INTERNATIONAL STANDARD

ISO 21995

First edition
2008-03-15

Road vehicles — Test of vehicle air braking systems with a permissible mass of over 3,5 t — Acquisition and use of reference values using a roller brake tester

Véhicules routiers — Essais des systèmes de freinage à air comprimé des véhicules de masse admissible de plus de 3,5 t — Acquisition et utilisation des valeurs de référence en utilisant un banc de freinage à rouleaux

Reference number
ISO 21995:2008(E)

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 21995 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 2, *Braking systems and equipment*.

Introduction

UNECE Regulation No.13, paragraph 5.1.4.6 (on reference braking forces) requires, as part of the type approval process, that the manufacturer provides the Type 0 braking performance figures as reference values arranged in a tabular or graphical form.

The purpose of reference values is to make adequate data available for conducting periodical vehicle tests, which are most easily performed on roller test benches. Within Council Directive 96/96/EC, testing in service is required to achieve a heavy truck brake efficiency of at least 45 %, and this can be performed by road testing or, more conveniently, on roller brake test benches. The roller brake tests are based on the available reference values declared by the vehicle manufacturer at type approval.

NOTE The minimum requirements are:

— 50 % in the case of vehicles of categories M2, M3, N2, N3, O3 and O4, except semi-trailers;

— 45 % in the case of semi-trailers.

This International Standard provides a procedure for testing both motor vehicles and trailers in service to the level of performance required for periodical technical inspection (PTI).

It is possible that the values will need adjustment to reflect national or international in-service requirements.

Road vehicles — Test of vehicle air braking systems with a permissible mass of over 3,5 t — Acquisition and use of reference values using a roller brake tester

1 Scope

This International Standard provides a method for the acquisition of suitable braking reference values that the manufacturer is required to provide, and for the use of these reference values in periodical technical inspection (PTI) on air brake systems.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

UNECE Regulation No.13, Rev. 6, 2008, *Uniform provisions concerning the approval of vehicles of categories M, N and O with regard to braking*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
braking system
combination of parts which either progressively reduces the speed of the moving vehicle, or brings the vehicle to a halt and/or holds it stationary, or fulfils both functions

3.1.2
brake
part of a **braking system** (3.1.1) in which the forces opposing the movement, or tendency to movement, of the vehicle are developed

3.1.3
braking force
force at the contact surface between a wheel and the ground, produced by the effect of a braking system, which opposes the rotation of the wheel or the tendency for movement of the vehicle

NOTE The force between the tyre and the rotating roller, produced at the circumference of the tyre during braking, opposes the force generated at the interface by the roller brake tester attempting to cause continuing rotation of the wheel.

3.1.4
total braking force
sum of the braking forces at all wheels of a vehicle

3.1.5
reference braking force
braking forces of each axle generated at the circumference of the tyre on a roller brake tester, relative to brake actuator pressure

3.1.6
braking force distribution
ratio between the braking force of each axle and the total braking force

3.1.7
total normal force
vertical force, corresponding to the total static mass on the axles of the vehicle

3.1.8
braking rate
z
ratio between the instantaneous deceleration of the vehicle, a, and the acceleration due to gravity, g, where only braking forces can be measured

$$z = \frac{a}{g}$$

NOTE 1 This ratio is not applicable to semi-trailers.

NOTE 2 Where a cannot be measured, the braking rate, z, is the ratio between the total braking force, F_f, and the total normal force, G_s, corresponding to the maximum loading vehicle weight.

3.1.9
roller brake tester
measuring machine consisting of two pairs of powered rollers used for the assessment of a vehicle's braking performance

3.1.10
guaranteed maximum cylinder pressure
pressure of the actuating fluid in the brake cylinder, resulting from full actuation of the brake pedal with the supply at the cut-in pressure

3.1.11
brake threshold pressure
brake chamber pressure at the intersection of brake force and pressure line (at force = 0 N) in the force–pressure diagram

3.2 Symbols

Symbol	Definition	Unit
a	instantaneous deceleration of vehicle	m/s^2
F_f	total braking force corresponding to maximum loading vehicle weight	N
$F_{f,min}$	total braking force needed to achieve z_{min}	N
F_{Ni}	braking force of axle i at cylinder pressure p_N needed to achieve z_{min}	N
F_{Ri}	braking force of axle i at cylinder pressure p_N [a]	N
$\sum F_{Ri}$	sum of all F_{Ri} on all axles	N
F_{RiPTI}	reference braking force of axle i suitable for PTI (i.e. at corresponding p_A level)	N
g	acceleration due to gravity	m/s^2
G_s	total normal force corresponding to maximum loading vehicle weight	N
p_A	brake actuator/cylinder pressure	kPa [b]
p_N	guaranteed maximum brake actuator/cylinder pressure	kPa [b]
p_{Ri}	brake actuator/cylinder pressure of axle i for calculated PTI value	kPa [b]
p_{0i}	brake threshold pressure of axle i	kPa [b]
z	braking rate	—
z_{min}	minimum demanded deceleration in relation to total normal force at PTI	—

a As declared by the manufacturer in accordance with UNECE Regulation No.13, paragraph 5.1.4.6.

