, paragraph 3.2. (parking braking cold performance) Yes / No 2/
- 3.3. The trailer fulfils the requirements of annex 4, paragraph 3.3. (emergency/automatic braking performance) Yes / No 2/

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\*/ An error made in the final and previous documents was corrected by the secretariat and the footnote renumbered into 2/.

- 3.4. The trailer fulfils the requirements of annex 10, paragraph 6. (braking performance in the case a failure in the braking distribution system) Yes / No 2/
- 3.5. The trailer fulfils the requirements of paragraph 5.2.2.14.1. to this Regulation (braking performance in the event of leakage from auxiliary equipment) Yes / No 2/
- 3.6. The trailer fulfils the requirements of annex 13 (anti-lock braking) Yes / No 2/

2/ Strike out what does not apply."

Annex 10,

Insert a new paragraph 1.3., to read

"1.3. In the case of vehicles of category O with pneumatic braking systems, when the alternative type approval procedure defined in annex 20 is utilised, the relevant calculations required in this annex shall be made using the performance characteristics obtained from the relevant annex 19 verification reports and the centre of gravity height determined by the method defined in annex 20, appendix 1."

Annex 11,

Paragraph 1.4., amend to read:

"1.4. The vehicle concerned is a trailer equipped with air operated S-cam or disc brakes 1/ which satisfies the ....."

Annex 11 - Appendix 2,

Paragraph 2., amend to read:

" .....

C = brake input torque

C<sub>max</sub> = maximum permissible brake input torque

C<sub>O</sub> = threshold brake input torque, i.e. minimum input torque necessary to produce a measurable output torque

.....

S<sub>p</sub> see annex 19, Appendix 7,

Th<sub>A</sub> see annex 19, Appendix 7,

.....

.....

p = brake actuation pressure"

Paragraph 3.4.1.4., amend to read:

" ..... outside of the brake drum or brake disc."

Paragraph 3.5.1.2., amend to read:

" ..... surface of the drums or discs. The applications shall be ..... shall not exceed 6.5 bar, and the brake input torque (C) shall not exceed the maximum permissible brake input torque ( $C_{max}$ ). The average of the three results shall be taken as the cold performance."

Paragraph 3.5.2.1., amend to read:

" ..... not exceeding 100 °C, measured at the outside surface of the brake drum or brake disc."

Paragraph 4.1., the table, amend to read:

"

Item	Criteria
4.1.1. <ul style="list-style-type: none"> <li>a) Brake drum cylindrical section</li> <li>b) Brake drum or brake disc material</li> <li>c) Brake drum or brake disc mass</li> </ul>	No Change allowed No Change allowed May increase up to + 20 per cent from the reference drum or disc mass
4.1.2. <ul style="list-style-type: none"> <li>a) Proximity of wheel to outside surface of brake drum or outside diameter of brake disc (dimension E)</li> <li>b) Part of brake drum or brake disc not covered by wheel (dimension F)</li> </ul>	Tolerances to be determined by the Technical Service conducting the tests.
4.1.3. <ul style="list-style-type: none"> <li>a) Brake lining or brake pad material</li> <li>b) Brake lining or brake pad width</li> <li>c) Brake lining or brake pad thickness</li> <li>d) Brake lining or brake pad actual surface area</li> <li>e) Brake lining or brake pad method of attachment</li> </ul>	) ) ) ) No change allowed ) ) )

4.1.4. Brake geometry (As in Fig.2A or 2B of appendix 3 as appropriate)	No change allowed
.....	.....

Paragraph 4.3.1.1., amend to read:

" .....

This value shall not exceed  $s_p$ . Where  $s_p$  has been verified and reported in accordance with the procedure defined in item 2 of annex 19 to this Regulation and may only be applied within the pressure range recorded in paragraph 3.3.1. of the test report defined in appendix 1 of annex 19."

Paragraph 4.3.1.3., amend to read:

"4.3.1.3. The brake input torque (C) is then calculated as follows:"

Annex 11 - Appendix 3.

Item 1.2., amend to read (introducing also new footnote 2/): \*/

" .....

Model .....

Technically permissible brake input torque  $C_{max}$  .....

Automatic brake adjustment drive: integrated/non-integrated 1/

Brake drum or Brake disc 1/:

Internal diameter of drum or outside diameter of disc 1/ .....

Effective radius .....

Thickness 2/ .....

Mass .....

Material .....

\*/ The footnote number was corrected by the secretariat.

Brake lining or pad 1/:

Manufacturer.....  
Type.....  
Identification (must be visible when the lining /pad is mounted  
on the brake shoe / backing plate).....  
Width.....  
Thickness.....  
Surface area.....  
Method of attachment.....

Brake geometry, attach dimension drawing as follows:

Drum brakes see fig. 2A of this appendix  
Disc brakes see fig. 2B of this appendix

2/ Applies to disc brakes only"

Item 1.3., amend to read:

" .....  
Rim diameter (D).....  
(Attach dimensioned drawing as in fig. 1A or fig 1B of this appendix, as  
appropriate."

Item 2., the reference to footnote 2/ and footnote 2/, renumber as footnote 4/. \*\*/

Item 2.1., replace the term "camshaft" to read "brake"

Item 2.2., replace the term "camshaft" to read "brake"

Insert a new item 2.3., to read:

"2.3. This item is to be completed only when the brake has been subject to the test  
procedure defined in paragraph 4. of annex 19 to this Regulation to verify the cold  
performance characteristics of the brake by means of the brake factor ( $B_F$ ). Where  
the brake factor is defined as input to output amplification ratio of the brake.

2.3.1. Brake factor  $B_F$ : ....."

\*\*/ Introduced by the secretariat to correct footnote numbering.



Items 2.3. and 2.3.1. (former), renumber as items 3. and 3.1.

Items 3. and 4. (former), should be deleted.

Item 5. (former), renumber as item 4., and amend to read:

"4. This test has been carried out and the results reported in accordance with appendix 2 to annex 11 and where appropriate paragraph 4. of annex 19 to ECE Regulation No. 13 as last amended by the ..... series of amendments

Technical Service 4/ carrying out the test

Signed: .....

Date: ....."

Insert a new item 5., to read:

"5. Approval Authority 4/

Signed: .....

Date: ....."

Footnote 4/, amend to read:

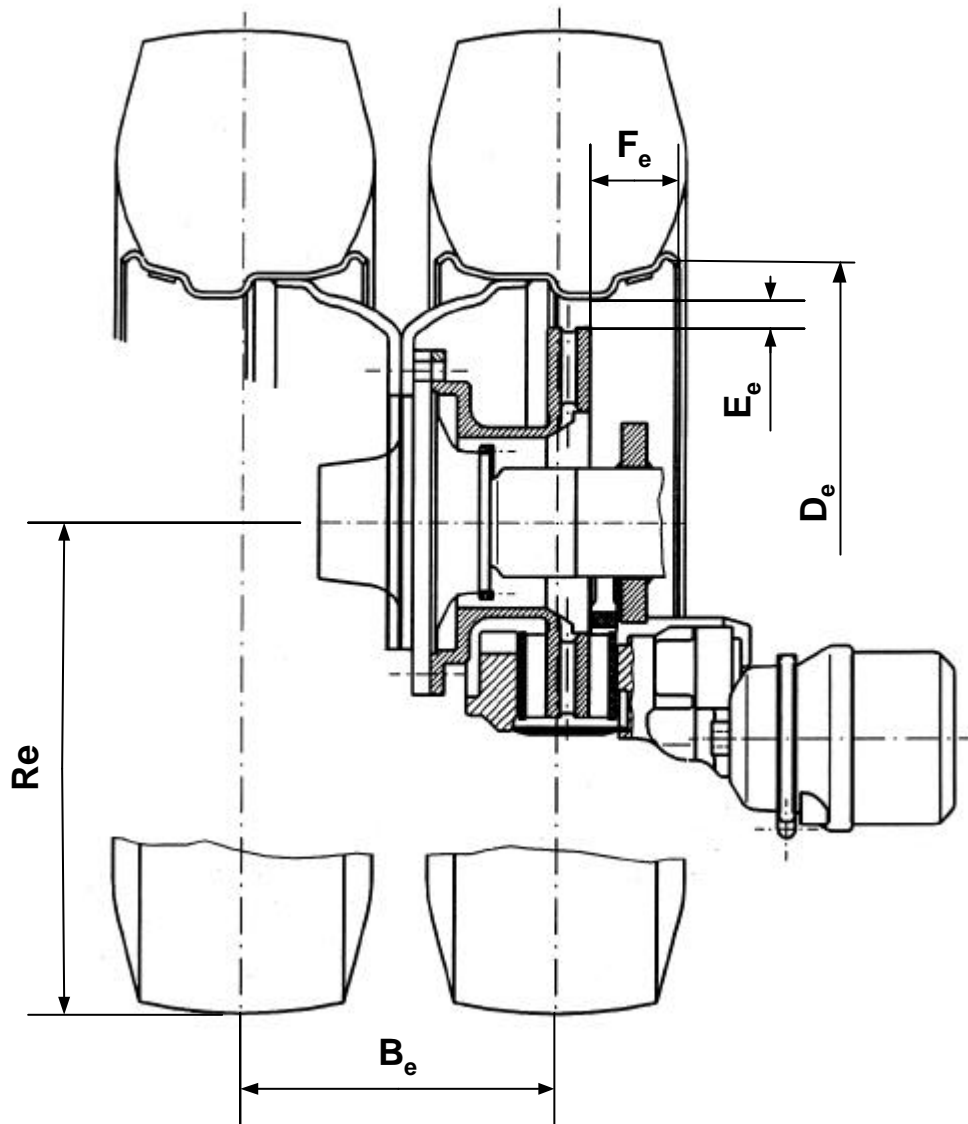
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"4/ To be signed by different persons even when the Technical Service and Approval Authority are the same or alternatively, a separate Approval Authority authorisation issued with the report."

Figure 1, renumber as Figure 1A.

