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To:	Mr Uwe CORSEPIUS, Secretary-General of the Council of the European Union
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Delegations will find attached document C(2014) 7410 final - ANNEXES 8-13.

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ANNEXES 8 to 13

ANNEXES

to the

Commission Delegated Regulation (EU) No .../..
of XXX

supplementing Regulation (EU) No 167/2013 of the European Parliament and of the Council with regard to vehicle braking requirements for the approval of agricultural and forestry vehicles

ANNEX VIII

Requirements applying to the testing of inertia braking systems, braking devices and trailer braking couplings and of vehicles fitted with them as regards braking

1. General provisions

1.1. The inertia braking system of a towed vehicle comprises the control device, the transmission and the brake.

1.2. The control device is the aggregate of the components integral with the traction device (coupling head).

1.3. The transmission is the aggregate of the components comprised between the last part of the coupling head and the first part of the brake.

1.4. Braking systems in which accumulated energy (e.g. electric, pneumatic or hydraulic energy) is transmitted to the towed vehicle by the tractor and is controlled only by the thrust on the coupling do not constitute inertia braking systems within the meaning of this Regulation.

1.5. Tests

1.5.1. Determination of essential characteristics of the brake.

1.5.2. Determination of essential characteristics of the control device and verification of the conformity of the control device with the provisions of this Regulation.

1.5.3. Checking on the vehicle:

1.5.3.1. the compatibility of the control device and the brake; and

1.5.3.2. the transmission.

2. Symbols

2.1. Units used

2.1.1. Mass: kg;

2.1.2. Force: N;

2.1.3. Acceleration due to gravity: $g = 9.81\ m/s^2$

2.1.4. Torques and moments: Nm;

2.1.5. Areas: cm^2;

2.1.6. Pressures: kPa;

2.1.7. Lengths: unit specified in each case.

2.2. Symbols valid for all types of brakes (see Figure 1 of Appendix 1)

2.2.1. G_A: towed vehicle's technically permissible ‘maximum mass’ as declared by the manufacturer;

2.2.2. G'_A: towed vehicle's ‘maximum mass’ capable of being braked by the control device, as declared by the manufacturer;

2.2.3. G_B: towed vehicle's ‘maximum mass’ capable of being braked by joint operation of all of the towed vehicle's brakes

$$G_B = n \cdot G_{Bo} ;$$

2.2.4. G_{Bo}: fraction of towed vehicle's permissible maximum mass capable of being braked by one brake, as declared by the manufacturer;

2.2.5. B*: required braking force;

2.2.6. B: required braking force taking account of rolling resistance;

2.2.7. D*: permissible thrust on coupling;

2.2.8. D: thrust on coupling;

2.2.9. P': control device output force;

2.2.10. K: supplementary force of control device, conventionally designated by the force D corresponding to the point of intersection with the axis of the abscissae of the extrapolated curve expressing P' in terms of D, measured with the device in the mid-travel position (see Figures 2 and 3 of Appendix 1);

2.2.11. K_A: force threshold of control device, i.e., the maximum thrust on the coupling head which can be applied for a short period of time without generating an output force from the control device. The symbol K_A is conventionally applied to the force measured when the coupling head begins to be pushed home at a speed of 10 to 15 mm/s, the control device transmission being uncoupled;

2.2.12. D_1: the maximum force applied to the coupling head when it is being pushed home at a speed of s mm/s + 10% , the transmission being uncoupled;

2.2.13. D_2: the maximum force applied to the coupling head when it is being pulled at a speed of s mm/s + 10% out of the position of maximum compression, the transmission being uncoupled;

2.2.14. η_{Ho}: efficiency of inertia control device;

2.2.15. η_{H1}: efficiency of transmission system;

2.2.16. η_H: overall efficiency of control device and transmission $\eta H = \eta Ho.\eta H_1$;

2.2.17. s: travel of control device in millimetres;

2.2.18. s': effective (useful) travel of control device in millimetres, determined in the test report;

2.2.19. s": spare travel of master cylinder, measured in millimetres at coupling head;

2.2.19.1. s_{Hz}: stroke of the master cylinder in millimetres according to Figure 8 of Appendix 1;

2.2.19.2. $s"_{Hz}$: spare travel of the master cylinder in millimetres at piston rod, according to Figure 8 of Appendix 1;

2.2.20. s_o: loss of travel, i.e., travel in millimetres of the coupling head when the latter is so actuated as to move from 300 mm above to 300 mm below the horizontal, the transmission remaining stationary;

2.2.21. $2s_B$: brake-shoe lift (brake-shoe application travel), in millimetres, measured on diameter parallel to applying device, the brakes not being adjusted during the test;

2.2.22. $2s_B$*: minimum brake shoe centre lift (minimum brake shoe application travel) (in millimetres) for wheel brakes with drum brakes

$$2s_{B^*} = 2.4 + \frac{4}{1000} . 2r;$$

2r being the diameter of the brake drum in millimetres (see Figure 4 of Appendix 1).

$$2s_B^* = 1.1 . \frac{10 . V_{60}}{F_{RZ}} + \frac{1}{1000} . 2r_A$$

For wheel brakes with disc brakes with hydraulic transmission

Where:

V_{60} = fluid volume absorbed by one wheel brake at a pressure corresponding to a braking force of $1.2\ B^* = 0.6 \cdot G_{Bo}$ and a maximum tyre radius;

and

$2r_A$ = outer diameter of brake disc (V_{60} in cm^3, F_{RZ} in cm^2 and r_A in mm).

2.2.23. M*: braking torque as specified by the manufacturer in point 5. of Appendix 3 of this Annex. This braking torque shall produce at least the prescribed braking force B*;

2.2.23.1. M_T: test braking torque in the case where no overload protector is fitted (according to point 6.2.1.);

2.2.24. R: dynamic tyre rolling radius (m), as specified by the tyre manufacturer. As an alternative, if such information is not available, the value calculated by the formula: "ETRTO overall diameter /2" may be used;

2.2.25. n: number of brakes.

2.2.26. M_r: maximum braking torque resulting from the maximum permissible travel s_r or the maximum permissible fluid volume V_r when the towed vehicle moves rearward (including rolling resistance = $0.01 \cdot g \cdot G_{Bo}$);

2.2.27. s_r: maximum permissible travel at the brake control lever when the towed vehicle moves rearward;

2.2.28. V_r: maximum permissible fluid volume absorbed by one braking wheel when the towed vehicle moves rearward;

2.3. Symbols valid for mechanical-transmission braking systems (see Figure 5 of Appendix 1);

2.3.1. i_{Ho}: reduction ratio between travel of coupling head and travel of lever at output side of control device;

2.3.2. i_{H1}: reduction ratio between travel of lever at output side of control device and travel of brake lever (gearing down of transmission);

2.3.3. i_H: reduction ratio between travel of coupling head and travel of brake lever

$$i_H = i_{Ho}.i_{H1}$$

2.3.4. i_g: reduction ratio between travel of brake lever and lift (application travel) at brake-shoe centre (see Figure 4 of Appendix 1);

2.3.5. P: force applied to the brake control lever; (see Figure 4 of Appendix 1);

2.3.6. P_o:brake-retraction force when the towed vehicle moves forward, i.e., in graph M = f(P), the value of the force P at the point of intersection of the extrapolation of this function with the abscissa (see Figure 6 of Appendix 1);

2.3.6.1. P_{or}: brake-retraction force when the towed vehicle moves rearward (see Figure 6 of Appendix 1);

2.3.7. P*: force applied to the brake control lever to produce the braking force B*;

2.3.8. P_T: test force according to point 6.2.1;

2.3.9. ρ: characteristic of the brake when the towed vehicle moves forward as defined from:

$$M = \rho (P - P_o)$$

2.3.9.1. ρ_r: characteristic of the brake when the towed vehicle moves rearward as defined from:

$$M_r = \rho_r (P_r - P_{or})$$

2.3.10. s_{cf}: rear cable or rod travel at compensator when brakes operate in forward direction[1];

[1] Points 2.3.10., 2.3.11. and 2.3.12. only apply to the parking braking system differential travel calculation method.