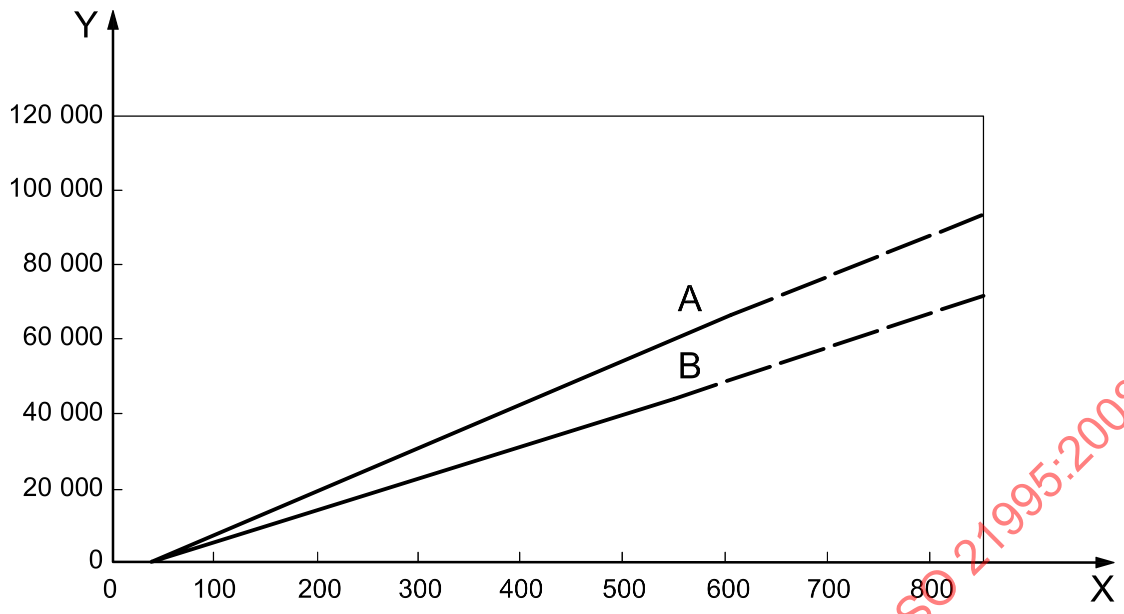
b 100 kPa = 1 bar.

4 Acquisition method

4.1 At type approval it is impossible to test every version of a particular vehicle range. Consequently, the vehicle manufacturer chooses a “worst case” vehicle to be covered on the type approval certificate. This means that the certificate will then include many variants of the tested vehicle, provided that they all have the same braking system.

In a Type 0 test, a modern heavy vehicle with an electronic braking system (EBS) and disc brakes normally achieves a deceleration of 6,0 m/s^2, whereas the minimum requirement is 5,0 m/s^2.

4.2 The brake force distribution involves both the static and dynamic brake force distribution. The static distribution is the result of the different dimensioning of the brakes at the different axles (e.g. different brake and actuating cylinder diameters). The dynamic distribution is the result of the brake pressure distribution adjustments during braking. The static distribution is theoretically constant in all situations (excluding the variation of the friction coefficient of brake pads, which is one of the parameters under assessment). This can be seen as the different gradient of the “brake force–cylinder pressure line” of the axles. The pressure distribution varies as a function of many factors (e.g. levels of deceleration and of loading). This is shown by the upper limit of the “brake force–cylinder pressure line” of the axles (see Figure 1).



Key

X cylinder pressure, in kPa

Y brake force, in N

NOTE Lines A and B illustrate how the gradient of the "brake force–cylinder pressure line" of the axles varies as a function of different factors.

Figure 1 — Static brake force distribution

In contrast to the identical gradient of the "brake force–cylinder pressure lines", the maximum cylinder pressures at the axles in a Type 0 test would be different in different vehicles with the same braking system. The manufacturer should therefore specify the reference braking forces described in UNECE Regulation No.13, paragraph 5.1.4.6, in order to cover the whole pressure range as generated under Type 0 conditions.