Insert a new Figure 1B for disc brakes, to read:

"Figure 1B

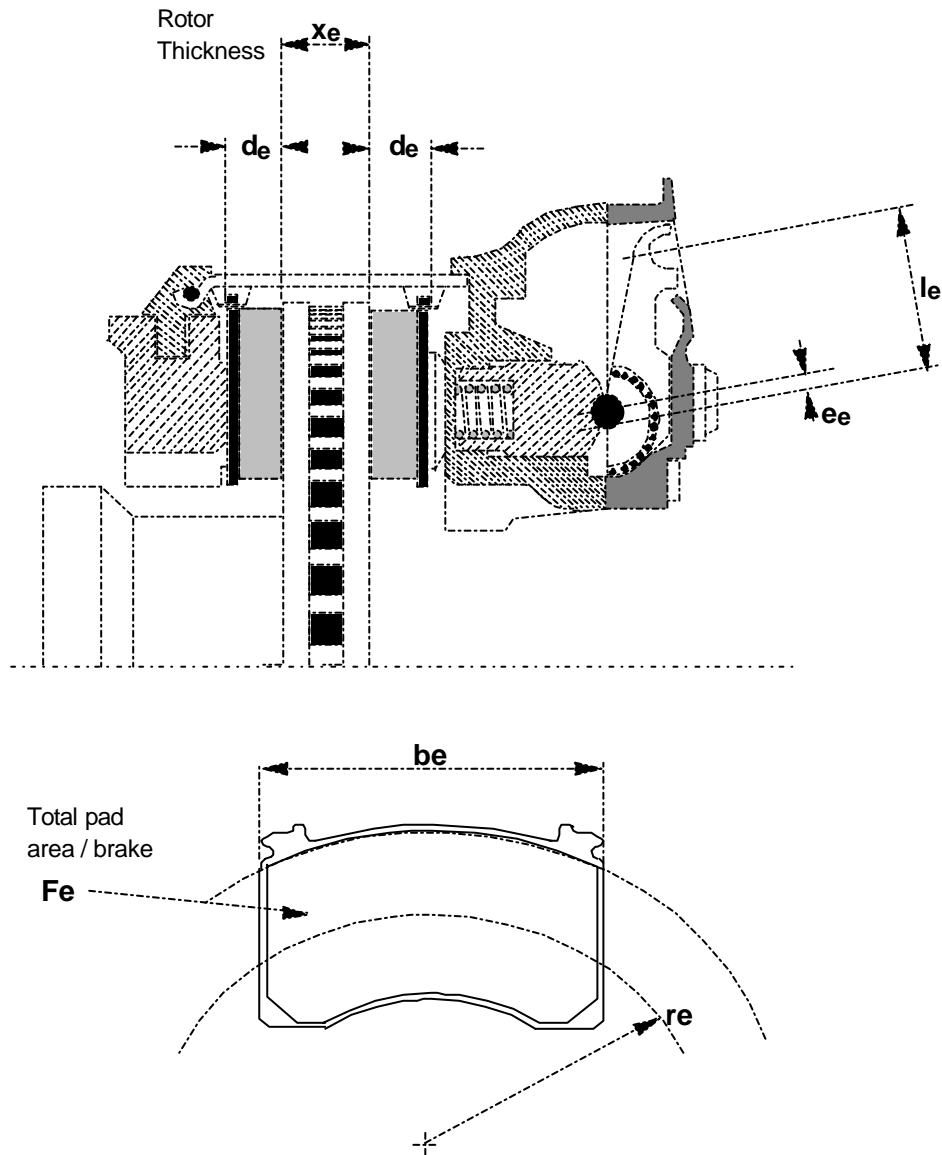


$B_e$ (mm)	$D_e$ (mm)	$E_e$ (mm)	$F_e$ (mm)	$R_e$ (mm)

Figure 2, renumber as Figure 2A.

Insert a new Figure 2B for disc brakes, to read:

"Figure 2B



$l_e$ (mm)	$e_e$ (mm)	$d_e$ (mm)	$x_e$ (mm)	$r_e$ (mm)	$b_e$ (mm)	$F_e$ (cm <sup>2</sup> )

Annex 11 - appendix 4,

Item 5., amend to read :

"5. This test has been carried out and the results reported in accordance with annex 11, appendix 2, paragraph 3.6.2. to ECE Regulation No. 13 as last amended by the .... series of amendments."

Item 6., amend to read :

"6. " .... were deemed to be: Fulfilled / Not fulfilled 1/"

Insert a new item 7., to read (including footnote 2/):

"7. Technical Service 2/ carrying out the test  
Signed: ..... Date: ....."

Insert a new item 8., to read (including footnote 2/):

"8. Approval Authority 2/  
Signed: ..... Date: ....."

Insert a new footnote 2/, to read:

"2/ To be signed by different persons even when the Technical Service and Approval Authority are the same or alternatively a separate Approval Authority authorisation issued with the report."

Annex 12, appendix 2,

Item 10., should be deleted.

Item 11 (former), renumber as item 10.

Insert new items 11. and 12. and the corresponding footnote 3/, to read:

"11. This test has been carried out and the results reported in accordance with relevant provisions of annex 12 to ECE Regulation No. 13 as last amended by the .... series of amendments.  
  
Technical Service 3/ carrying out the test

Signed: ..... Date: .....

12. Approval Authority 3/

Signed: ..... Date: .....

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3/ To be signed by different persons even when the Technical Service and Approval Authority are the same or alternatively, a separate Approval Authority authorisation issued with the report."

Annex 12, appendix 3,

Item 10., should be deleted.

Item 11 (former), renumber as item 10.

Insert new items 11. and 12., and the corresponding footnote 3/, to read:

"11. This test has been carried out and the results reported in accordance with relevant provisions of annex 12 to ECE Regulation No. 13 as last amended by the .... series of amendments.

Technical Service 3/ carrying out the test

Signed: ..... Date: .....

12. Approval Authority 3/

Signed: ..... Date: .....

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3/ To be signed by different persons even when the Technical Service and Approval Authority are the same or alternatively, a separate Approval Authority authorisation issued with the report."

Annex 12, appendix 4,

Item 6., should be deleted.

Item 7 (former), renumber as item 6.

Insert new items 7. and 8., and the corresponding footnote 3/, to read:

"7. This test has been carried out and the results reported in accordance with relevant provisions of annex 12 to ECE Regulation No. 13 as last amended by the .... series of amendments.

Technical Service 3/ carrying out the test

Signed: ..... Date: .....

8. Approval Authority 3/

Signed: ..... Date: .....

3/ To be signed by different persons even when the Technical Service and Approval Authority are the same or alternatively, a separate Approval Authority authorisation issued with the report."

Insert new annexes 19 and 20, to read:

"Annex 19

PERFORMANCE TESTING OF BRAKING COMPONENTS

1. General

This annex defines the test procedures applicable in defining the performance of the following:

1.1.1. Diaphragm brakes chambers (refer to paragraph 2).

1.1.2. Spring brakes (refer to item 3).

1.1.3. Trailer brakes - cold performance characteristics (refer to paragraph 4.).

1.1.4. Anti-lock braking systems (refer to paragraph 5.)

(NOTE: Procedures for determining the fade test performance for trailer brakes and automatic brake wear adjustment devices are defined in annex 11 of this Regulation).

- 1.2. The above test reports may be used in conjunction with the procedures defined in annex 20 to this Regulation or at the time of evaluating a trailer which is being subject to actual performance requirements defined for the respective trailer.
2. Performance characteristics for diaphragm brake chambers
- 2.1. General
- 2.1.1. This section defines the procedure by which the thrust/stroke/pressure characteristics are determined for diaphragm brake chambers which are used in compressed air braking systems 1/ to generate forces required in brakes with mechanical actuation.
- 2.1.2. The verified performance characteristics declared by the manufacturer shall be used in all calculations relating to the brake compatibility requirements of annex 10, the Type-0 cold service braking performance requirements of annex 20 and the determination of the available actuator stroke with respect to the verification of the hot performance of annex 11.
- 2.2. Test procedure:
- 2.2.1. Zero datum position of the brake chamber is to be taken as the non-pressurised position.
- 2.2.2. In nominal pressure increments of  $\leq 1$  bar, through a pressure range of 1 to  $\geq 8$  bar, the corresponding thrust generated is to be monitored over the full stroke range available for a stroke displacement of  $\leq 10$  mm/s or a stroke increment of  $\leq 10$  mm and whilst not permitting the applied pressure to deviate  $\pm 0.05$  bar.
- 2.2.3. For each pressure increment the corresponding average thrust ( $Th_A$ ) and the effective stroke ( $s_p$ ) will be determined as per appendix 7 of this annex.
- 2.3. Verification
- 2.3.1. With reference to appendix 1 of this annex, paragraphs 3.1., 3.2. and 3.3., a minimum of 6 samples are to be tested, with a verification report being issued, providing no one result deviates by more than 4 per cent of the declared

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1/ Other brake chamber designs may be approved upon presentation of equivalent information.

characteristics. However, with respect to the verification of the  $s_p$  characteristics the pressure range over which the 4 per cent tolerance is fulfilled shall be recorded and specified in paragraph 3.3.1. of appendix 1 of this annex. Outside of this pressure range the tolerance may exceed 4 per cent.

- 2.3.2. The test results recorded shall be reported on a form, a model of which is shown in appendix 2 to this annex and shall be included with the verification report detailed within paragraph 2.4.
- 2.4. Verification report:
- 2.4.1. The manufacturer's declared performance characteristics, verified by the test results recorded in accordance with paragraph 2.3.2., shall be reported on a form, a model of which is shown in appendix 1 to this annex.
3. Performance characteristics for spring brakes
- 3.1. General:
- 3.1.1. This section defines the procedure by which the thrust/stroke/pressure characteristics are determined for spring brakes 2/ that are used in compressed air braking systems to generate forces required in brakes with mechanical actuation.
- 3.1.2. The performance characteristics declared by the manufacturer shall be used in all calculations relating to the parking braking performance requirements of annex 20.
- 3.2. Test procedure:
- 3.2.1. Zero datum position of the spring brake chamber is to be taken as the fully pressurised position.
- 3.2.2. In nominal stroke increments of  $\leq 10$  mm, the corresponding thrust generated is to be monitored over the full stroke range available at zero pressure.
- 3.2.3. The pressure shall then be gradually increased until the stroke is 10 mm from the zero datum position, and this pressure, defined as the release pressure, shall be recorded.

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2/ Other spring brake designs may be approved upon presentation of equivalent information.



- 3.2.4. The pressure shall then be increased to 8.5 bar, or the maximum working pressure declared by the manufacturer, whichever is lower.
- 3.3. Verification:
- 3.3.1. With reference to appendix 3, items 2.1., 3.1., 3.2. and 3.3., a minimum of 6 samples shall be tested, with a verification report being issued providing the following conditions are met:
- 3.3.1.1. Over a range of stroke from 10 mm to 2/3 of the maximum stroke, no one result, measured in accordance with item 3.2.2., deviates by more than 6 per cent from the declared characteristics.
- 3.3.1.2. No one result, measured in accordance with paragraph 3.2.3., exceeds the declared value.
- 3.3.1.3. Each spring brake continues to function correctly after completion of the test in accordance with paragraph 3.2.4.
- 3.3.2. The test results recorded shall be reported on a form, a model of which is shown in appendix 4 to this annex, and shall be included with the verification report detailed within paragraph 3.4.
- 3.4. Verification report:
- 3.4.1. The manufacturer's declared performance characteristics, verified by the test results recorded in accordance with paragraph 3.3.2., shall be reported on a form, a model of which is shown in appendix 3 to this annex.
4. Cold performance characteristics for trailer brakes
- 4.1. General:
- 4.1.1. This procedure covers the testing of the "cold" performance characteristics of air operated S cam and disc brakes 3/ fitted to trailers.
- 4.1.2. The performance characteristics declared by the manufacturer shall be used for all calculations relating to the braking compatibility requirements of annex 10 and to the Type-0 cold service braking and parking braking performance requirements of annex 20.

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3/ Other brake designs may be approved upon presentation of equivalent information.