2.3.11. s_{cr}: rear cable or rod travel at compensator when brakes operate in rearward direction[1];

2.3.12. s_{cd}: differential travel at compensator when only one brake operates in the forward direction and the other in the reverse direction[1];

Where: $s_{cd} = s_{cr} - s_{cf}$ (see Figure 5A of Appendix 1);

2.4. Symbols valid for hydraulic-transmission braking systems (see Figure 8 of Appendix 1)

2.4.1. i_h: reduction ratio between travel of coupling head and travel of piston in master cylinder;

2.4.2. i'_g: reduction ratio between travel of cylinder thrust point and lift (application travel) of brake-shoe centre;

2.4.3. F_{RZ}: surface area of piston of one wheel cylinder for drum brake(s); for disc brake(s), sum of the surface area of the caliper piston(s) on one side of the disc;

2.4.4. F_{HZ}: surface area of piston in master cylinder;

2.4.5. p: hydraulic pressure in brake cylinder;

2.4.6. p_o: retraction pressure in the brake cylinder when the towed vehicle moves forward; i.e., in graph of M = f(p), the value of the pressure p at the point of intersection of the extrapolation of this function with the abscissa (see Figure 7 of Appendix 1);

2.4.6.1. p_{or}: brake retraction pressure when the towed vehicle moves rearward (see Figure 7 of Appendix 1);

2.4.7. p*: hydraulic pressure in the brake cylinder to produce the braking force B*;

2.4.8. p_T: test pressure according to point 6.2.1.:

2.4.9. ρ': characteristic of the brake when the towed vehicle moves forward as defined from:

$$M = \rho' (p - p_o)$$

2.4.9.1. ρ'_r: characteristic of the brake when the towed vehicle moves rearward as defined from:

$$M_r = \rho'_r (p_r - p_{or})$$

2.5. Symbols with respect to the braking requirements relating to overload protectors

2.5.1. D_{op}: application force at the input side of the control device, at which the overload protector is activated

2.5.2. M_{op}: brake torque at which the overload protector is activated (as declared by the manufacturer)

2.5.3. M_{Top}: minimum test braking torque in the case when an overload protector is fitted (according to point 6.2.2.2.).

2.5.4. P_{op}_min: force applied to the brake at which the overload protector is activated (according to point 6.2.2.1.).

2.5.5. P_{op}_max: maximum force (when the coupling head is pushed fully home) which is applied by the overload protector to the brake (according to point 6.2.2.3.).

2.5.6. p_{op}_min: pressure applied to the brake at which the overload protector is activated (according to point 6.2.2.1.).

2.5.7. p_{op}_max: maximum hydraulic pressure (when the coupling head is pushed fully home) which is applied by the overload protector to the brake actuator (according to point 6.2.2.3.).

2.5.8. P_{Top}: minimum test brake force in the case when an overload protector is fitted (according to point 6.2.2.2.).

2.5.9. p_{Top}: minimum test brake pressure in the case when an overload protector is fitted (according to point 6.2.2.2.).

2.6 Types of vehicle classes with regard to inertia braking systems

2.6.1. Vehicle Class A

Vehicle Class A means vehicles of categories R1, R2 and S1

2.6.2. Vehicle Class B

Vehicle Class B means vehicles with a mass exceeding 3,500 kg and not exceeding 8000 kg of categories R3 and S2

2.6.3. Vehicle Class C

Vehicle Class C1 means vehicles of categories R and S with maximum design speed not exceeding 30 km/h

Vehicle Class C2 means vehicles of categories R and S with maximum design speed not exceeding 40 km/h

Vehicle Class C3 means vehicles of categories R and S with maximum design speed exceeding 40 km/h

3. General requirements

3.1. The transmission of force from the coupling head to the towed vehicle's brakes shall be effected either by rod linkage or by one or more fluids. However, a sheathed cable (Bowden cable) may provide part of the transmission; this part shall be as short as possible. The control rods and cables shall not contact the towed vehicle frame or other surfaces that may affect the application or release of the brake.

3.2. All bolts at joints shall be adequately protected. In addition, these joints shall be either self-lubricating or readily accessible for lubrication.

3.3. Inertia braking devices shall be so arranged that in the case when the coupling head travels to its fullest extent, no part of the transmission seizes, undergoes permanent distortion, or breaks. This shall be checked by uncoupling the end of the transmission from the brake control levers.

3.4. The inertia braking system shall allow the towed vehicle to be reversed with the tractor without imposing a sustained drag force exceeding $0.08\ g \cdot G_A$. Devices used for this purpose shall act automatically and disengage automatically when the towed vehicle moves forward.

3.5. Any special device incorporated for the purpose of point 3.4. shall be such that the parking performance when facing up a gradient shall not be adversely affected.

3.6. Inertia braking systems may incorporate overload protectors. They shall not be activated at a force of less than $D_{op} = 1.2 \cdot D^*$ (when fitted at the control device) or at a force of less than $P_{op} = 1.2 \cdot P^*$ or at a pressure of less than pop = $1.2 \cdot p^*$ (when fitted at the brake) where the force P* or the pressure p* corresponds to a braking force of $B^* = 0{,}5 \cdot g \cdot G_{Bo}$ (in the case of Classes C2 and C3 vehicles) and $B^* = 0.35 \cdot g \cdot G_{Bo}$ (in the case of Class C1 vehicles).

4. Requirements for control devices

4.1. The sliding members of the control device shall be long enough to enable the full travel to be used even when the towed vehicle is coupled.

4.2. The sliding members shall be protected by a bellows or some equivalent device. They shall either be lubricated or be constructed of self-lubricating materials. The surfaces in frictional contact shall be made of a material such that there is neither electrochemical torque nor any mechanical incompatibility liable to cause the sliding members to seize.

4.3. The stress threshold (K_A) of the control device shall be not less than $0.02\ g \cdot G'_A$ and not more than $0.04\ g \cdot G'_A$. However, in the case of classes C1 and C2 vehicles the stress threshold (K_A) of the control device may be in the range between $0.01\ g \cdot G'_A$ and $0.04\ g \cdot G'_A$.

4.4. The maximum insertion force D_1 shall not exceed $0.10\ g \cdot G'_A$ in rigid drawbar towed vehicles and centre-axle towed vehicles and $0.067\ g \cdot G'_A$ in multi-axled drawbar towed vehicles.

4.5. The maximum tractive force D_2 shall be not less than $0.1\ g \cdot G'_A$ and not more than $0.5\ g \cdot G'_A$.

In the case of vehicles of class B, also the condition $D_2 \geq 1750\ N + 0.05\ g \cdot G'_A$ is permitted as long as $D_2 \leq 0.5\ g \cdot G'_A$.

5. Tests and measurements to be carried out on the control devices

5.1. Control devices submitted to the Technical Service conducting the tests shall be checked for conformity with the requirements laid down in points 3. and 4.

5.2. The following shall be measured in respect of all types of brakes:

5.2.1. Travel s and effective travel s';

5.2.2. Supplementary force K;

5.2.3. Force threshold K_A;

5.2.4. Insertion force D_1;

5.2.5. Tractive force D_2.

5.3. In the case of mechanical-transmission inertia braking systems, the following should be determined:

5.3.1. The reduction ratio i_{Ho} measured at the mid-travel position of the control;

5.3.2. The control-device output force P' as a function of the thrust D on the drawbar;

the supplementary force K and the efficiency are derived from the representative curve obtained

$$\eta_{H0} = \frac{1}{i_{H0}} \cdot \frac{P'}{D - K}$$

from these measurements

(see Figure 2 of Appendix 1).

5.4. In the case of hydraulic-transmission inertia braking systems, the following shall be determined:

5.4.1. The reduction ratio i_h measured at the mid-travel position of the control device;

5.4.2. The master cylinder output pressure p as a function of the thrust D on the drawbar and of the surface area F_{HZ} of the master-cylinder piston, as specified by the manufacturer; the supplementary force K and the efficiency are derived from the representative curve

$$\eta_{H0} = \frac{1}{i_h} \cdot \frac{p \cdot F_{HZ}}{D - K}$$

obtained from these measurements

(see Figure 3 of Appendix 1);

5.4.3. The spare travel of the master cylinder s", as referred to in point 2.2.19.;

5.4.4. Surface area F_{HZ} of the piston in the master cylinder;

5.4.5. Stroke s_{Hz} of the master cylinder (in millimetres);

5.4.6. Spare travel s''_{Hz} of the master cylinder (in millimetres).

5.5. In the case of inertia braking system on multi-axled drawbar towed vehicles, the loss of travel s_o referred to in the test report shall be measured.

6. Requirements for brakes

6.1. In addition to the brakes to be checked, the manufacturer shall submit to the Technical Service conducting the tests, drawings of the brakes showing the type, dimensions and material of the essential components and the make and type of the linings. In the case of hydraulic brakes, these drawings shall show the surface area F_{RZ} of the brake cylinders. The manufacturer shall also specify the braking torque M* and the mass G_{Bo} specified in point 2.2.4.

6.2. Testing conditions

6.2.1. In the case when an overload protector is neither fitted nor intended to be fitted within the inertia braking system, the wheel brake shall be tested with the following test forces or pressures:

$P_T = 1.8\ P^*$ or $p_T = 1.8\ p^*$ and $M_T = 1.8\ M^*$ as appropriate.