4.3 The purpose of the brake performance test at PTI is to verify that the vehicle achieves a minimum deceleration in relation to maximum static mass.

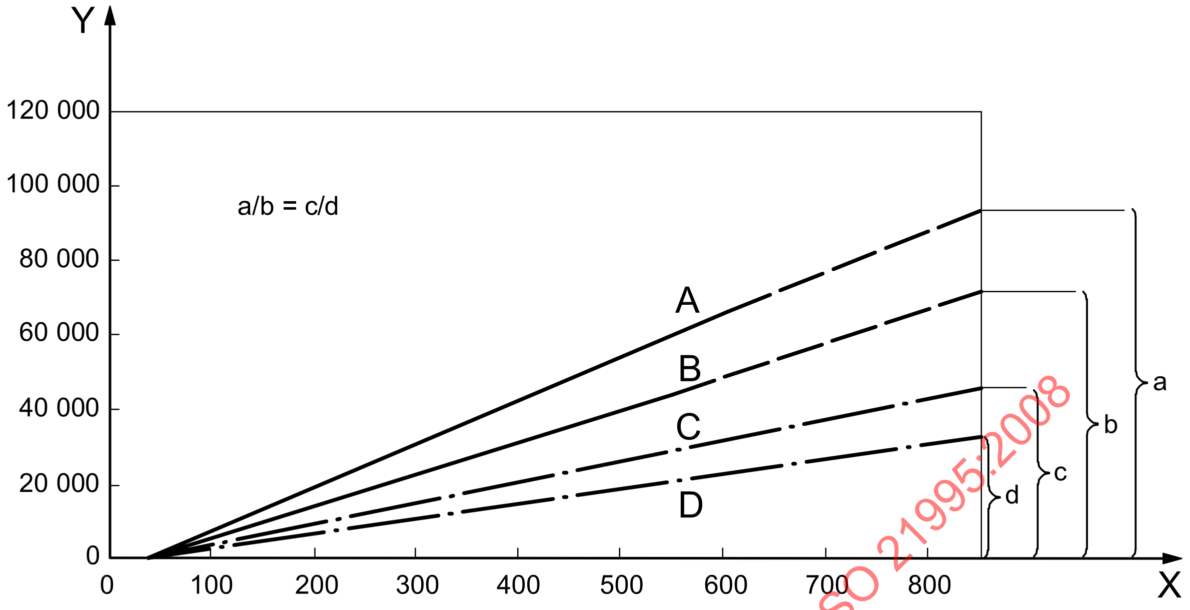
NOTE In the case of Council Directive 96/96/EC, this needs to be 4,5 m/s^2.

It is easy to calculate the total braking force $F_{\text{f,min}}$ needed to achieve this deceleration: the deceleration rate z_{min} (e.g. 0,45) needs to be multiplied by the force G_{s} corresponding to the total static mass on the axles of the vehicle (e.g. 180 kN for a vehicle with two axles and a maximum static mass of 18 t), as shown in Equation (1):

$$F_{\text{f,min}} = z_{\text{min}} \times G_{\text{s}} \tag{1}$$

Because the roller brake test is a series of single axle tests, the minimum total brake force, $F_{\text{f,min}}$, as calculated in Equation (1), shall be achieved by summing the axle braking forces.

It is reasonable to assume that the installed static brake force distribution for the Type 0 test (see a and b in Figure 2) is distributed in a similar way to the brake force in the lower level characteristics needed to satisfy the PTI requirements. Therefore, the calculation of reference values for PTI shall include the same proportion in the reduced brake performance from each axle (see c and d in Figure 2).



Key

X cylinder pressure, in kPa

Y brake force, in N

NOTE Lines A and B represent the installed static brake force distribution for the Type 0 test. Lines C and D indicate the reduced brake performance.

Figure 2 — Static brake force distribution showing reduced brake performance

4.4 It is therefore possible to calculate the braking force, F_{Ni}, of each axle needed to achieve the minimum demanded deceleration at PTI. This should be done using Equation (2):

$$F_{Ni} = \frac{F_{Ri} \times F_{f,min}}{\sum F_{Ri}} \tag{2}$$

where

F_{Ri} is the braking force of axle i at cylinder pressure p_N shown by the manufacturer;

$F_{f,min}$ is the total braking force needed to achieve z_{min};

$\sum F_{Ri}$ is the sum of all F_{Ri} on all axles.

F_{Ni} is the lowest force that should be reached at the guaranteed maximum cylinder pressure.