- 4.2. Brake factor and brake threshold torque
- 4.2.1. The preparation of the brake shall be in accordance with paragraph 4.4.2. of this annex.
- 4.2.2. The brake factor is the resultant amplification factor achieved through the friction forces generated by the individual components comprising the brake assembly, and is expressed as a ratio between the output torque and the input torque. This brake factor is denoted by the symbol  $B_F$  and shall be verified for each of the lining or pad materials specified in paragraph 4.3.1.3.
- 4.2.3. The brake threshold torque shall be expressed in a manner that remains valid for variations of brake actuation and is denoted by the symbol  $C_0$ .
- 4.2.4. The values of  $B_F$  shall remain valid for variations of the following parameters:
- 4.2.4.1. Mass per brake up to that defined in paragraph 4.3.1.5.
- 4.2.4.2. Dimensions and characteristics of external components used to actuate the brake.
- 4.2.4.3. Wheel size/tyre dimensions.
- 4.3. Information document
- 4.3.1. The brake manufacturer shall provide the Technical Service with at least the following information:
- 4.3.1.1 A description of the brake type, model, size etc.
- 4.3.1.2 Details of the brake geometry
- 4.3.1.3. The make and type of brake lining(s) or brake pad(s)
- 4.3.1.4. The brake drum or brake disc material
- 4.3.1.5. The maximum technically permitted mass for the brake
- 4.3.2. Additional information
- 4.3.2.1. Wheel and tyre sizes to be used for the test
- 4.3.2.2. The declared brake factor  $B_F$

- 4.3.2.3. The declared threshold torque  $C_o$
- 4.4. Test procedure
- 4.4.1. Preparation
- 4.4.1.1. A graph defining the acceptable performance variation shall be constructed, following the model shown in Diagram 1, using the manufacturers declared brake factor.
- 4.4.1.2. The performance of the device used to actuate the brake shall be calibrated within an accuracy of 1 per cent.
- 4.4.1.3. The dynamic tyre radius at the test loading shall be determined as prescribed for the test method.
- 4.4.2. Bedding in (burnishing) procedure
- 4.4.2.1. In the case of drum brakes the tests shall start with new brake linings and new drum(s), the brake linings shall be machined to achieve the best possible initial contact between the linings and drum(s).
- 4.4.2.2. In the case of disc brakes the tests shall start with new brake pads and new disc(s), machining of the pad material shall be at the discretion of the brake manufacturer.
- 4.4.2.3. Make 20 brake applications from an initial speed of 60 km/h with an input to the brake theoretically equal to 0.3 TR/Test Mass. The initial temperature at the lining/drum or pad/disc interface shall not exceed 100 °C before each brake application.
- 4.4.2.4. Carry out 30 brake applications from 60 km/h to 30 km/h with an input to the brake equal to 0.3 TR/Test Mass and with a time interval between applications of 60 s 4/. The initial temperature at the lining/drum or pad/disc interface on the first brake application shall not exceed 100 °C.
- 4.4.2.5. On completion of the 30 brake applications defined in paragraph 4.4.2.4. above and after an interval of 120 s carry out 5 brake applications from 60 km/h to

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4/ If the track test method or the rolling road test methods are to be utilised, energy inputs equivalent to those specified shall be used.

30 km/h with an input to the brake equal to 0.3 TR/Test Mass and with an interval of 120 s between applications 4./

- 4.4.2.6. Make 20 brake applications from an initial speed of 60 km/h with an input to the brake equal to 0.3 TR/Test Mass. The initial temperature at the lining/drum or pad/disc interface shall not exceed 150 °C before each brake application.
- 4.4.2.7. Carry out a performance check as follows:
- 4.4.2.7.1. Determine the input torque to produce theoretical performance values equivalent to 0.2, 0.35 and  $0.5 \pm 0.05$  TR/Test Mass.
- 4.4.2.7.2. Once the input torque value has been determined for each braking rate, this value shall remain constant throughout each and subsequent brake applications (e.g. constant pressure).
- 4.4.2.7.3. Make a brake application with each of the input torques determined in paragraph 4.4.2.7.1. from an initial speed of 60 km/h. The initial temperature at the lining/drum or pad/disc interfaces shall not exceed 100 °C before each application.
- 4.4.2.8. Repeat the procedures defined in paragraphs 4.4.2.6. and 4.4.2.7.3. above until the performance of five consecutive non monotonic measurements at each constant input value has stabilised within a tolerance of  $\pm 5$  per cent.
- 4.4.2.9. In the case of this procedure being carried out on an inertia dynamometer or rolling road, unlimited use of cooling air is permitted.
- 4.4.3. Verification test
- 4.4.3.1. The temperature measured at the lining/drum or pad/disc interface shall not exceed 100 °C, at the start of each brake application.
- 4.4.3.2. The brake threshold torque shall be determined from the measured value of brake input by reference to a calibrated input device.
- 4.4.3.3. The initial speed for all brake applications is  $60 \pm 2$  km/h.
- 4.4.3.4. A minimum of six consecutive brake applications shall be made from 0.15 to 0.55 TR/Test Mass at ascending increments of application pressure, following by six brake applications made with the same application pressures in descending increments.

- 4.4.3.5. For each of the brake applications in paragraph 4.4.3.4. the braking rate is calculated, corrected to take account of rolling resistance, and plotted on the graph specified in paragraph 4.4.1.1. of this annex.
- 4.5. Test methods
- 4.5.1. Track test
- 4.5.1.1. The brake performance test shall be carried out on a single axle only.
- 4.5.1.2. The tests shall be carried out on a straight level track, with a surface affording good adhesion, and performed when there is no wind liable to affect the results.
- 4.5.1.3. The trailer shall be loaded (as closely as possible) to the maximum technically permitted mass for each brake, however, additional mass may be added if required to ensure that sufficient mass is over the axle under test to achieve a braking rate of  $0.55 \text{ TR}/(\text{maximum technically permitted mass per brake})$  without wheel lock.
- 4.5.1.4. The dynamic rolling radius of the tyre may be verified at low speed,  $< 10 \text{ km/h}$ , by measuring the distance travelled as a function wheel revolutions, the minimum number of revolutions required to determine the dynamic rolling radius is 10.
- 4.5.1.5. The rolling resistance of the vehicle combination is to be determined by measuring the time taken for the vehicle speed to reduce from 55 to 45 km/h and the distance covered, when tested in the same direction in which the verification test will be carried out and with the engine disconnected and any endurance brake system disengaged.
- 4.5.1.6. Only the brakes of the axle under test shall be actuated and reach an input pressure at the brake input device of  $90 \pm 3$  per cent (after maximum build up time of 0.7 s) of its asymptotic value. The test shall be carried out with the engine disconnected and any endurance braking system disengaged.
- 4.5.1.7. The brakes shall be closely adjusted at the start of the test.
- 4.5.1.8. The brake input for the purpose of calculating the brake threshold torque shall be determined by lifting the wheel and gradually applying the brake whilst the wheel is rotated by hand until resistance is detected.
- 4.5.1.9. The final speed  $v_2$  shall be determined in accordance with annex 11, appendix 2, paragraph 3.1.5.

- 4.5.1.10. The braking performance of the axle under test shall be determined by calculating the deceleration determined from a direct measurement of velocity and distance between  $0.8 v_1$  and  $v_2$ , where  $v_2$  shall not be less than  $0.1 v_1$ . This shall be deemed to be equivalent to the mean fully developed deceleration (MFDD) as defined in annex 4 above.
- 4.5.2. Inertia dynamometer test
- 4.5.2.1. The test shall be carried out on a single brake assembly.
- 4.5.2.2. The test machine shall be capable of generating the inertia required by paragraph 4.5.2.5. of this annex.
- 4.5.2.3. The test machine shall be calibrated for speed and brake output torque within an accuracy of 2 per cent.
- 4.5.2.4. The instrumentation for the test shall be capable of providing at least the following data:
- 4.5.2.4.1. A continuous recording of brake application pressure or force.
- 4.5.2.4.2. A continuous recording of brake output torque.
- 4.5.2.4.3. A continuous recording of the temperature measured at the lining/drum or pad/disc interface.
- 4.5.2.4.4. Speed during the test.
- 4.5.2.5. The inertia ( $I_T$ ) of the dynamometer shall be set as close as possible, with  $\pm 5$  per cent tolerance, including the internal friction of the dynamometer, to that part of the linear inertia of the vehicle acting upon one wheel necessary for a performance of  $0.55TR$ /maximum technically permitted mass according to the following formula:

$$I_T = Pd R^2$$

where

- $I_T$  = actual rotary inertia ( $\text{kgm}^2$ )  
 $R$  = tyre rolling radius defined by the formula 0.485 D

D =  $d + 2H \underline{5/}$   
d = rim diameter conventional number (mm)  
H = Nominal section height (mm) =  $S_1 \times 0.01 Ra$   
 $S_1$  = Section width (mm)  
Ra = nominal aspect ratio  
Pd = Maximum technically permitted mass/brake as defined in paragraph 4.3.1.5.

- 4.5.2.6. Cooling air at ambient temperature may be used, flowing at a velocity not exceeding  $0.33 v$  over the brake in a direction perpendicular to its axis of rotation.
- 4.5.2.7. The brake shall be closely adjusted at the start of the test.
- 4.5.2.8. The brake input for the purpose of calculating the brake threshold torque shall be determined by gradually applying the brake until the onset of brake torque generation is observed.
- 4.5.2.9. The brake performance shall be determined by applying the following formula to the measured brake output torque

$$\text{braking rate} = \frac{M_t R}{I g}$$

where:

$M_t$  = Average brake output torque (Nm) - based on distance  
g = deceleration due to gravity (m/s/s)

The average brake output torque ( $M_t$ ) shall be calculated from the deceleration determined from a direct measurement of velocity and distance between  $0.8 v_1$  and  $0.1 v_1$ . This shall be deemed to be equivalent to the mean fully developed deceleration (MFDD) as defined in annex 4 above.

- 4.5.3. Rolling road test
- 4.5.3.1. The test will be carried out on single axle with one or two brakes.

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5/ Outer diameter of tyre, as defined in Regulation No. 54.

4.5.3.2. The test machine shall have a calibrated means of imposing load to simulate the required mass for the brake(s) to be tested.

4.5.3.3. The test machine shall be calibrated for speed and brake torque within an accuracy of 2 per cent taking into account the internal friction characteristics. The dynamic rolling radius of the tyre (R) shall be determined by measuring the rotational speed of the rolling road and the unbraked wheels of the axle under test at a speed equivalent to 60 km/h, and calculated by the formula

$$R = R_R \frac{n_D}{n_W}$$

where:

$R_R$  = radius of the rolling road

$n_D$  = rotational speed of rolling road

$n_W$  = rotational speed of the unbraked wheels of the axle

4.5.3.4. Cooling air at ambient temperature may be used, flowing at a velocity not exceeding 0.33 v over the brake(s).

4.5.3.5. The brake(s) shall be closely adjusted at the start of the test.

4.5.3.6. The brake input for the purpose of calculating the brake threshold torque shall be determined by gradually applying brake(s) until the onset of brake torque generation is observed.

4.5.3.7. The brake performance shall be determined by measuring the brake force at the periphery of the tyre calculated to braking rate, taking into account the rolling resistance. The rolling resistance of the loaded axle will be determined by measuring the force at the periphery of the tyre at a speed of 60 km/h.

The average brake output torque ( $M_t$ ) shall be based on the measured values between the moment the application pressure/force reaches its asymptotic value from the onset of pressure rise at the brake input device and when the energy input has reached the value  $W_{60}$  that is defined in paragraph 4.5.3.8.