6.2.2. In the case when an overload protector is fitted or intended to be fitted within the inertia braking system, the wheel brake shall be tested with the following test forces or pressures:

6.2.2.1. The minimum design values for an overload protector shall be specified by the manufacturer and shall not be less than

$P_{op} = 1.2\ P^*$ or $p_{op} = 1.2\ p^*$

6.2.2.2. The ranges of minimum test force P_{Top} or minimum test pressure p_{Top} and the minimum test torque M_{Top} are:

$P_{Top} = 1.1$ to $1.2\ P^*$ or $p_{Top} = 1.1$ to $1.2\ p^*$

and

$M_{Top} = 1.1$ to $1.2\ M^*$

6.2.2.3. The maximum values (P_{op}_max or p_{op}_max) for the overload protector shall be specified by the manufacturer and shall not be more than P_T or p_T respectively.

7. Tests and measurements to be carried out on the brakes

7.1. Brakes and components submitted to the Technical Service conducting the tests shall be tested for conformity with the requirements of point 6.

7.2. The following should be determined:

7.2.1. The minimum brake-shoe lift (minimum brake-shoe application travel), $2s_B^*$;

7.2.2. The brake-shoe centre lift (brake-shoe application travel) $2s_B$ (which shall be greater than $2s_B^*$);

7.3. In the case of mechanical brakes, the following shall be determined:

7.3.1. Reduction ratio i_g (see Figure 4 of Appendix 1);

7.3.2. Force P* for braking torque M*;

7.3.3. Torque M* as a function of the force P* applied to the control lever in mechanical-transmission systems.

The rotational speed of the braking surfaces shall correspond to an initial vehicle speed of 30 km/h in the case of Class C1 vehicle, 40 km/h in the case of Class C2 vehicle, 60 km/h in the case of Class C3 vehicle, when the towed vehicle moves forward and 6 km/h when the towed vehicle moves rearward. The following shall be derived from the curve obtained from these measurements (see Figure 6 of Appendix 1):

7.3.3.1. The brake-retraction force Po and the characteristic value ρ when the trailer moves forward;

7.3.3.2. The brake-retraction force P_{or} and the characteristic value ρ_r when the towed vehicle moves rearward;

7.3.3.3. Maximum braking torque M_r up to the maximum permissible travel s_r when the towed vehicle moves rearward (see Figure 6 of Appendix 1);

7.3.3.4. Maximum permissible travel at the brake control lever when the towed vehicle moves rearward (see Figure 6 of Appendix 1).

7.4. In the case of hydraulic brakes, the following shall be determined:

7.4.1. Reduction ratio i_g' (see Figure 8 of Appendix 1)

7.4.2. Pressure p* for braking torque M*

7.4.3. Torque M* as a function of the pressure p* applied to the brake cylinder in hydraulic transmission systems.

The rotational speed of the braking surfaces shall correspond to an initial vehicle speed of 30 km/h in the case of Class C1 vehicle, 40 km/h in the case of Class C2 vehicle, 60 km/h in the case of Class C3 vehicle, when the towed vehicle moves forward and 6 km/h when the towed vehicle moves rearward. The following shall be derived from the curve obtained from these measurements (see Figure 7 of Appendix 1):

7.4.3.1. The retraction pressure p_o and the characteristic ρ' when the towed vehicle moves forward;

7.4.3.2. The retraction pressure p_{or} and the characteristic ρ'_r when the towed vehicle moves rearward;

7.4.3.3. Maximum braking torque M_r up to the maximum permissible fluid volume V_r when the towed vehicle moves rearward (see Figure 7 of Appendix 1);

7.4.3.4. Maximum permissible fluid volume V_r absorbed by one braking wheel when the towed vehicle moves rearward (see Figure 7 of Appendix 1).

7.4.4. Surface area F_{RZ} of the piston in the brake cylinder.

7.5. Alternative procedure for the Type-I test

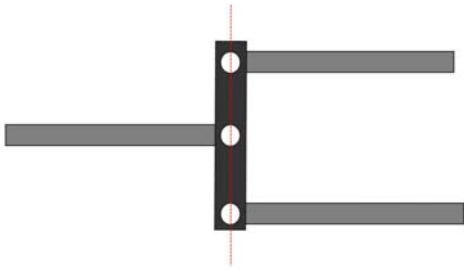
7.5.1. The Type-I test according to Annex II, point 2.3. does not have to be carried out on a vehicle submitted for type approval, if the braking system components are tested on an inertia test bench to meet the prescriptions of Annex II, points 2.3.2. and 2.3.3.

7.5.2. The alternative procedure for the Type-I test shall be carried out in accordance with the provisions laid down in Annex VII, Appendix 1, point 3.5.2. (in analogy also applicable for disc brakes).

8. Simulated gradient parking braking system force differential

8.1. Calculation method

8.1.1. The pivot points in the compensator shall lie in a straight line with the park brake at the rest position.



All compensator pivots to be in-line

Alternative arrangements can be used, if they provide equal tension in both rear cables, even when there are differences in travel between the rear cables.

8.1.2. Drawing details are to be provided to demonstrate that the compensator articulation is sufficient to ensure equal cable tension is applied to each of the rear cables. The compensator needs to have sufficient distance across the width to facilitate the differential travels left to right. The jaws of the yokes also need to be deep enough relative to their width to make sure that they do not prevent articulation when the compensator is at an angle.

Differential travel at compensator (s_{cd}) shall be derived from:

$$s_{cd} \geq 1.2 \cdot (S_{cr} - S_c')$$

Where:

$S_c' = S'/i_H$ (travel at compensator - forward operation) and $S_{c'} = 2 \cdot S_B/i_g$

$S_{cr} = S_r/i_H$ (travel at compensator - rearward operation)

9. Test reports

Applications for the approval of towed vehicles equipped with inertia braking systems shall be accompanied by the test reports relating to the control device and the brakes and the test report on the compatibility of the inertia type control device, the transmission

device and the brakes of the towed vehicle, these reports including at least the particulars prescribed on the basis of Article 27 (1) of Regulation (EU) 167/2013.

10. Compatibility between the control device and the brakes of a vehicle

10.1. A check shall be made on the vehicle to verify in the light of the characteristics of the control device, the characteristics of which are mentioned in the test report, the characteristics of the brakes mentioned in the test report and the towed vehicle characteristics referred to in the test report, whether the towed vehicle's inertia braking system meets the prescribed requirements.

10.2. General checks for all types of brakes

10.2.1. Any parts of the transmission not checked at the same time as the control device or the brakes shall be checked on the vehicle. The results of the check shall be entered in the test report (e.g., i_{H1} and η_{H1}).

10.2.2. Mass

10.2.2.1. The maximum mass G_A of the towed vehicle shall not exceed the maximum mass G'_A for which the control device is authorized.

10.2.2.2. The maximum mass G_A of the towed vehicle shall not exceed the maximum mass G_B which can be braked by joint operation of all of the towed vehicle's brakes.

10.2.3. Forces

10.2.3.1. The force threshold K_A shall not be below 0.02 g · G_A and not above 0.04 g · G_A.

10.2.3.2. The maximum insertion force D_1 may not exceed 0.10 g · G_A in rigid drawbar towed vehicles and centre-axle towed vehicles and 0.067 g · G_A in multi-axled drawbar towed vehicles.

10.2.3.3. The maximum tractive force D_2 shall be between 0.1 g · G_A and 0.5 g · G_A.

10.3. Check of braking efficiency

10.3.1. The sum of the braking forces exerted on the circumference of the towed vehicle wheels shall not be less than B* = 0.50 g · GA (in the case of Classes C2 and C3 vehicles) and B* = 0.35 · g · G_A (in the case of Class C1 vehicles), including a rolling resistance of 0.01 g · GA: this corresponds to a braking force B of 0.49 g · GA (in the case of Classes C2 and C3 vehicles) and B* = 0.34 · g · G_A (in the case of Class C1 vehicles). In this case, the maximum permissible thrust on the coupling shall be:

D* = 0.067 g · GA in the case of multi-axled drawbar towed vehicles;

and

D* = 0.10 g · GA in the case of rigid drawbar towed vehicles and centre-axle towed vehicles.

To check whether these conditions are complied with the following inequalities shall be applied:

$$\left[\frac{B.R}{\rho} + n\,P_o\right]\frac{1}{(D^* - K).\eta_H} \leq i_H$$

10.3.1.1. In mechanical-transmission inertia braking systems:

$$\left[\frac{B.R}{n.\rho'} + p_o\right]\frac{1}{(D^* - K).\eta_H} \leq \frac{i_h}{F_{HZ}}$$

10.3.1.2. In hydraulic-transmission inertia braking systems:

10.4. Check of control device travel

10.4.1. In control devices for multi-axled drawbar towed vehicles where the brake rod linkage depends on the position of the towing device, the control device travel s shall be longer than the effective (useful) control device travel s', the difference being at least equivalent to the loss of travel s_o. The travel loss of s_o shall not exceed 10 per cent of the effective travel s'.