A linear equation that describes the PTI reference braking forces needs a second point of reference, which is given by the pressure at the increasing point of braking force.

The mathematical function given with the reference values of the manufacturer can be calculated for this point simply by using the mathematical equation for linear functions.

With these two points, it is possible to establish an equation that describes the reference braking forces for each axle of a vehicle corresponding to the minimum demanded deceleration level at PTI bases on the national regulation.

4.5 The following formulae use given reference values (F_{R1}, p_{R1}, F_{R2}, p_{R2}) which are points from one axle of the given values. F_{Ri} and p_{Ri} are points for the calculated PTI values.

$$F_{f,min} = z_{min} \times z$$

$$F_{f,min2} = \frac{F_{f,min} \times F_{R2}}{F_{R1} + F_{R2}}$$

$$F_{R1} = F_{f,min} - F_{R2}$$

$$F_{RiPTI} = \left(\frac{F_{R1} - F_{R2}}{p_{R1} - p_{R2}} \right) \times p_{RiPTI} + F_{R1} - \left(\frac{F_{R1} - F_{R2}}{p_{R1} - p_{R2}} \right) \times p_{R1} \qquad (3)$$

where

$F_{f,min1}$ is the minimum braking force needed to achieve z_{min} for the vehicle on the front axle;

$F_{f,min2}$ is the minimum braking force needed to achieve z_{min} for the vehicle on the rear axle;

F_{R1} is the front axle minimum brake force for PTI to achieve z_{min};

F_{R2} is the rear axle minimum brake force for PTI to achieve z_{min};

p_{RiPTI} is the reference break actuator/cylinder pressure of axle i suitable for PTI.

For special conditions, the formula in Equation (3) can be simplified.

For example, for the condition $\left[F_{R1} > F_{R2} \, ; p_{R1} > p_{R2} \right]$, if $F_{R2} = 0$, then F_{RiPTI} is derived from F_{R1}, as follows:

$$F_{RiPTI} = F_{R1} \times \left(1 + \frac{p_{RiPTI}}{p_{R1} - p_{R2}} - \frac{p_{R1}}{p_{R1} - p_{R2}} \right)$$

If $F_{R2} = 0$, then the corresponding value of p_{R2} is x_{Ri}, the pressure at the point of intersection with the brake force axle (for force = 0).

4.6 The general formula for calculating x_{Ri} is as shown in Equation (4):

$$x_{Ri} = \frac{F_{R1} - \left(\frac{F_{R1} - F_{R2}}{p_{R1} - p_{R2}} \right) \times p_{R1}}{-\left(\frac{F_{R1} - F_{R2}}{p_{R1} - p_{R2}} \right)} \qquad (4)$$

which can be simplified into:

$$x_{Ri} = p_{R1} - \frac{p_{R1} - p_{R2}}{\left(\frac{F_{R2}}{F_{R1}} \right) - 1}$$

For example, using Equation (4), if F_{R1} = 13 000 N, p_{R1} = 200 kPa, F_{R2} = 5 400 N and p_{R2} = 100 kPa, then x_{Ri} is calculated as follows:

$$x_{\mathrm{R}i} = \frac{F_{\mathrm{R1}} - \left(\dfrac{F_{\mathrm{R1}} - F_{\mathrm{R2}}}{p_{\mathrm{R1}} - p_{\mathrm{R2}}}\right) \times p_{\mathrm{R1}}}{-\left(\dfrac{F_{\mathrm{R1}} - F_{\mathrm{R2}}}{p_{\mathrm{R1}} - p_{\mathrm{R2}}}\right)}$$

$$= \frac{13\,000 - \left(\dfrac{13\,000 - 5\,400}{200 - 100}\right) \times 200}{-\left(\dfrac{13\,000 - 5\,400}{200 - 100}\right)}$$

$$= \frac{13\,000 - 76 \times 200}{-76}$$

$$= \frac{-2\,200}{-76}$$

$$= 28{,}95 \text{ kPa } (0{,}298\,5 \text{ bar})$$

By using the formula given in Equation (4), the given reference brake forces can be adjusted to reflect the national or international requirements for PTI of brake efficiency.

5 Use of reference values for testing on roller brake testers

For the purpose of PTI of braking systems, reference values may be used to validate the efficiency of the whole braking systems on roller brake testers. Each reference value is a combination of brake cylinder pressure and corresponding brake force at each axle. For each axle brake, specific values of braking force are generated within the pressure range 100 kPa (1 bar) to the upper limit equal to the Type 0 test pressure, e.g. in the range up to 450 kPa (4,5 bar). Within the PTI procedure, the mentioned pressure values will be applied at the brake cylinder while the axle is placed on the roller test bench. If the measured brake force at this pressure is equal to or higher than the value shown from the reference table or graph, the condition of the brakes is to fulfil the minimum requirement for PTI efficiency. No additional extrapolation or calculation is needed. To ensure sufficient accuracy, the measurement should be made at as high a pressure as possible, and certainly not below 200 kPa (2 bar), in order to avoid instability in the measurements.