4.5.3.8. For determining the braking rate an energy input  $W_{60}$  equivalent to the kinetic energy of the corresponding mass for the brake under test when braked from 60 km/h to standstill, must be taken into account.



where:

$$W_{60} = \int_0^{t(W_{60})} F_B \cdot v \cdot dt$$

- 4.5.3.8.1. If the test speed  $v$  cannot be maintained at  $60 \pm 2$  km/h during the measurement of the braking rate according to paragraph 4.5.3.8., the braking rate shall be determined from the direct measurement of brake force  $F_B$  and/or brake output torque  $M_t$ , so that the measurement of this/these parameter(s) are not affected by the dynamic forces of the inertia mass of the rolling road test machine.
- 4.6. Verification report
- 4.6.1. The manufacturer's declared performance characteristics, verified by the test results recorded in accordance with paragraph 4.4.3. above, shall be reported on a form, a model of which is shown in appendix 3 to annex 11.
5. Anti-lock braking systems (ABS)
- 5.1. General
- 5.1.1. This paragraph defines the procedure to determine the performance of a trailer anti-lock braking system.
- 5.2. Information document
- 5.2.1. The manufacturer of the ABS shall supply to the Technical Service an Information Document of the system(s) requiring performance verification. This document shall contain at least the information defined in appendix 5 to this annex.
- 5.3. Definition of test vehicles
- 5.3.1. Based on the information supplied in the information document, in particular the trailer applications defined in paragraph 2.1. of appendix 5, the Technical Service shall carry out tests on representative trailers having up to three axles and equipped with the respective anti-lock braking system/configuration. Additionally, when selecting trailers for evaluation consideration shall also be given to the parameters defined in the following paragraphs.
- 5.3.1.1. Suspension type: the method of evaluating the performance of the anti-lock braking system relative to the suspension type will be selected in the following way:

Semi-trailers: for each suspension group e.g. balanced mechanical etc. a representative trailer shall be evaluated.

Full trailers: Evaluation to be carried out on a representative trailer equipped with any one suspension type.

- 5.3.1.2. Wheelbase: for semi-trailers the wheelbase shall not be a limiting factor, but for full trailers the shortest wheelbase shall be evaluated.
- 5.3.1.3. Brake type: approval shall be limited to S cam or disc brakes but should other types become available then comparative testing may be required.
- 5.3.1.4. Load sensing device: The utilisation of adhesion shall be determined with the load sensing valve set to laden and unladen conditions. In all cases the requirements of paragraph 2.7. of annex 13 to this Regulation shall apply.
- 5.3.1.5. Brake actuation: differentials in the level of actuation shall be recorded for evaluation during the tests to determine the utilisation of adhesion. Results obtained from tests for one trailer may be applied to other trailers of the same type.
- 5.3.2. For each type of trailer under test, documentation showing brake compatibility as defined in annex 10 to this Regulation (diagrams 2 and 4) shall be made available to demonstrate conformity.
- 5.3.3. For the purpose of the approval, semi-trailers and centre axle trailers shall be deemed to be of the same vehicle type.
- 5.4. Test schedule
- 5.4.1. The following tests shall be conducted by the Technical Service on the vehicle(s) defined in paragraph 5.3. of this annex for each ABS configuration taking into consideration the application list defined in paragraph 2.1. of appendix 5 to this annex. However, worst case cross referencing may eliminate certain tests. If worst case testing is actually used, this should be stated in the test report.
- 5.4.1.1. Utilisation of adhesion - Tests shall be carried out according to the procedure defined in paragraph 6.2. of annex 13 to this Regulation for each ABS configuration and trailer type, as defined in the manufacturer's information document (see paragraph 2.1. of appendix 5 to this annex).

5.4.1.2. Energy consumption

5.4.1.2.1. Axle loading - The trailer(s) to be tested shall be loaded so that the axle load is 2,500 kg or 25 per cent of the permissible axle load whichever is the lower.

5.4.1.2.2. It shall be ensured that anti-lock cycling can be achieved throughout the dynamic tests defined in paragraph 6.1.3. of annex 13 to this Regulation.

5.4.1.2.3. Energy consumption test - The test shall be carried out according to the procedure defined in paragraph 6.1. of annex 13 to this Regulation for each ABS configuration.

5.4.1.2.4. To enable trailers submitted for approval to be checked for conformity to the anti-lock energy consumption requirements (see paragraph 6.1. of annex 13), the following checks shall be carried out:

5.4.1.2.4.1. Prior to the commencement of the energy consumption test (paragraph 5.4.1.2.3.) in the case of brakes with non integrated brake wear adjustment the brakes shall be set to a condition where the relationship ( $R_l$ ) of brake chamber push rod travel ( $s_T$ ) against lever length ( $l_T$ ) is 0.2. This relationship shall be determined for a brake chamber pressure of 6.5 bar.

Example  $l_T = 130$  mm,  
 $s_T$  at 6.5 bar brake chamber pressure = 26 mm

$$R_l = s_T / l_T = 26/130 = 0.2$$

In the case of brakes with integrated automatic brake wear adjustment the brakes shall be set to the normal running clearance specified by the manufacturer.

Setting of the brakes as defined above shall be carried out when the brakes are cold ( $< 100$  °C)

5.4.1.2.4.2. With the load sensing valve set to the laden condition and the initial energy level set according to paragraph 6.1.2. of annex 13 to this Regulation the energy storage device(s) shall be isolated from further supply of air. The brakes shall be applied with a control pressure of 6.5 bar at the coupling head and then released. Further applications shall be made until the pressure in the brake chambers is the same as that obtained after following the test procedure defined in paragraphs 5.4.1.2.1 and 5.4.1.2.2 above. The number of equivalent brake applications ( $n_{er}$ ) shall be noted.

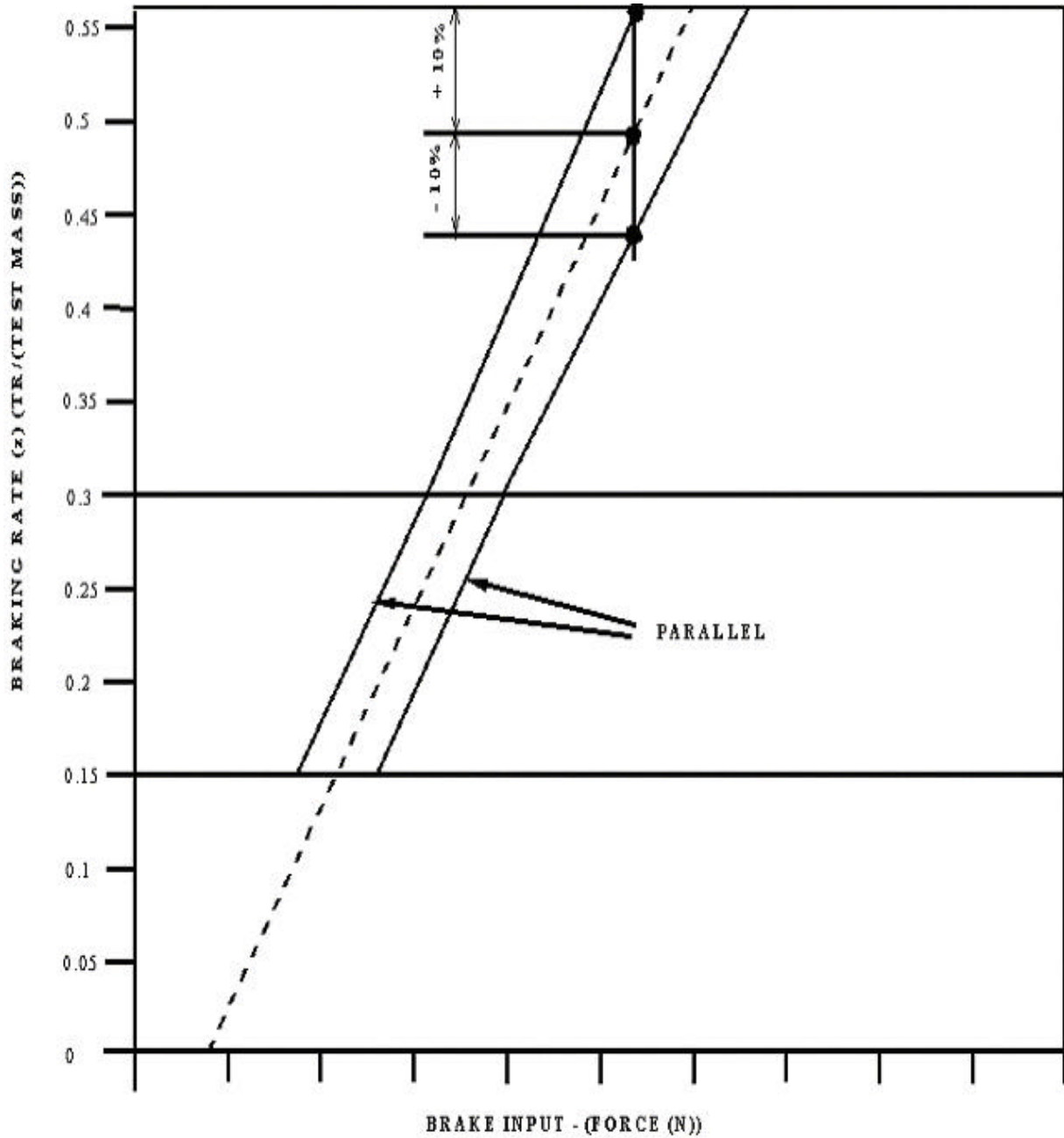
The equivalent number of static brake applications ( $n_e$ ) is to be recorded in the test report.

Where  $n_e = 1.2 \cdot n_{er}$  and is to be rounded up to the nearest whole integer

- 5.4.1.3. Split Friction Test - Where an anti-lock braking system is to be defined as category A system then all such ABS configurations shall be subject to the performance requirements of paragraph 6.3.2. of annex 13 to this Regulation.
- 5.4.1.4. Low and high speed performance
- 5.4.1.4.1. With the trailer set as for utilisation of adhesion evaluation, verification of the low and high speed performance shall be carried out according to paragraph 6.3.1. of annex 13 to this Regulation.
- 5.4.1.4.2. Where a tolerance exists between the number of exciter teeth and tyre circumference, functional checks shall be carried out at the extremes of tolerance in accordance with paragraph 6.3. of annex 13 to this Regulation. This may be achieved by utilising different tyre sizes or by producing special exciters to simulate frequency extremes.
- 5.4.1.5. Additional checks
- The following additional checks shall be carried out with the towing vehicle unbraked and the trailer unladen.
- 5.4.1.5.1. When the axle bogie passes from a high adhesion surface ( $k_H$ ) to a low adhesion surface ( $k_L$ ) where  $k_H \geq 0.5$  and  $k_H / k_L \geq 2$ , with a control pressure at the coupling head of 6.5 bar, the directly controlled wheels shall not lock. The running speed and the instant of applying the trailer brakes is so calculated that with the anti-lock braking system full cycling on the high adhesion surface, the passage from one surface to the other being made at approximately 80 km/h and at 40 km/h.
- 5.4.1.5.2. When the trailer passes from a low adhesion surface ( $k_L$ ) to a high adhesion surface ( $k_H$ ) where  $k_H \geq 0.5$  and  $k_H / k_L \geq 2$ , with a control pressure at the coupling head of 6.5 bar, the pressure at the brake chambers shall rise to an appropriate high value within a reasonable time and the trailer shall not deviate from its initial course. The running speed and the instant of applying the brakes is so calculated that, with the anti-lock braking system full cycling on the low adhesion surface, the passage from one surface to the other occurs at approximately 50 km/h.

- 5.4.1.6. Documentation relating to the controller(s) shall be made available as required by paragraph 5.1.5 of the Regulation and paragraph 4.1. of annex 13 to this Regulation, including footnote 12.
- 5.5. Approval report
- 5.5.1. An approval report shall be produced, the content of which is defined in appendix 6 to this annex.