10.4.2. The effective (useful) travel of control device s' shall be determined for single and multi-axle towed vehicles as follows:

10.4.2.1. If the brake rod linkage is affected by the angular position of the towing device, then:

$$s' = s - s_o;$$

10.4.2.2. If there is no loss of travel, then:

$$s' = s;$$

10.4.2.3. In hydraulic braking systems:

$$s' = s - s''.$$

10.4.3. The following inequalities shall be applied to check whether control device travel is adequate;

10.4.3.1. In mechanical-transmission inertia braking systems:

$$i_H \leq \frac{s'}{s_{B^*} \cdot i_g}$$

10.4.3.2. in hydraulic-transmission inertia braking systems:

$$\frac{i_h}{F_{HZ}} \leq \frac{s'}{2 s_{B^*} . nF_{RZ} . i'_g}$$

10.5. Additional checks

10.5.1. In mechanical-transmission inertia braking systems a check shall be made to verify that the rod linkage by which the forces are transmitted from the control device to the brakes is correctly fitted.

10.5.2. In hydraulic-transmission inertia braking systems a check shall be made to verify that the travel of the master cylinder is not less than s/i_h. A lower level shall not be permitted.

10.5.3. The general behaviour of the vehicle when braking shall be the subject of a road test carried out at different road speeds with different levels of brake effort and rates of application. Self-excited, undamped oscillations shall not be permitted.

11. General comments

The above requirements apply to the most usual embodiments of mechanical-transmission or hydraulic-transmission inertia braking systems where, in particular, all of the towed vehicle's wheels are equipped with the same type of brake and the same type of tyre. For checking less usual embodiments, the above requirements shall be adapted to the circumstances of the particular case.

Appendix 1

Explanatory diagrams

Figure 1

Symbols valid for all types of brakes

(See point 2.2. of this Annex)

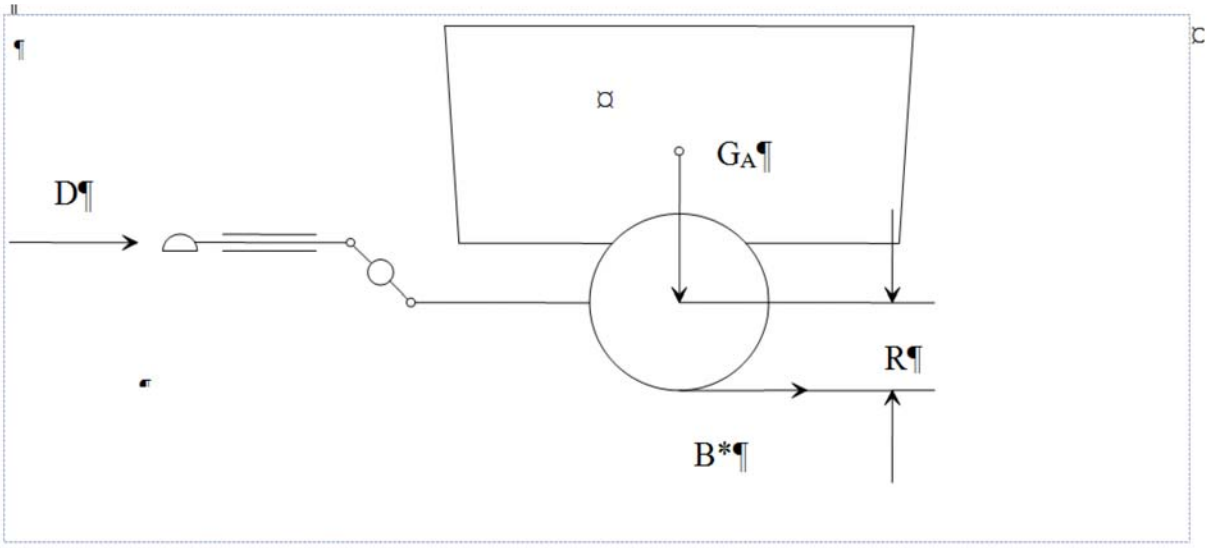
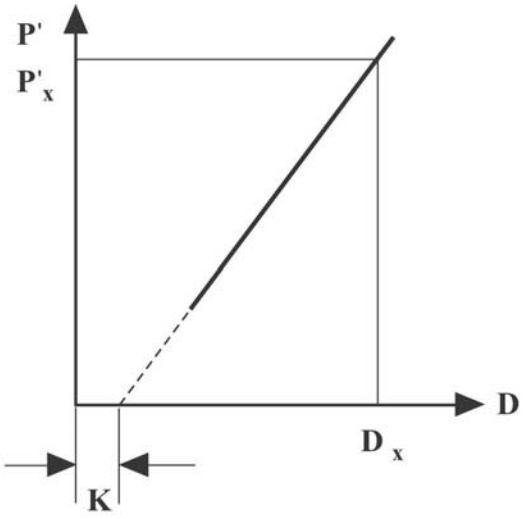


Figure 2

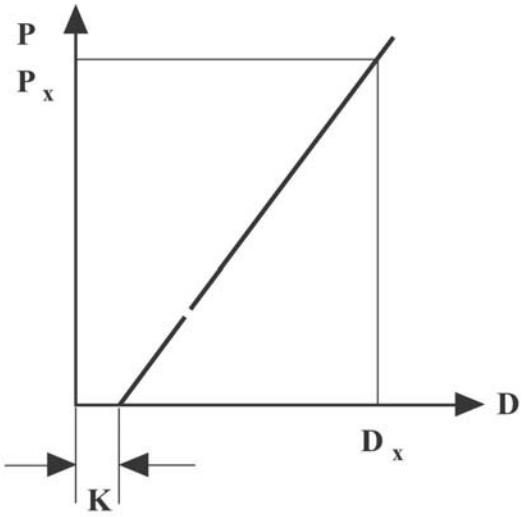
Mechanical-transmission

(See points 2.2.10. and 5.3.2. of this Annex)



$$\eta_{H0} = \frac{P'x}{D_x - K} \cdot \frac{1}{i_{HO}}$$

Figure 3
Hydraulic-transmission
(See points 2.2.10. and 5.4.2. of this Annex)



$$\eta_{H0} = \frac{Px}{D_x - K} \cdot \frac{F_{Hz}}{i_H}$$

Figure 4

Brake checks

(See point 2.2.22. and 2.3.4. of this Annex)

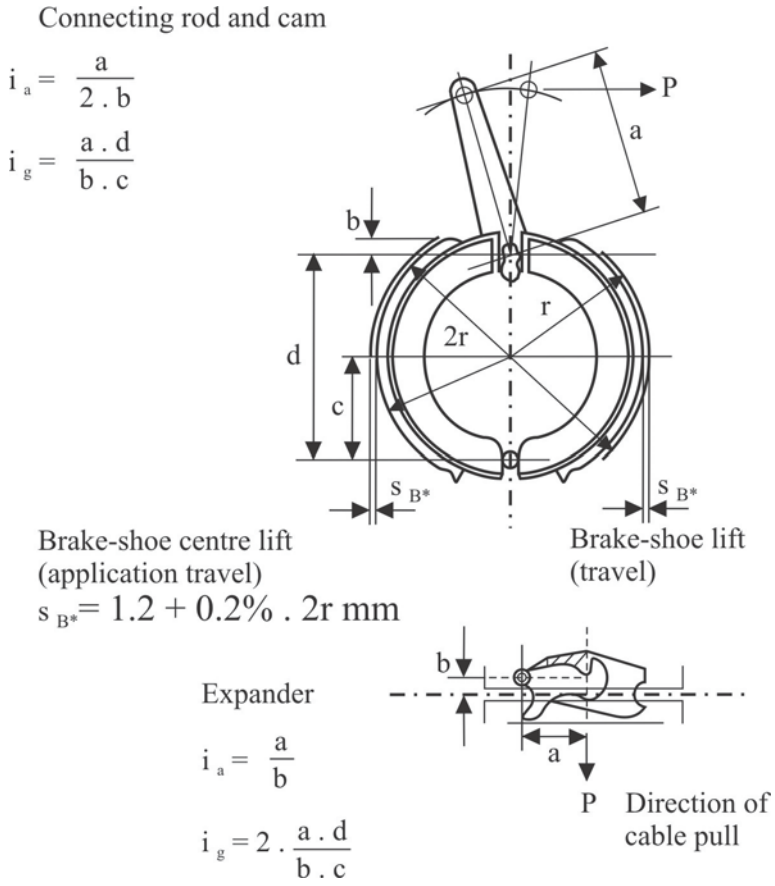


Figure 5

Mechanical -transmission braking system

(See point 2.3. of this Annex)