6 Data acquisition and distribution by the vehicle manufacturers

Reference braking forces shall be determined for a brake actuator pressure range from 100 kPa (1 bar) to the pressure generated under Type 0 test conditions for each axle. The applicant for type approval shall nominate reference braking forces for a brake activator pressure range from 100 kPa (1 bar). These data shall be made available by the vehicle manufacturer. In accordance with UNECE Regulation No.13, paragraph 5.1.4.5.1, the data of the compressed air braking system for the functional and efficiency test shall be specified on the vehicle in a visible position in indelible form, or made freely available in another way (e.g. handbook, electronic data recording).

7 Documentation of results and evaluation

ISO 21069-1 gives some guidelines. When using reference values, other values are likely to be documented, i.e.

— minimum values, given by the vehicle manufacturer for this specific vehicle/axle/brake system;

— tyre type and brake system specific diameters, e.g. cylinder diameter, disc diameter as it is defined by the vehicle manufacturer;

— additional values, if given by general requirements from national authorities.

Annex A
(informative)

Examples

A.1 General

This annex gives examples of reference values, as well as the mathematical calculation to adapt these values to national requirements for PTI regulation.

A.2 Example reference values

The following reference values are used in the examples in this annex:

— truck: 18 t, 4 × 2;

— year of construction: March 2005;

— mileage: 9 500 km;

— front axle: brake chamber Type 24;

— rear axle: brake chamber Type 20;

— reference brake forces given by the vehicle manufacturer are as specified in Table A.1.

Table A.1 — Reference brake forces given by the vehicle manufacturer

Brake chamber pressure p_R kPa	**Brake force – front axle** (brake chamber Type 24) $F_{R,front}$ N	**Brake force – rear axle** (brake chamber Type 20) $F_{R,rear}$ N
100[a]	5 400[b]	4 300
150	9 200	7 500
200	13 000	10 700
250	16 850	13 850
300	20 650	17 050
350	24 450	20 250
400[c]	28 250	23 400
450	32 100	26 600
500	35 900	29 800
550	39 700	32 950
600	43 500	36 150
650	47 350	39 300
700	51 150	42 500
750	54 950	45 700
800	58 750	48 850
850	62 600	52 050
900	66 440	55 250
950[d]	70 200[e]	58 400

a p_{R2} = 100 kPa.

b F_{R2} = 5 400 N.

c p_{Ri} = 400 kPa.

d p_{R1} = 950 kPa.

e F_{R1} = 70 200 N.

A.3 Example calculation

The following example calculation of PTI values is based on the manufacturer reference values, in accordance with Clause 4.

NOTE The numerical values used in the following example calculation are taken from Table A.1.

$$F_{\text{f,min}} = z_{\text{min}} \times G_{\text{s}}$$

$$F_{\text{f,min}} = 0{,}45 \times 180\,000$$

$$\underline{F_{\text{f,min}} = 81\,000\ \text{N}}$$

$$F_{\text{R}i\text{PTI}} = \frac{F_{\text{R}i} \times F_{\text{fmin}}}{\sum F_{\text{R}i}}$$

$$F_{\text{R}i\text{PTI,front}} = \frac{70\,200 \times 81\,000}{70\,200 + 58\,400}$$

$$\underline{F_{\text{R}i\text{PTI,front}} = 44\,216\ \text{N}}$$

$$F_{\text{R}i\text{PTI,rear}} = F_{\text{f,min}} - F_{\text{R}i\text{PTI,front}}$$

$$F_{\text{R}i\text{PTI,rear}} = 81\,000 - 44\,216$$

$$\underline{F_{\text{R}i\text{PTI,rear}} = 36\,784\ \text{N}}$$

$F_{\text{R}i\text{PTI,front}}$ and $F_{\text{R}i\text{PTI,rear}}$ are the minimum requirements for the brake forces during PTI for the front axle and the rear axle, respectively, if the vehicle is fully laden and the guaranteed pressure is 950 kPa (9,5 bar).

Because the available data are only given beginning with 100 kPa (1 bar), the calculation needs to be done with a linear function down to the intersection with the theoretical zero line.

The calculated values are shown in Figure A.1.