DIAGRAM 1



Annex 19 - Appendix 1

MODEL VERIFICATION REPORT FORM FOR DIAPHRAGM BRAKE CHAMBERS

Report No .....

1. Identification

1.1. Manufacturer: (Name and address)

1.2. Make: 1/

1.3. Type: 1/

1.4. Part number: 1/

2. Operating conditions:

2.1. Maximum working pressure:

3. Performance characteristics declared by the manufacturer:

3.1. Maximum stroke ( $s_{max}$ ) at 6.5 bar 2/

3.2. Average thrust ( $Th_A$ ) -  $f(p)$  2/

3.3. Effective stroke ( $s_p$ ) -  $f(p)$  2/

3.3.1. Pressure range over which the above affected stroke is valid: (compare paragraph 2.3.1. of annex 19)

4. Name of Technical Service/Approval Authority 3/ conducting the test:

5. Date of test:

6. This test has been carried out and the results reported in accordance with annex 19 to ECE Regulation No. 13 as last amended by the .... series of amendments.

Technical Service 4/ conducting the test

Signed: ..... Date: .....

7. Approval Authority 4/

Signed: ..... Date: .....

8. Test documents:

Appendix 2, ....., .....

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1/ To be marked on brake chamber, however for inclusion within the test report only the parent part number is required, model variants need not be indicated.

2/ Identification must be amended when changes are made which have an influence on the performance characteristics, paragraphs 3.1., 3.2. and 3.3.

3/ Delete as appropriate.

4/ To be signed by different persons even when the Technical Service and Approval Authority are the same or alternatively, a separate Approval Authority authorisation issued with the report.

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Annex 19 - Appendix 2

MODEL REFERENCE RECORD OF TEST RESULTS FOR DIAPHRAGM BRAKE CHAMBERS

Report No. ....

1. Record of test results 1/ for part number .....

Pressure <u>2/</u> p - (bar)	Average thrust Th <sub>A</sub> - (N)	Effective stroke S <sub>p</sub> - (mm)

1/ To be created for each of the 6 samples tested.

2/ Pressure "p" will be actual pressure values used in the test as defined in paragraph 2.2.2. of this annex.

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Annex 19 - Appendix 3

MODEL VERIFICATION REPORT FORM FOR SPRING BRAKES

Report No .....

1. Identification:

1.1. Manufacturer: (Name and address)

1.2. Make: 1/

1.3. Type: 1/

1.4. Part number: 1/

2. Operating conditions:

2.1. Maximum working pressure:

3. Performance characteristics declared by the manufacturer:

3.1. Maximum stroke ( $s_{max}$ ) 2/

3.2. Spring thrust ( $Th_s$ ) -  $f$  (s) 2/

3.3. Release pressure (at 10 mm stroke) 2/

4. Date of test:

5. This test has been carried out and the results reported in accordance with annex 19 to ECE Regulation No. 13 as last amended by the .... series of amendments.

Technical Service 3/ conducting the test

Signed : ..... Date: .....

6. Approval Authority 3/

Signed: ..... Date: .....

7. Test documents:

Appendix 4, ..... , .....

1/ To be marked on the spring brake, however for inclusion within the test report only the parent part number is required, model variants need not be indicated.

2/ Identification must be amended when changes are made which have an influence on the performance characteristics, paragraphs 3.1., 3.2. and 3.3.

3/ To be signed by different persons even when the Technical Service and Approval Authority are the same or alternatively, a separate Approval Authority authorisation issued with the report.

Annex 19 - Appendix 4

MODEL REFERENCE RECORD OF TEST RESULTS FOR SPRING BRAKES

Report No .....

1. Record of test results 1/ for part number: .....

Stroke <u>2/</u> s - (mm)	Thrust Th <sub>s</sub> - (N)

Release pressure (at 10 mm stroke) ..... bar

1/ To be created for each of the 6 samples tested.

2/ Stroke "s" will be the actual stroke values used in the test as defined in paragraph 3.2.2. of this annex.

Annex 19 - Appendix 5

TRAILER ANTI-LOCK BRAKING SYSTEM INFORMATION DOCUMENT

1. General
  - 1.1. Name of manufacturer
  - 1.2. System name
  - 1.3. System variations
  - 1.4. System configurations (e.g. 2S/1M, 2S/2M etc.)
  - 1.5. Explanation of the basic function and/or philosophy of the system.
2. Applications
  - 2.1. List of trailer types and ABS configurations for which approval is required.
  - 2.2. Schematic diagrams of the system configurations installed on the trailers defined in item 2.1. above with consideration given to the following parameters:
    - Sensor locations
    - Modulator locations
    - Lift axles
    - Steering axles
    - Tube: type - bore size(s) and lengths
  - 2.3. Relationship of tyre circumference to the resolution of the exciter, including tolerances.
  - 2.4. Tolerance of tyre circumference between one axle and another fitted with the same exciter.
  - 2.5. Scope of application with respect to suspension type e.g. balanced mechanical etc. with reference to the manufacturer and model/type.
  - 2.6. Recommendations on differential brake input torque (if any) in relation to the ABS configuration and trailer bogie.
  - 2.7. Additional information (if applicable) to the application of the anti-lock braking system.

3. Component description
    - 3.1. Sensor(s)  
Function  
Identification (e.g. part number(s))
    - 3.2. Controller(s)  
General description and function  
Identification (e.g. part number(s))  
Safety aspects of controller(s)  
Additional features (e.g. retarder control, automatic configuration, variable parameters, diagnostics)
    - 3.3. Modulator(s)  
General description and function  
Identification (e.g. part number(s))  
Limitations (e.g. maximum delivery volumes to be controlled)
    - 3.4. Electrical Equipment  
Circuit diagram(s)  
Powering methods  
Warning lamp sequence(s)
    - 3.5. Pneumatic Circuits  
Braking schematics covering the ABS configurations as applied to the trailer types defined in paragraph 5.2.1.2.1.  
Limitations on pipe, tube sizes and associated lengths that have an effect on system performance (e.g. between modulator and brake chamber)
    - 3.6. Electro Magnetic Compatibility
      - 3.6.1. Documentation demonstrating compliance with the provisions of paragraph 4.4. of annex 13 to this Regulation.
-

Annex 19 - Appendix 6

TRAILER ANTI-LOCK BRAKING SYSTEM TEST REPORT

Test Report No: .....

1. Identification
  - 1.1. Manufacturer of the anti-lock braking system (name and address)
  - 1.2. System name/model
2. System(s) and Installation(s) approved
  - 2.1. ABS configuration(s) approved (e.g. 2S/1M, 2S/2M etc.):
  - 2.2. Range of application (type of trailer and number of axles):
  - 2.3. Methods of powering: ISO 7638, ISO 1185 etc.
  - 2.4. Identification of approved sensor(s), controller(s) and modulator(s):
  - 2.5. Energy consumption - equivalent number of static brake applications.
  - 2.6. Additional features e.g. retarder control, lift axle configuration etc.
3. Test Data and Results
  - 3.1. Test vehicle data:
  - 3.2. Test surface information:
  - 3.3. Test results:
    - 3.3.1. Utilisation of adhesion:
    - 3.3.2. Energy consumption:
    - 3.3.3. Split friction test:
    - 3.3.4. Low speed performance:
    - 3.3.5. High-speed performance:

- 3.3.6. Additional checks:
  - 3.3.6.1. Transition from high to low adhesion surfaces:
  - 3.3.6.2. Transition from low to high adhesion surfaces:
- 3.3.7. Failure mode simulation:
- 3.3.8. Functional checks of optional power connections:
- 3.3.9. Electro-magnetic compatibility
- 4. Limits of installation.
  - 4.1. Relationship of tyre circumference to the resolution of the exciter:
  - 4.2. Tolerance on tyre circumference between one axle and another fitted with the same exciter:
  - 4.3. Suspension type:
  - 4.4. Differential(s) in brake input torque within the trailer bogie:
  - 4.5. Wheel base of full trailer:
  - 4.6. Brake type:
  - 4.7. Tube sizes and lengths
  - 4.8. Load sensing device application:
  - 4.9. Warning lamp sequence:
  - 4.10. System configurations and applications that comply with the category A requirements.
  - 4.11. Other recommendations/limitations (e.g. location of sensors, modulator(s), lift axle(s), steering axle(s)):

5. Date of Test:

This test has been carried out and the results reported in accordance with annex 19 to ECE Regulation No. 13 as last amended by the ..... series of amendments.

Technical Service 1/ conducting the test

Signed: ..... Date: .....

6. Approval Authority 1/

Signed: ..... Date: .....

Attachment: Manufacturer's information document

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1/ To be signed by different persons even when the Technical Service and Approval Authority are the same or alternatively, a separate Approval Authority authorisation issued with the report.

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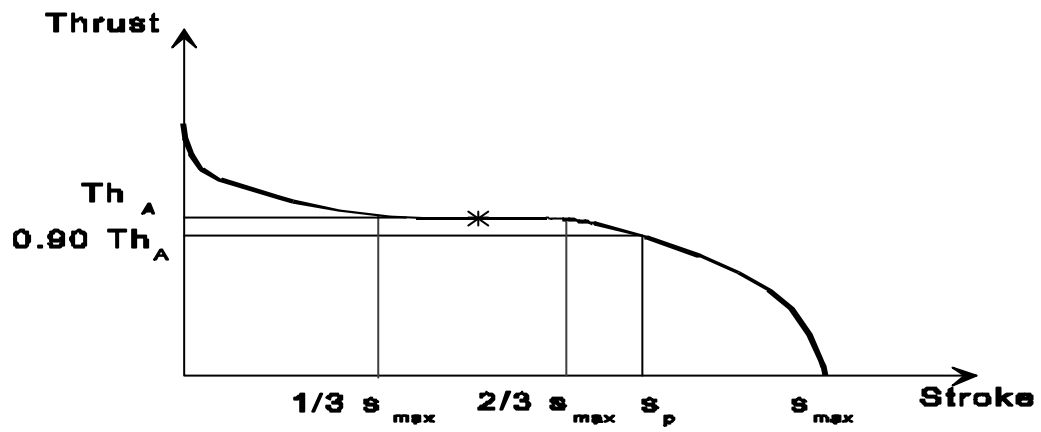
Annex 19 - Appendix 7

SYMBOLS AND DEFINITIONS

SYMBOL	DEFINITION
$B_F$	Brake factor (input torque to output torque amplification ratio)
$C_O$	Threshold input torque (minimum torque necessary to produce a measurable brake torque)
$D$	Outer tyre diameter (overall diameter of an inflated new tyre)
$d$	A conventional number denoting the nominal rim diameter and corresponding to the diameter of the rim expressed either in inches or mm
$F_B$	Brake force
$H$	Nominal tyre section height (the distance equal to half the difference between the outer diameter of the tyre and the nominal rim diameter)
$I$	Rotary inertia
$l_T$	Brake lever length of reference test trailer
$M_t$	Average brake output torque
$n_e$	Equivalent number of static brake applications for the purpose of type approval
$n_{er}$	Equivalent number of static applications obtained during testing
$n_D$	Rotational speed of the rolling road
$n_W$	Rotational speed of the unbraked wheels of the axle
$P_d$	Maximum technically permitted mass for the brake
$p$	Pressure
$R$	Dynamic tyre rolling radius (calculated using $0.485D$ )



SYMBOL	DEFINITION
R <sub>a</sub>	Nominal aspect ratio of the tyre (one hundred times the number obtained by dividing the number expressing the nominal section height of the tyre in mm by the number expressing the nominal section width in mm).
R <sub>f</sub>	Ratio of $s_T / l_T$
R <sub>R</sub>	Radius of the rolling road
S <sub>1</sub>	Section width of the tyre (linear distance between the outsides of the sidewalls of an inflated tyre, excluding elevations due to labelling (marking), decorations or protective bands or ribs).
S	Actuator stroke (working stroke plus free stroke)
S <sub>max</sub>	Total actuator stroke
S <sub>p</sub>	Effective stroke (the stroke at which the output thrust is 90per cent of the average thrust Th <sub>A</sub> )
S <sub>T</sub>	Brake chamber push rod travel of reference test trailer in mm
Th <sub>A</sub>	Average thrust (the average thrust is determined by integrating the values between 1/3 and 2/3 of the total stroke S <sub>max</sub> )
Th <sub>s</sub>	Spring thrust of the spring brake
TR	Sum of braking forces at periphery of all wheels of trailer or semi-trailer
V	Rolling road test speed
V <sub>1</sub>	Initial speed, when braking starts
V <sub>2</sub>	Speed at end of braking
W <sub>60</sub>	Energy input, equivalent to the kinetic energy of the corresponding mass for the brake under test when braked from 60 km/h to standstill
Z	Braking rate of vehicle



Annex 20

ALTERNATIVE PROCEDURE FOR THE TYPE APPROVAL OF TRAILERS

1. General

This annex defines an alternative procedure for type approving trailers, utilising information from test reports issued in accordance with annexes 11 and 19.