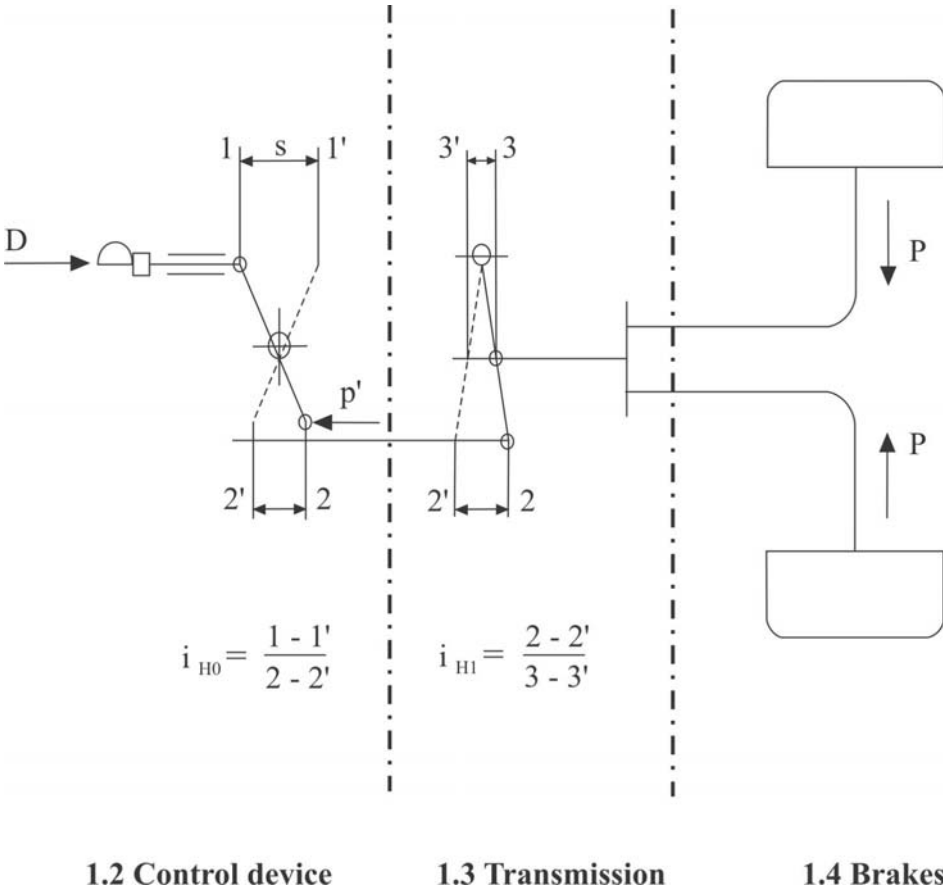
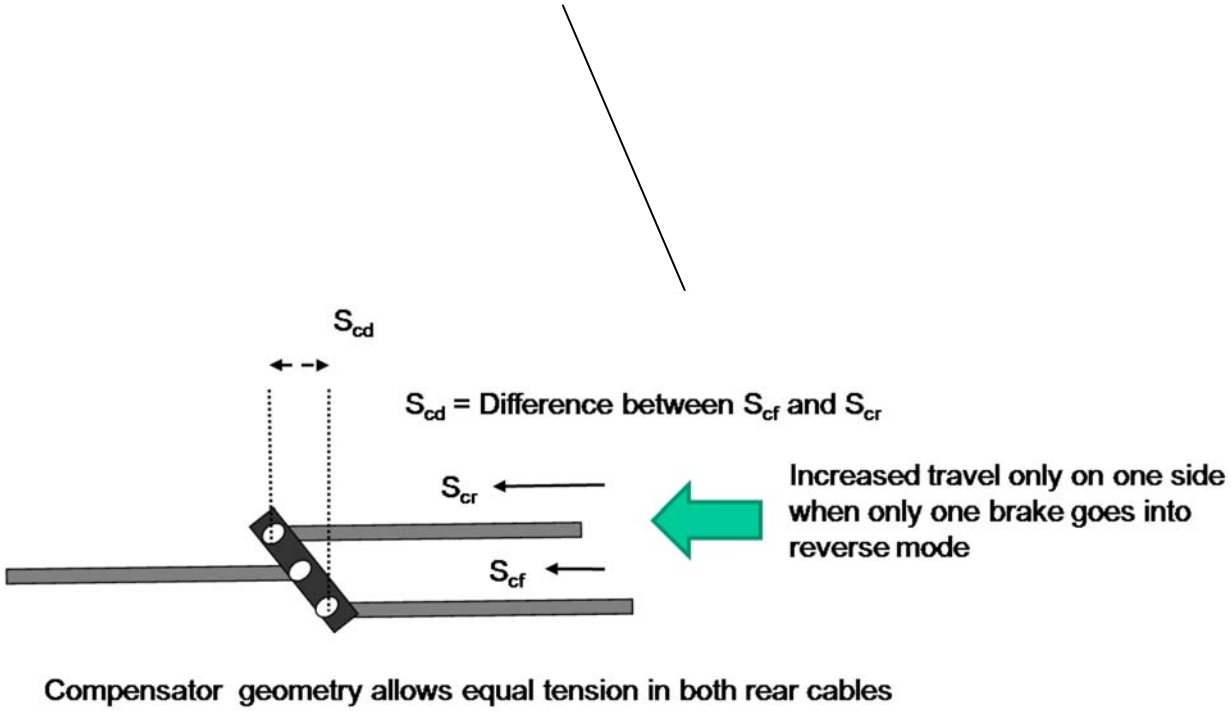
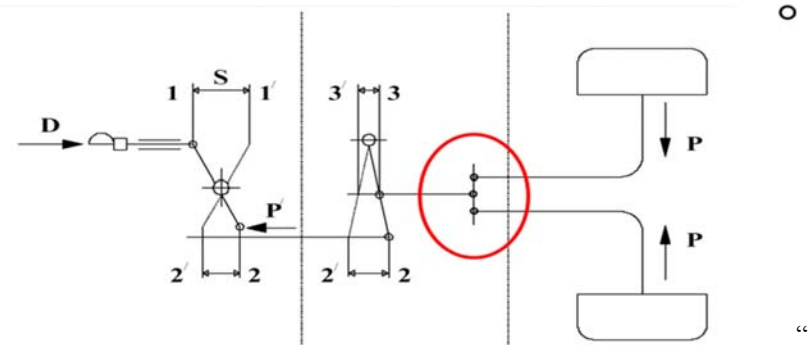


Figure 5A

Mechanical-transmission braking system

(See point 2.3. of this Annex)





"

Figure 6

Mechanical Brake

(see point 2. of this Annex)

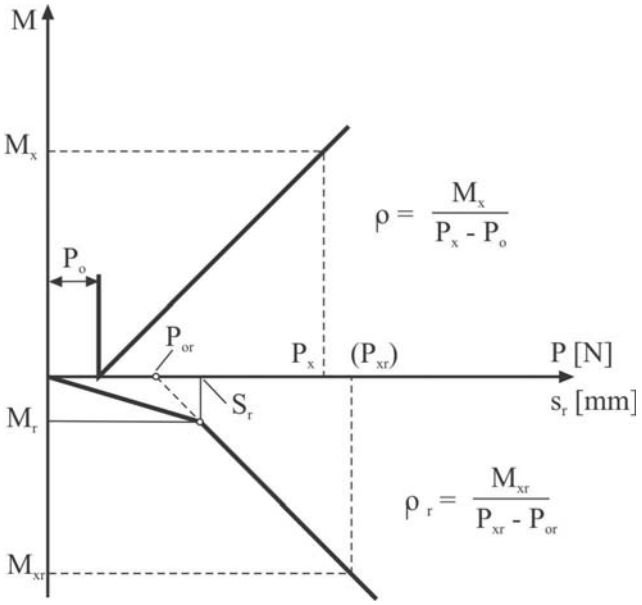


Figure 7

Hydraulic Brake

(See point 2. of this Annex)