1.2. On completion of the verification procedures described in paragraphs 3., 4., 5., 6., 7. and 8. of this annex, the Technical Service / Approval Authority shall issue an ECE type approval certificate conforming to the model specified in annex 2, appendix 1 to this Regulation.

1.3. For the purposes of the calculations defined within this annex the centre of gravity height shall be determined in accordance with the method defined in appendix 1 to this annex

2. Application for type approval

2.1. The application for ECE type approval of a trailer type with regard to the braking equipment shall be submitted by the trailer manufacturer. In support of the approval the trailer manufacturer shall supply to the Technical Service at least the following:

2.1.1. A copy of the ECE or EU Type Approval Certificate and an Information Document of a trailer hereafter referred to as the "reference trailer" on which the service braking performance comparison is to be based. This trailer will have been subject to the actual tests defined in annex 4 to this Regulation for the appropriate trailer or equivalent EU Directive. A trailer that has been approved to the alternative procedure defined in this annex shall not be used as a reference trailer.

2.1.2. Copies of the annex 11 and annex 19 test reports.

2.1.3 A documentation package that contains the relevant verification information including the relevant calculations for the following:

Performance Requirements	Annex 20 reference
Cold service braking performance	3.0
Parking brake performance	4.0
Emergency brake performance	5.0
Failure of brake distribution system	6.0
Breakage or leakage from auxiliary systems	7.0
Anti-lock braking	8.0

- 2.1.4. A trailer, representative of the trailer type to be approved hereafter referred to as the "subject trailer".
- 2.2. The manufacturer of the "reference trailer" and "subject trailer" shall be the same.
3. Alternative procedure for demonstrating the Type-0 service braking cold performance.
- 3.1. To demonstrate compliance with the Type-0 service braking cold performance it shall be verified, by calculation, that the "subject trailer" has sufficient brake force (TR) available to achieve the prescribed service braking performance and that there is sufficient adhesion available on a dry road surface (assumed to have a coefficient of adhesion of 0.8) to utilise this brake force.
- 3.2. Verification
- 3.2.1. The requirements of annex 4, paragraph 1.2.7. and 3.1.2. (cold performance requirement and achievement without wheel lock, deviation or abnormal vibration) are considered to be satisfied by the subject trailer if it meets the verification criteria described in the following paragraphs, in both the laden and unladen conditions:
- 3.2.1.1. The wheelbase of the subject trailer shall not be less than 0.8 times the reference trailer wheelbase.
- 3.2.1.2. Any difference in the brake input torque between one axle and another within a bogie of the "subject trailer" shall not differ from that of the "reference trailer".
- 3.2.1.3. The number and arrangement of axles i.e. lifting, steering etc. of the "subject trailer" shall not differ from that of the reference trailer.

- 3.2.1.4. The percentage distribution of the laden static axle load of the subject trailer shall not differ from that of the reference trailer by more than 10 per cent.
- 3.2.1.5. For semi trailers, a graph, in accordance with appendix 2, shall be constructed and, from this graph, it shall be verified that:
- $TR_{max} \geq TR_{pr}$  (i.e. line (1) shall not be below line (3)), and
- $TR_L \geq TR_{pr}$  (i.e. line (2) shall not be below line (3)).
- 3.2.1.6. For centre axle trailers, a graph, in accordance with appendix 3, shall be constructed and, from this graph, it shall be verified that:
- $TR_{max} \geq TR_{pr}$  (i.e. line (1) shall not be below line (3)), and
- $TR_L \geq TR_{pr}$  (i.e. line (2) shall not be below line (3)).
- 3.2.1.7. For full trailers, a graph, in accordance with appendix 4, shall be constructed and, from this graph, it shall be verified that:
- $TR_{max} \geq TR_{pr}$  (i.e. line (1) shall not be below line (2)), and
- $TR_{Lf} \geq TR_{prf}$  (i.e. line (4) shall not be below line (3)), and
- $TR_{Lr} \geq TR_{prr}$  (i.e. line (6) shall not be below line (5)).
4. Alternative procedure for demonstrating the parking brake performance.
- 4.1. General
- 4.1.1. This procedure provides an alternative to physically testing trailers on a gradient and ensures that trailers fitted with spring brake actuated parking mechanisms can meet the prescribed parking brake performance. This procedure shall not be applied to trailers fitted with parking mechanisms operated by means other than spring brakes. Such trailers shall be subjected to the physical test prescribed in annex 4.
- 4.1.2. The prescribed parking braking performance shall be demonstrated by calculation, using the formulae contained in paragraphs 4.2. and 4.3.
- 4.2. Parking performance

4.2.1. The parking brake force at the periphery of the tyres of axle(s) braked by the spring brake actuated parking mechanism shall be calculated using the following formula:

$$T_{pi} = (Th_s \cdot l - C_o) \cdot n \cdot B_F / R_s$$

4.2.2. The normal reaction of the road surface on the axles of a stationary trailer facing uphill and downhill on an 18 per cent gradient shall be calculated using the following formulae:

4.2.2.1. In the case of full trailers:

4.2.2.1.1. Facing uphill

$$N_{FU} = PR_F - \frac{\tan P \times h \times P}{E_L} \cos P$$

$$N_{FU_i} = \frac{N_{FU}}{i_F}$$

$$N_{RU} = PR_R + \frac{\tan P \times h \times P}{E_L} \cos P$$

$$N_{RU_i} = \frac{N_{RU}}{i_R}$$

4.2.2.1.2. Facing downhill

$$N_{FD} = PR_F + \frac{\tan P \times h \times P}{E_L} \cos P$$

$$N_{FD_i} = \frac{N_{FD}}{i_F}$$

$$N_{RD} = PR_R - \frac{\tan P \times h \times P}{E_L} \cos P$$

$$N_{RD_i} = \frac{N_{RD}}{i_R}$$

4.2.2.2. In the case of centre axle trailers:

4.2.2.1. Facing uphill

$$N_{RU} = P + \frac{\tan P \times h \times P}{E_L} \cos P$$

$$N_{RU_i} = \frac{N_{RU}}{i_R}$$

4.2.2.2.2. Facing downhill

$$N_{RD} = P - \frac{\tan P \times h \times P}{E_L} \cos P$$

$$N_{RD_i} = \frac{N_{RD}}{i_R}$$

4.2.2.3. In the case of semi-trailers:

4.2.2.3.1. Facing uphill

$$N_{RU} = P - \frac{P_s \times E_R}{E_L} + \frac{\tan P \times h \times P}{E_L} \cos P$$

$$N_{RU_i} = \frac{N_{RU}}{i_R}$$

4.2.2.3.2. Facing downhill

$$N_{RD} = P - \frac{P_s \times E_R}{E_L} - \frac{\tan P \times h \times P}{E_L} \cos P$$

$$N_{RD_i} = \frac{N_{RD}}{i_R}$$

4.3. Verification

4.3.1. The parking brake performance of the trailer shall be verified using the following formulae:

$$\left( \frac{\sum A_{Di} + \sum B_{Di}}{P} + 0.01 \right) \times 100 \geq 18\%$$

and:

$$\left( \frac{\sum A_{Ui} + \sum B_{Ui}}{P} + 0.01 \right) \times 100 \geq 18\%$$

5. Alternative procedure for demonstrating the emergency/automatic braking performance

5.1. General

5.1.1. To demonstrate compliance with the automatic braking performance requirements, either a comparison is made between the chamber pressure required to achieve the specified performance and the asymptotic chamber pressure after disconnection of the supply line, as defined in paragraph 5.2.1., or it shall be verified that the brake force provided by the axle(s) fitted with spring brakes is sufficient to achieve the specified performance, as defined in paragraph 5.2.2.

5.2. Verification

5.2.1. The requirements of annex 4, paragraph 3.3., are considered to be satisfied by a subject trailer if the asymptotic chamber pressure ( $p_c$ ) after disconnection of the supply line is greater than the chamber pressure ( $p_c$ ) to achieve a performance of 13.5 per cent of the maximum stationary wheel load. The supply line pressure being stabilised at 7.0 bar prior to disconnection.

5.2.2. The requirements of annex 4, paragraph 3.3., are considered to be satisfied by a spring brake equipped subject trailer if:

$$s T_{pi} \geq 0.135 \cdot PR \cdot g$$



where  $T_{pi}$  is calculated in accordance with paragraph 4.2.1.

6. Alternative procedure for demonstrating braking performance in the case of failure of the braking distribution system
  - 6.1. General
    - 6.1.1. To demonstrate compliance with the braking performance requirements in the case of a failure of the braking distribution system, a comparison is made between the chamber pressure required to achieve the specified performance and the chamber pressure available when a failure in the braking distribution system exists.
  - 6.2. Verification
    - 6.2.1. The requirements of annex 10, appendix, paragraph 6., are considered to be satisfied by the subject trailer if the pressure defined in paragraph 6.2.1.1. is greater than or equal to the pressure defined in paragraph 6.2.1.2., in both laden and unladen conditions.
      - 6.2.1.1. The chamber pressure ( $p_c$ ) of the subject trailer, when  $p_m = 6.5$  bar, the supply line pressure = 7.0 bar and a failure in the braking distribution system exists.
      - 6.2.1.2. The chamber pressure ( $p_c$ ) to achieve a braking rate of 30 per cent of the service braking performance prescribed for the subject trailer.
7. Alternative procedure for demonstrating the anti-lock braking performance
  - 7.1. General
    - 7.1.1. Testing of a trailer in accordance with annex 13 to this Regulation may be waived at the time of type approval of the trailer provided that the anti-lock braking system (ABS) complies with the requirements of annex 19 to this Regulation.
  - 7.2. Verification
    - 7.2.1. Verification of components and installation  
The specification of the ABS installed on the trailer to be type approved shall be verified by satisfying each of the following criteria:

Paragraph		CRITERIA
7.2.1.1.	(a) Sensor(s)	No change allowed
	(b) Controller(s)	No change allowed
	(c) Modulator(s)	No change allowed
7.2.1.2.	Tube size(s) and lengths	
	(a) Reservoir supply to modulator(s)	
	Minimum inside diameter	May be increased
	Maximum overall length	May be reduced
	(b) Modulator delivery to brake chambers	
	Inside diameter	No change allowed
	Maximum overall length	May be reduced
7.2.1.3.	Warning signal sequence	No change allowed
7.2.1.4.	Differentials in brake input torque within a bogie	Only approved differentials (if any) permitted
7.2.1.5.	For other limitations refer to paragraph 4. of the test report as described in appendix 6 of annex 19 to this Regulation	Installation to be within the scope of the limitations defined - No deviations allowed

### 7.3. Verification of reservoir capacity

7.3.1. As the range of braking systems and auxiliary equipment used on trailers is diverse it is not possible to have a table of recommended reservoir capacities. To verify that adequate storage capacity is installed, testing may be conducted according to paragraph 6.1. of annex 13 to this Regulation or by the procedure defined below:

- 7.3.1.1. In the case of brakes with non integrated brake wear adjustment the brakes on the subject trailer shall be set to a condition where the relationship ( $R_l$ ) of brake chamber push rod travel ( $s_T$ ) against lever length ( $l_T$ ) is 0.2.