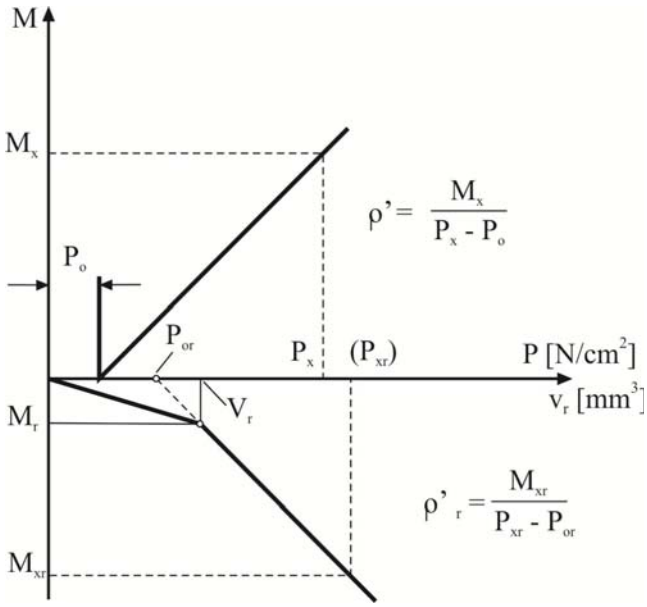
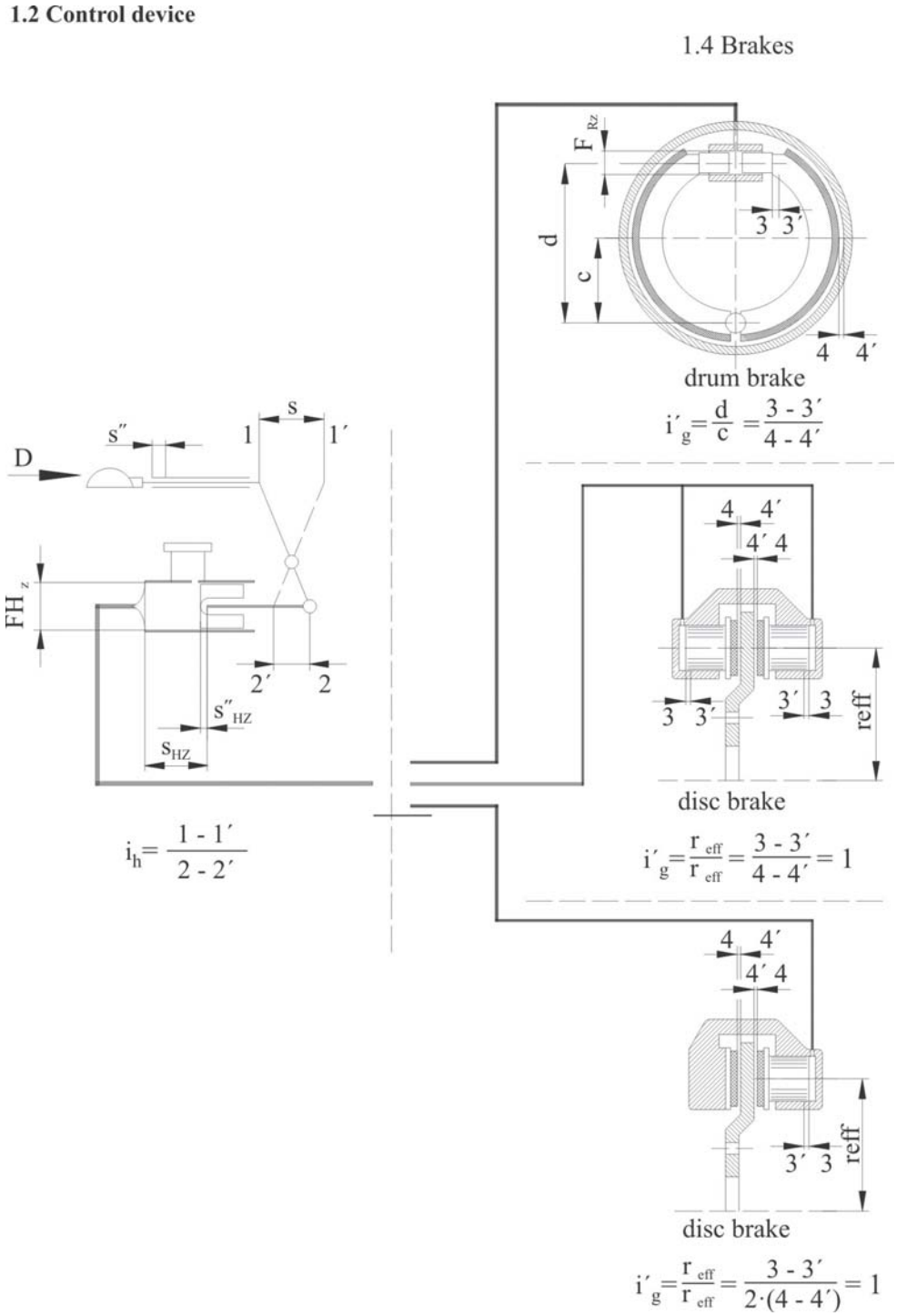


Figure 8

Hydraulic-Transmission Braking System

(See point 2. of this Annex)



ANNEX IX
Requirements applying to vehicles with hydrostatic drive and their braking devices and braking systems

1. Definitions

For the purposes of this Annex:

1.1. ‘hydrostatic braking system’ means a braking system (either as a service and/or secondary braking system) that only uses the braking power of the hydrostatic drive;

1.2. ‘combination hydrostatic braking system’ means a braking system utilising both, the hydrostatic and friction braking effect, where, however, the braking forces are generated by a predominant braking proportion generated by the hydrostatic drive. The minimum prescribed proportion of the friction brake on the braking effect is specified in point 6.3.1.1.;

1.3. ‘combination friction braking system’ means a braking system utilising both, the friction and hydrostatic braking effect, where, however, the braking forces are generated by a predominant braking proportion generated by the friction brakes. The minimum prescribed proportion of the friction brake on the braking effect is specified in point 6.3.1.2.;

1.4. ‘friction braking system’ means a braking system where the braking forces are generated only by the friction brakes without taking into account of the braking effect of the hydrostatic braking system;

1.5. ‘graduated hydrostatic braking’ means the hydrostatic braking through which the driver is able to increase or decrease the vehicle speed at any time by a progressive action on its control device.

1.6. ‘hydrostatic drive control device’ which means a device, such as a lever or pedal, used to vary the vehicle speed.

1.7. ‘service brake control device’ means the control device by whose operation the prescribed service braking performance is attained;

1.8. ‘inch device’ means the device that affects the speed of the vehicle independently of the hydrostatic drive control.

2. Scope

This Annex applies to vehicles with maximum design speed up to 40 km/h, equipped with a hydrostatic drive which cannot be disengaged during travel and is declared by the vehicle manufacturer to act as a braking system or braking device which may be either:

2.1. a service braking system and a secondary braking system or one of those two systems. A service braking system may be one of the braking systems mentioned below under the condition that the service braking performance as specified in point 6.3.1. is fulfilled:

2.1.1. ‘Hydrostatic braking system’,

2.1.2. ‘Combination hydrostatic braking system’,

2.1.3. ‘Combination friction braking system’,

2.1.4. ‘Friction braking system’;

or

2.2. a part of the braking systems mentioned under 2.1.

3. Special purpose vehicles

For special purpose works, some vehicles are equipped with a hydrostatic drive used both to retard and to propel the vehicle. This type of drive can therefore be recognised as a braking system, whether alone or in combination with a friction brake.

4. Classification of vehicles

4.1. Class I: vehicles with a maximum design speed ≤ 12 km/h.

4.2. Class II: vehicles with a maximum design speed > 12 km/h and ≤ 30 km/h.

4.3. Class III: vehicles with a maximum design speed > 30 km/h and ≤ 40 km/h.

5. Requirements

5.1. General

5.1.1. The drive control device shall be constructed in such a way that accidental reversing is prevented during a journey on the road.

5.1.2. To facilitate vehicle recovery, a device is required disengaging the connection between engine and drive wheels.

It shall be impossible to operate this device from the driving position during the journey on the road.

If a tool is needed to operate this device, it shall be carried on the vehicle.

5.2. Design requirements for the braking systems.

5.2.1. Service braking system

5.2.1.1. It shall be possible to apply graduated braking action of the service braking system. The driver shall be able to achieve this braking action from his driving seat and retain control of the steering device on the tractor with at least one hand.

5.2.1.2. The performance of the service braking system required under the Regulation shall be obtained by the actuation of a single control device.

5.2.1.2.1. This requirement is also deemed to be satisfied when the foot is moved from the drive pedal to the brake pedal or when at the start of the braking sequence, the drive control device is released or moved to neutral position by hand or foot.

5.2.1.2.2. The control device of the service braking system shall be designed to return to the initial position automatically when released.

This does not apply to the hydrostatic section of the braking system when the release of the hydrostatic drive control device creates the braking effect.

5.2.1.3. Contrary to point 5.2.1.1., with vehicles of Class I and Class II, when braking with the service brake system another brake system may also be used (secondary or parking braking system) to bring the vehicle to a stop on a gradient in the event of a residual creep speed.

5.2.2. Secondary braking system

5.2.2.1. With regard to the secondary braking system the relevant requirements of point 2.1.2.2. of Annex I shall be fulfilled.

5.2.2.2. If, in the case of a hydrostatic drive, the vehicle cannot be stopped on a gradient, then it is permissible to operate the parking braking system to stop the vehicle from residual creep speed to standstill. For this purpose the parking braking system has to be designed such that it is possible for it to be actuated during driving.

5.2.3. Parking braking system

With regard to the parking braking system the requirements of point 2.1.2.3. of Annex I shall be fulfilled.

5.3. Characteristics of the braking systems

5.3.1. The set of braking systems with which a vehicle is equipped shall satisfy the requirements laid down for service, secondary and parking braking systems.

5.3.2. In the event of breakage of any component other than the brakes or the components referred to in point 2.2.1.2.7. of Annex I, or of any other failure of the service braking system the secondary braking system or that part of the service braking system which is not affected by the failure, shall be able to bring the vehicle to a halt in the conditions prescribed for secondary braking, in particular, when the secondary braking system and the service braking system have a common control device and a common transmission; for example, when the braking effect is dependent on the operation of the proper operation of the power transmission i.e. converter, hydraulic pumps, pressure pipes, hydraulic motors or comparable components.

5.3.3. The systems providing service, secondary and parking braking may have common components as long as they fulfil the conditions as specified in point 2.2.1.2. of Annex I.

5.3.4. The braking force distribution of the service brake system must be designed in such a way that during braking there is no significant moment around the vertical axis of the vehicle if the limit of adhesion between tyres and road on homogeneous road surfaces is not attained.

5.3.5. The braking force distribution of the service braking system shall be by design such that during braking with the service brake system on surfaces with different coefficients of

friction of split-μ 0.2/0.8 a minimum deceleration can be achieved that is at least 55% of the mean fully deceleration dm of the service braking system prescribed for the respective vehicle class (see point 6.3.). This can be proven by calculations; in this case the rolling resistance shall not be taken into consideration.

5.3.6. By way of derogation from point 5.3.2., in the event of a failure in the pump control device of the hydrostatic drive, it shall be possible to stop the vehicle with the performance prescribed for the secondary braking system. However, under this failure condition an additional device may be actuated that can always be easily operated from the driving position (for example a device acting on the engine speed, including the engine shut off control).

5.3.7. In the case of an inch device, or other comparable device, which can be operated during driving, provisions shall be taken to ensure that all prescribed requirements of this Annex (especially the braking performance) are still complied with when this type of device is actuated.

5.3.8. Warning signals and warning devices

The relevant requirements of point 2.2.1.29. and point 2.2.1.12. of Annex I shall be fulfilled.

5.3.9. The energy storage devices (energy reservoirs) of power-driven vehicles shall be such that after eight full-stroke actuations of the service braking system control device the pressure remaining in the energy storage device(s) shall be not less than the pressure required to obtain the specified secondary braking performance.

5.3.10. The pneumatic/hydraulic auxiliary equipment shall be supplied with energy in such a way that during its operation, the prescribed deceleration values can be reached and that even in the event of damage to the source of energy the operation of the auxiliary equipment cannot cause the reserves of energy feeding the braking systems to fall below the level indicated in point 2.2.1.12. of Annex I.

5.3.11. Wear of the brakes

The relevant requirements of point 2.2.1.10. of Annex I shall be fulfilled.

5.3.12. In the case of a tractor equipped with a complex electronic vehicle control systems according to Annex X, the requirements of that Annex shall be applied and the operation of the system shall not be adversely affected by magnetic or electrical fields. This shall be demonstrated by compliance with the technical requirements laid down in accordance with the relevant provisions of Article 17(2)(g) and (5) of Regulation (EU) No 167/2013.

5.3.13. If a tractor with a hydrostatic drive is authorised to tow a category R2, R3, R4 or S2 vehicle shall satisfy the relevant requirements of point 2.1.4., 2.1.5., 2.2.1.16., 2.2.1.17. and 2.2.1.18. of Annex I.

5.3.14. Response time

Where a tractor is fitted with a service braking system which is totally or partially dependent on a source of energy other than the muscular effort of the driver, the requirements of point 3.3 of Annex II shall be satisfied for the non-hydrostatic part of the service braking system.

6. Braking tests

6.1. General

6.1.1. The relevant requirements of point 2.1. of Annex II shall be fulfilled.

6.1.2. During the brake test the drivability shall be assessed (e.g. tendency for lifting the rear axle due to the braking action of the service brakes).

6.1.2.1. Lift-off is not permitted for Class III vehicles.

6.1.2.2. Lifting-off of an axle is permissible for vehicles of Class I and Class II at a deceleration exceeding 4.5 m/s^2; however, the driving stability shall be preserved.
Here, the braking effect of the hydrostatic drive has also to be taken into account.

6.2. Type-0 test

6.2.1. General

6.2.1.1. The brake shall be cold. A brake is deemed to be cold when the conditions as specified in point 2.2.1.1. of Annex II are met.

6.2.1.2. The test shall be conducted under the conditions as specified in point 2.2.1.3. of Annex II.

6.2.1.3. The road shall be level.

6.2.2. In the case of manually operated drive control device (Class I and Class II vehicles), the performance of the service brake shall be assessed by moving the drive lever to neutral just before operating the service brake in order to ensure not to brake against the hydrostatic system. In the case of Class III vehicles this sequence shall be automatic, using only the service brake control.

6.2.3. Service braking system

The limits prescribed for minimum performance, both for tests with the vehicle unladen and for tests with the vehicle laden, are those laid down in point 6.3. for each class of vehicle.

The service braking system has to meet the requirements in point 6.3.1.

When used as a service braking system,

6.2.3.1. a combination hydrostatic braking system shall also meet the requirements with regard to the minimum braking portion of friction brake(s) as specified in point 6.3.1.

6.2.3.2. a combination friction braking system shall also meet the requirements with regard to the minimum braking portion of friction brake(s) as specified in point 6.3.1.

The performance of the friction brake shall also be determined. In this type of test, the effect of the hydrostatic transmission shall be neutralised to assess the friction brake and rolling resistance.

If the hydrostatic brake cannot be disconnected for technical reasons, the proportion of the friction brake may be determined by another method, e.g.:

6.2.3.3. Successive brake tests are performed

6.2.3.3.1 with the combination hydrostatic braking system with the friction brake(s) connected

6.2.3.3.2 with the combination hydrostatic braking system with the friction brake(s) rendered inoperative (only 'hydrostatic braking')

Then this formula is used:

$z_F = z_{Hy+F} - z_{Hy} + R$

$\mathbf{z_F}$: Mean fully developed deceleration of the friction braking system including rolling resistance

$\mathbf{z_{Hy}}$: Mean fully developed deceleration related only to the braking effect of the hydrostatic braking system including rolling resistance

$\mathbf{z_{Hy+F}}$: Mean fully developed deceleration of the combination hydrostatic braking system.

R: Rolling resistance = 0.02

6.2.4. Secondary braking system

6.2.4.1. The secondary braking effectiveness test shall be conducted by either simulating the actual failure conditions in the service braking system or by carrying out this test with a secondary braking system which is independent from the service braking system.

6.2.4.2. The system shall be tested with the appropriate control device.

The prescribed performance shall be obtained by applying to the control device a force not exceeding 600 N on a foot or 400 N on a hand operated control device. The control device shall be so placed that it can be easily and quickly applied by the driver.

6.2.4.3. The limits prescribed for minimum performance, both for tests with the vehicle unladen and for tests with the vehicle laden, are those laid down in point 6.3.2. for each class of vehicle.

6.3. Performance tests of service and secondary braking system (Type-0)

	Laden & Unladen		**Class I**	**Class II**	**Class III**
	(v in km/h; s in m; d_m in m/s^2)	**v**	≤ 12	≤ 30	≤ 40
6.3.1.	Service braking system	**s**	≤ 0.15v +v²/78	≤ 0.15v + v²/92	≤ 0.15v + v²/130
		d_m	≥ 3.0	≥ 3.55	≥ 5.0
6.3.1.1.	Minimum braking portion of friction brake(s) in a combination hydrostatic braking system	**s**	≤ 0.15v +v²/26	≤ 0.15v + v²/40	≤ 0.15v + v²/40
		d_m	≥ 1.0	≥ 1.5	≥ 1.5
6.3.1.2.	Minimum braking portion of friction brake(s) within a combination friction braking system	**s**	≤ 0.15v +v²/52	≤ 0.15v + v²/52	≤ 0.15v + v²/78
		d_m	≥ 2.0	≥ 2.0	≥ 3.0
6.3.2.	Secondary braking system	**s**	≤ 0.15v + v²/40	≤ 0.15v + v²/40	≤ 0.15v + v²/57
		d_m	≥ 1.5	≥ 1.5	≥ 2.2

6.4. Brake test Type-I (fade)

6.4.1. The service brakes shall be tested in such a manner that, the vehicle being laden, the energy input to the brakes is equivalent to that recorded in the same period of time with a laden vehicle driven at a steady speed of 40 km/h on a 7 per cent down-gradient for a distance of 1.7 km.