Example:

$$l_T = 130 \text{ mm}$$

$$R_e = s_T/l_T = s_T/130 = 0.2$$

$s_T$  = Push rod travel at 6.5 bar brake chamber pressure

$$= 130 \times 0.2 = 26 \text{ mm}$$

- 7.3.1.2. In the case of brakes with integrated automatic brake wear adjustment the brakes shall be set to a normal running clearance.

- 7.3.1.3. Setting of the brakes as defined above shall be carried out when the brakes are cold ( $\leq 100$  °C).

- 7.3.1.4. With the brakes adjusted according to relevant procedure defined above and the load sensing device(s) set to the laden condition and the initial energy level set according to paragraph 6.1.2. of annex 13 to this Regulation, the energy storage device(s) shall be isolated from further supply. The brakes shall be applied with a control pressure of 6.5 bar at the coupling head and then fully released. Further brake applications shall be made up to the number  $n_e$  determined from the test conducted in accordance with paragraph 5.4.1.2.4.2. of annex 19 to this Regulation and defined in paragraph 2.5. of the anti-lock braking system Approval Report. During this application, the pressure in the operating circuit shall be sufficient to provide a total braking force at the periphery of the wheels equal to not less than 22.5 per cent of the maximum stationary wheel load and without causing automatic application of any braking system not under the control of the anti-lock braking system.

8. Functional and installation checks

- 8.1. The Technical Service / Approval Authority shall carry out functional and installation checks covering the following paragraphs:

- 8.1.1. Anti-lock function

- 8.1.1.1. This shall be limited to a dynamic check of the anti-lock braking system. To ensure full cycling it may be necessary to adjust the load sensing device or utilise a surface having a low tyre to road adhesion. If the anti-lock system does not have an annex 19 approval, the trailer shall be tested in accordance with annex 13 and comply with the relevant requirements contained in that annex.
- 8.1.2. Response time measurement
- 8.1.2.1. The Technical Service shall verify that the subject trailer conforms to the requirements of annex 6.
- 8.1.3. Static energy consumption
- 8.1.3.1. The Technical Service shall verify that the subject trailer conforms to the requirements of annex 7 and annex 8 as appropriate.
- 8.1.4. Service brake function
- 8.1.4.1. The Technical Service shall verify that there are no abnormal vibrations during braking.
- 8.1.5. Parking brake function
- 8.1.5.1. The Technical Service shall apply and release the park brake to ensure correct function.
- 8.1.6. Emergency/automatic braking function
- 8.1.6.1. The Technical Service shall verify that the subject trailer complies with the requirements of paragraph 5.2.1.18.4.2. of this Regulation
- 8.1.7. Vehicle and component identification verification
- 8.1.7.1. The Technical Service shall check the subject trailer against the details contained in the type approval certificate.
- 8.1.8. Additional checks
- 8.1.8.1. The Technical Service may request additional checks to be carried out, if necessary.
-

Annex 20 - Appendix 1

METHOD OF CALCULATING THE CENTRE OF GRAVITY HEIGHT

The centre of gravity height for the complete vehicle (laden and unladen) can be calculated as follows:

$h1$  = centre of gravity height of axle(s) assembly (inc. tyres, springs, etc.) =  $R \cdot 1.1$

$h2$  = centre of gravity height of frame (laden) =  $(h6 + h8) \cdot 0.5$

$h3$  = centre of gravity height of payload and bodywork (laden)  
=  $(h7 \cdot 0.3) + h6$

$h4$  = centre of gravity height of frame (unladen) =  $h2 + s$

$h5$  = centre of gravity height of bodywork (unladen) =  $(h7 \cdot 0.5) + h6 + s$

where:

$h6$  = frame height, top

$h7$  = body dimensions, inside

$h8$  = frame height, bottom

$P$  = total mass of the trailer

$PR$  = total mass on all wheels of a semi trailer or centre axle trailer

$R$  = radius of the tyre

$s$  = spring deflection between laden and unladen

$W1$  = mass of axle(s) assembly (inc. tyres, springs, etc.) =  $P \cdot 0.1$

$W2$  = mass of the frame =  $(P_{unl} - W1) \cdot 0.8$

$W3$  = mass of payload and bodywork

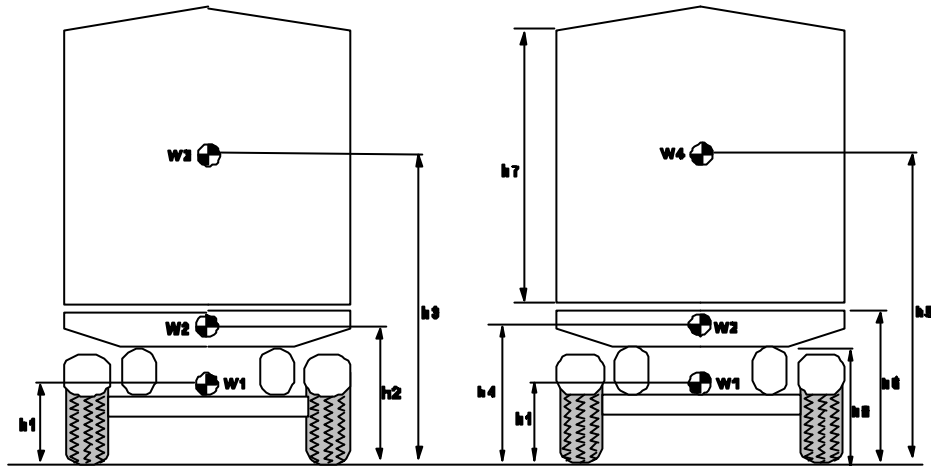
$W4$  = mass of bodywork =  $(P_{unl} - W1) \cdot 0.2$

LADEN:

$$h_{Rlad} = \frac{h1.W1 + h2.W2 + h3.W3}{P_{lad}}$$

UNLADEN:

$$h_{Runl} = \frac{h1.W1 + h4.W2 + h5.W4}{P_{unl}}$$

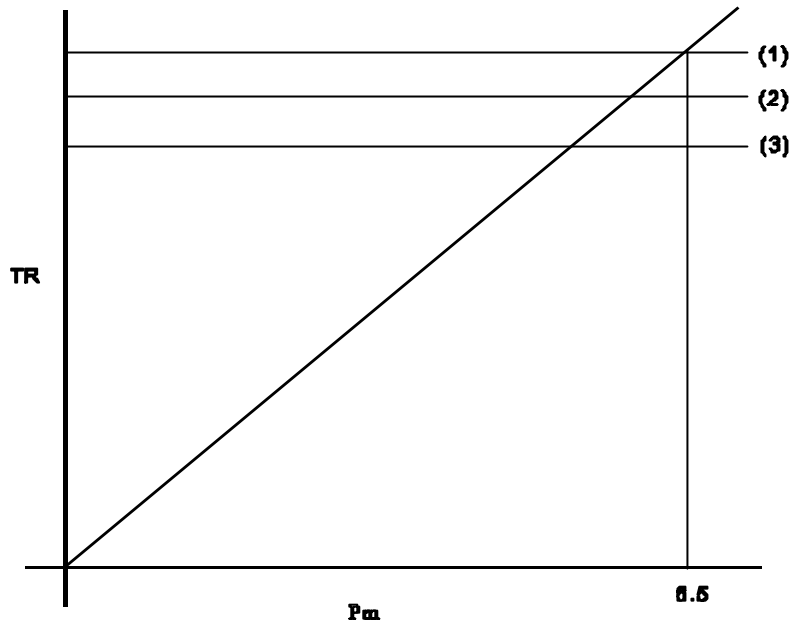


NOTES:

- (1) For flat bed type trailers, a maximum height of 4 m shall be used.
- (2) For trailers where the exact centre of gravity height of the payload is not known, it shall be taken as 0.3 times the inside dimensions of the body.
- (3) For trailers with air suspension, the value of s shall be taken as zero.
- (4) For semi-trailers and centre axle trailers, replace P with PR wherever it occurs.

Annex 20 - Appendix 2

VERIFICATION GRAPH FOR PARAGRAPH 3.2.1.5. - SEMI TRAILERS



- (1) =  $TR_{max}$  , when  $p_m = 6.5$  bar and supply line = 7.0 bar.  
(2) =  $F_{Rdyn} \cdot 0.8 = TR_L$   
(3) =  $0.45 \cdot F_R = TR_{pr}$

where:

$$F_{Rdyn} = F_R - \frac{(TR_{pr} \times h_k) + (P \times g \times z_c (h_R - h_k))}{E_R}$$

the value of  $z_c$  being calculated using the following formula:

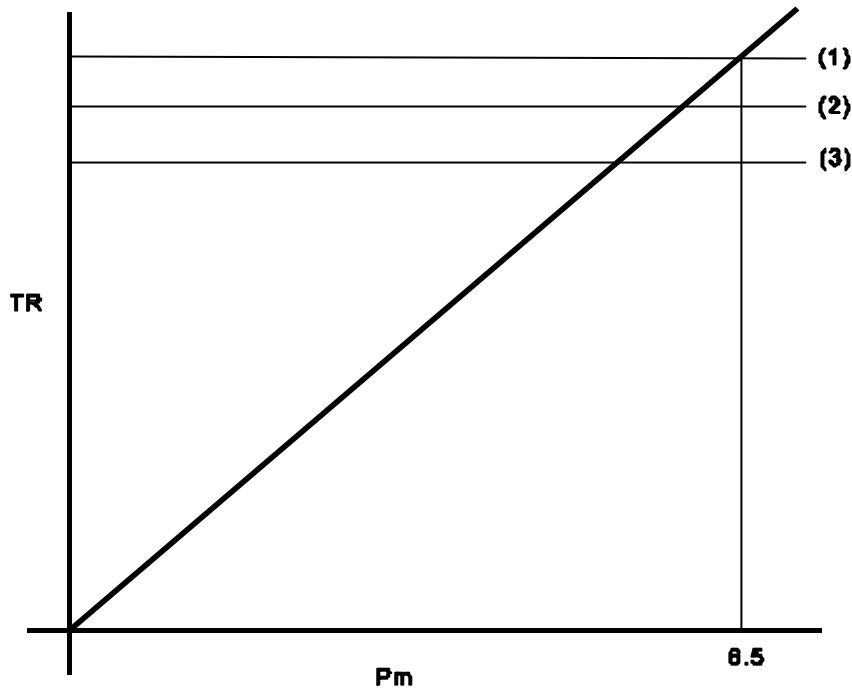
$$z_c = 0.45 + 0.01 \left( \frac{F_R}{(P + 7000) g} \right) + 0.01$$

NOTES:

- (1) The value of 7,000 above represents the mass of a towing vehicle with no trailer attached.  
(2) For the purpose of these calculations, closely spaced axles (having an axle spread of less than 2 metres) may be treated as one axle.

Annex 20 - Appendix 3

VERIFICATION GRAPH FOR PARAGRAPH 3.2.1.6 - CENTRE AXLE TRAILERS



(1) =  $TR_{max}$  , when  $p_m = 6.5$  bar and supply line = 7.0 bar.

(2) =  $F_{Rdyn} \cdot 0.8 = TR_L$

(3) =  $0.5 \cdot F_R = TR_{pr}$

where:

$$F_{Rdyn} = F_R - \frac{(TR_{pr} \times h_k) + (P \times g \times z_c (h_R - h_k))}{E_R}$$

the value of  $z_c$  being calculated using the following formula:

$$z_c = 0.5 - 0.01 \left( \frac{F_R}{(P + 7000) g} \right) + 0.01$$

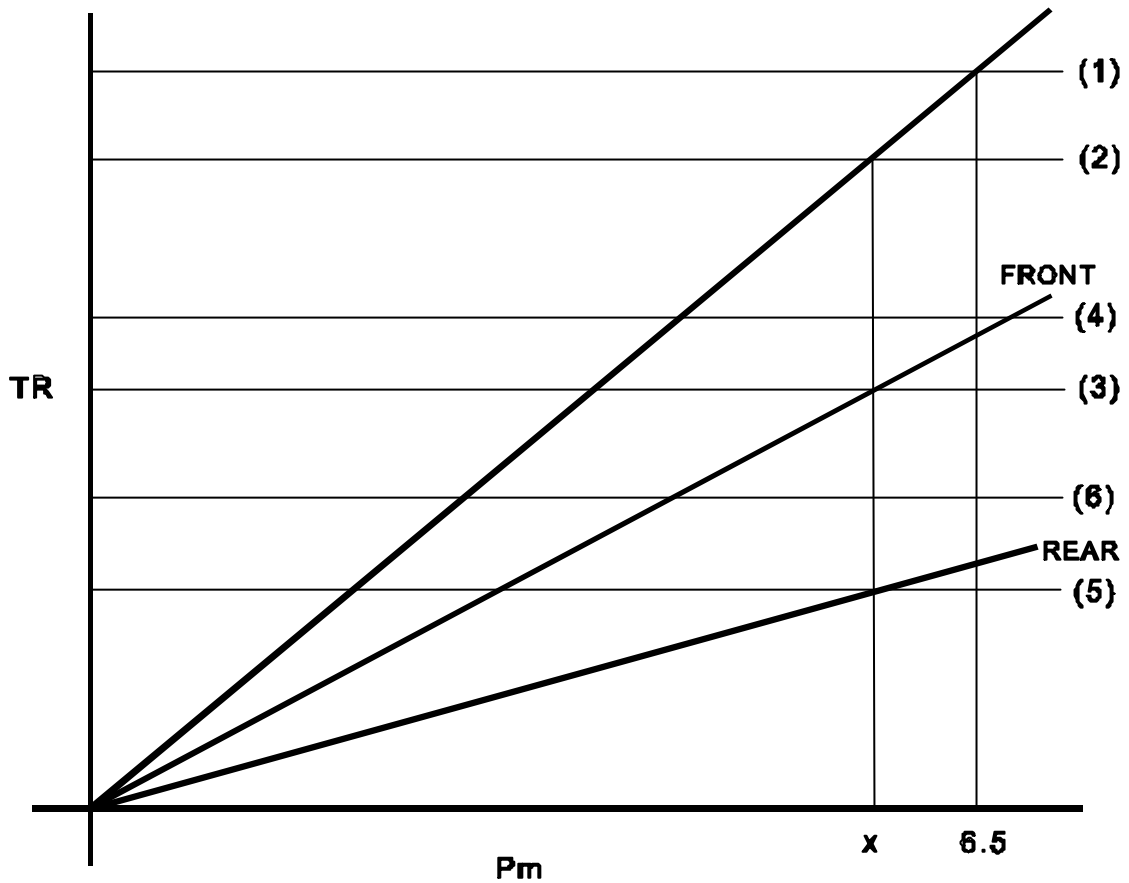
NOTES:

- (1) The value of 7,000 above represents the mass of a towing vehicle with no trailer attached.
- (2) For the purpose of these calculations, closely spaced axles (having an axle spread of less than 2 metres) may be treated as one axle.



Annex 20 - Appendix 4

VERIFICATION GRAPH FOR PARAGRAPH 3.2.1.7. - FULL TRAILERS



(1) =  $TR_{max}$  , when  $p_m = 6.5$  bar and supply line = 7.0 bar.

(2) =  $0.5 \cdot F_R = TR_{pr}$

(3) =  $TR_{prf} = TR_f$  , when  $p_m = x$

(4) =  $F_{fdyn} \cdot 0.8 = TR_{Lf}$

(5) =  $TR_{pirr} = TR_r$  , when  $p_m = x$

(6) =  $F_{rdyn} \cdot 0.8 = TR_{Lr}$

where:

$$F_{fgdyn} = F_f + \frac{P \times g \times Z_c \times h_R}{E}$$

and

$$F_{rdyn} = F_r - \frac{P \times g \times Z_c \times h_R}{E}$$

the value of  $z_c$  being calculated using the following formula:

$$z_c = 0.5 - 0.01 \left( \frac{F_R}{(P + 7000) g} \right) + 0.01$$

NOTES:

- (1) The value of 7,000 above represents the mass of a towing vehicle with no trailer attached.
  - (2) For the purpose of these calculations, closely spaced axles (having an axle spread of less than 2 metres) may be treated as one axle.
-

Annex 20 - Appendix 5

SYMBOLS AND DEFINITIONS

SYMBOL	DEFINITION
$A_{Di}$	$T_{pi}$ when $T_{pi} \leq 0.8 N_{FDi}$ for front axles, or $0.8 N_{FDi}$ when $T_{pi} > 0.8 N_{FDi}$ for front axles
$B_{Di}$	$T_{pi}$ when $T_{pi} \leq 0.8 N_{RDi}$ for rear axles, or $0.8 N_{RDi}$ when $T_{pi} > 0.8 N_{RDi}$ for rear axles
$A_{Ui}$	$T_{pi}$ when $T_{pi} \leq 0.8 N_{FU_i}$ for front axles, or $0.8 N_{FU_i}$ when $T_{pi} > 0.8 N_{FU_i}$ for front axles
$B_{Ui}$	$T_{pi}$ when $T_{pi} \leq 0.8 N_{RU_i}$ for rear axles, or $0.8 N_{RU_i}$ when $T_{pi} > 0.8 N_{RU_i}$ for rear axles
$B_F$	brake factor
$C_o$	threshold camshaft input torque (minimum camshaft torque necessary to produce a measurable brake torque)
$E$	wheelbase
$E_L$	distance between the coupling support leg or landing legs to the centre of the axle(s) of a centre axle trailer or semi-trailer
$E_R$	distance between king-pin and centre of axle or axles of semi-trailer
$F$	force (N)
$F_f$	total normal static reaction of road surface on front axle(s)
$F_{fdyn}$	total normal dynamic reaction of road surface on front axles(s)
$F_f$	total normal static reaction of road surface on rear axle(s)
$F_{rdyn}$	total normal dynamic reaction of road surface on rear axle(s)

SYMBOL	DEFINITION
$F_R$	total normal static reaction of road surface on all wheels of the trailer or semi-trailer
$F_{Rdyn}$	total normal dynamic reaction of road surface on all wheels of the trailer or semi-trailer
$g$	acceleration due to gravity ( $9.81 \text{ m/s}^2$ )
$h$	height above ground of centre of gravity
$h_K$	height of fifth wheel coupling (king pin)
$h_r$	height of centre of gravity of trailer
$i$	axle index
$i_F$	number of front axles
$i_R$	number of rear axles
$l$	lever length
$n$	number of spring brake actuators per axle
$N_{FD}$	total normal reaction of road surface on front axle(s) when facing downhill on an 18 per cent gradient
$N_{FDi}$	normal reaction of road surface on front axle $i$ when facing downhill on an 18 per cent gradient
$N_{FU}$	total normal reaction of road surface on front axle(s) when facing uphill on an 18 per cent gradient
$N_{FUi}$	normal reaction of road surface on front axle $i$ when facing uphill on an 18 per cent gradient
$N_{RD}$	total normal reaction of road surface on rear axle(s) when facing downhill on an 18 per cent gradient

SYMBOL	DEFINITION
$N_{RD_i}$	normal reaction of road surface on rear axle i when facing downhill on an 18 per cent gradient
$N_{RU}$	total normal reaction of road surface on rear axle(s) when facing uphill on an 18 per cent gradient
$N_{RU_i}$	normal reaction of road surface on rear axle i when facing uphill on an 18 per cent gradient
$p_m$	pressure at coupling head of control line
$p_c$	pressure in the brake chamber
$P$	mass of individual vehicle
$P_s$	static mass at fifth wheel coupling at trailer mass P
$PR$	total normal static reaction of road surface on wheels of trailer or semi-trailer
$PR_F$	total normal static reaction of road surface on the front axles on level ground
$PR_R$	total normal static reaction of road surface on the rear axles on level ground
$R_s$	static laden radius of the tyre, calculated using the following formula: $R_s = 1/2 dr + F_R \cdot H$ where: dr = nominal rim diameter H = design section height = $1/2 (d - dr)$ d = rim diameter convention number $F_R$ = factor, as defined by ETRTO (Engineering Design Information 1994, page CV.11)
$T_{p_i}$	brake force at periphery of all wheels of axle i provided by the spring brake(s)
$Th_s$	spring thrust of the spring brake
$TR$	sum of braking forces at periphery of all wheels of the trailer or semi-trailer

SYMBOL	DEFINITION
$TR_f$	sum of braking forces at periphery of all wheels of the front axle(s)
$TR_r$	sum of braking forces at periphery of all wheels of the rear axle(s)
$TR_{max}$	sum of maximum available braking forces at periphery of all wheels of the trailer or semi-trailer
$TR_L$	sum of braking forces at periphery of all wheels of the trailer or semi-trailer at which the limit of adhesion is reached
$TR_{Lf}$	sum of braking forces at periphery of all wheels of the front axle(s) at which the limit of adhesion is reached
$TR_{Lr}$	sum of braking forces at periphery of all wheels of the rear axle(s) at which the limit of adhesion is reached.
$TR_{pr}$	sum of braking forces at periphery of all wheels of the trailer or semi-trailer required to achieve the prescribed performance
$TR_{prf}$	sum of braking forces at periphery of all wheels of the front axle(s) required to achieve the prescribed performance
$TR_{prr}$	sum of braking forces at periphery of all wheels of the rear axle(s) required to achieve the prescribed performance
$Z_c$	braking rate of the vehicle combination, with the trailer only braked
cos P	cosine of angle subtended by slope of 18 per cent and horizontal plane = 0.98418
tan P	tangent of angle subtended by slop of 18 per cent and horizontal plane = 0.18