6.4.2. Alternately, the test may be carried out on a level road, the tractor being drawn by a tractor; during the test, the force applied to the control device shall be adjusted so as to keep the resistance of the towed vehicle constant (7 per cent of the maximum total stationary axle load of the tested tractor). If the power available for hauling is insufficient, the test can be conducted at a lower speed but over a greater distance as shown in the table below:

Speed [km/h]	*Distance [metres]*
40	1,700
30	1,950
20	2,500
15	3,100

6.4.3. As an alternative to the procedure with continuous braking described in points 6.4.1 and 6.4.2., the test procedure described in point 2.3.1. of Annex II with repeated braking may also be used.

6.4.4. Hot performance

At the end of the Type-I test the hot performance of the service braking system shall be measured in the same conditions (and in particular at a constant control force no greater than the mean force actually used) as for the Type-0 test (the temperature conditions may be different).

6.4.4.1. The hot braking performance of the service braking system shall not be below the limits given in the table of following point 6.4.4.2.

6.4.4.2. Minimum prescribed hot performance (Type-I test)

Service braking system	**Hot performance as % of the prescribed value**	**Hot performance as % of the value recorded during Type-0 test**
Hydrostatic braking system	90	90
Combination hydrostatic braking system	90	80
Combination friction braking system	80	60
Friction braking system	75	60

6.4.5. The type-I Test can be omitted provided that the following two conditions are met:

6.4.5.1. At least 60 % of the total braking forces during the Type-0 test of the service braking system (see point 6.2.3.) is produced by the braking with the hydrostatic drive.

6.4.5.2. The manufacturer can prove that overheating of the brakes in case of permanent operation is prevented.

6.5. Parking braking system

6.5.1. With regard to the parking braking system the requirements of point 3.1.3. of Annex II shall be fulfilled.

6.5.2. To check compliance with the requirement specified in point 2.2.1.2.4. of Annex I, a Type-0 test shall be carried out with the laden vehicle at an initial test speed of $v \geq 0.8\ v_{max}$. The mean fully developed deceleration on application of the control device of the parking braking system and the deceleration immediately before the vehicle stops shall not be less than 1.5 m/s². The force exerted on the braking control device shall not exceed the specified values.

In the case of a manually operated drive control (Class I and Class II vehicles), the performance of the parking brake system in motion shall be assessed by moving the drive control to neutral just before operating the parking braking system in order to ensure not to brake against the hydrostatic system. In the case of Class III vehicles this sequence shall be automatic, using only the service brake control.

ANNEX X

Requirements applying to the safety aspects of complex electronic vehicle control systems

1. General

This Annex lays down the requirements for type-approval testing, fault strategy and verification with respect to the safety aspects of complex electronic vehicle control systems related to the braking of agricultural and forestry vehicles.

2. Requirements

All complex electronic vehicle control systems shall comply with the provisions of Annex 18 to UNECE Regulation No 13, as referenced in the following table:

UNECE Regulation No	Subject	Series of amendments	OJ Reference
13	Approval of vehicles of categories M, N and O with regard to braking	Supplement 5 to the 10 series of amendments 11 series of amendments	L 257, 30.9.2010, p. 1 L 297, 13.11.2010, p. 183

ANNEX XI
Requirements and test procedures applying to anti-lock braking systems and to vehicles fitted with them

1. Definitions

For the purposes of this Annex:

1.1. ‘integrated endurance braking system’ means an endurance braking system whose control device is integrated with that of the service braking system in such a way that both endurance and service braking systems are applied simultaneously or suitably phased by operation of the combined control device;

1.2. ‘sensor’ means a component designed to identify and transmit to the controller the conditions of rotation of the wheel(s) or the dynamic conditions of the vehicle;

1.3. ‘controller’ means a component designed to evaluate the data transmitted by the sensor(s) and to transmit a signal to the modulator;

1.4. ‘modulator’ means a component designed to vary the braking force(s) in accordance with the signal received from the controller;

1.5. ‘indirectly controlled wheel’ means a wheel whose braking force is modulated according to data provided by the sensor(s) of other wheel(s);

1.6. ‘full cycling’ means that the anti-lock braking system is repeatedly modulating the brake force to prevent the directly controlled wheels from locking and excluding brake applications where modulation only occurs once during the stop;

1.7. ‘full force’ means the maximum force laid down in the braking tests and performance of braking systems according to this Regulation.

For the purposes of directly and indirectly controlled wheels, anti-lock braking systems with ‘select-high’ control are deemed to include both directly and indirectly controlled wheels; in systems with ‘select-low’ control, all sensed wheels are deemed to be directly controlled wheels.

2. General

2.1. This Annex lays down the required braking performance for agricultural vehicles fitted with anti-lock braking systems.

The maximum design speed for which such requirements are provided is meant, throughout this Annex, to be in the forward direction of the vehicle travel, unless otherwise explicitly mentioned.

2.2. The anti-lock braking systems known at present comprise a sensor or sensors, a controller or controllers and a modulator or modulators. Any device of a different design which may be introduced in the future, or where an anti-lock braking function is integrated into another system, shall be deemed to be anti-lock braking systems within the meaning of this Annex if they provide performances equal to those prescribed by this Annex.

2.3. Deviations from the prescribed test procedures are permitted in case that testing conditions cannot be complied with due to a too low maximum design speed of the tractor. In such a case the equivalence of the prescribed performances has to be demonstrated with the method of assessment and results being appended to the type approval report.

3. Types of anti-lock braking systems

3.1. A tractor is deemed to be equipped with an anti-lock braking system if one of the following systems is fitted:

3.1.1. Category 1 anti-lock braking system:

A vehicle equipped with a category 1 anti-lock braking system shall meet all the relevant requirements of this Annex.

3.1.2. Category 2 anti-lock braking system:

A vehicle equipped with a category 2 anti-lock braking system shall meet all the relevant requirements of this Annex, except those of point 5.3.5.

3.1.3. Category 3 anti-lock braking system:

A vehicle equipped with a category 3 anti-lock braking system shall meet all the relevant requirements of this Annex except those of points 5.3.4. and 5.3.5. On such vehicles, any individual axle (or bogie) which does not include at least one directly controlled wheel shall fulfil the conditions of adhesion utilization and the wheel-locking sequence of Appendix 1 to Annex II, with regard to the braking rate and the load respectively. Those requirements may be checked on high- and low-adhesion coefficient road surfaces (about 0.8 and 0.3 maximum) by modulating the service braking control force.

3.2. A towed vehicle shall be deemed to be equipped with an anti-lock braking system when at least two wheels on opposite sides of the vehicle are directly controlled and all remaining wheels are either directly or indirectly controlled by the anti-lock braking system. In the case of drawbar towed vehicles, at least two wheels on one front axle and two wheels on one rear axle shall be directly controlled with each of these axles having at least one independent modulator and all remaining wheels are either directly or indirectly controlled. In addition, the anti-lock equipped towed vehicle shall meet one of the following conditions:

3.2.1. Category A anti-lock braking system:

A towed vehicle equipped with a category A anti-lock braking system shall meet all the relevant requirements of this Annex.

3.2.2. Category B anti-lock braking system:

A towed vehicle equipped with a category B anti-lock braking system shall meet all the relevant requirements of this Annex, except point 6.3.2.

4. General requirements

4.1. Failures within the electric control transmission of the anti-lock braking system that affects the system with respect to the functional and performance requirements in this Annex, shall be signalled to the driver by a specific optical warning signal. The yellow warning signal specified in point 2.2.1.29.1.2. of Annex I shall be used for this purpose.

Until uniform test procedures have been agreed, the manufacturer shall provide the Technical Service with an analysis of potential failures within the control transmission and their effects. That information shall be subject to discussion and agreement between the Technical Service and the vehicle manufacturer.

4.1.1. Sensor anomalies, which cannot be detected under static conditions, shall be detected not later than when the vehicle speed exceeds 10 km/h. However, to prevent erroneous fault indication when a sensor is not generating a speed output, due to non-rotation of a wheel, verification may be delayed but detected not later than when the vehicle speed exceeds 15 km/h. The warning signal may light up again while the vehicle is stationary, provided that it is extinguished before the vehicle speed reaches 10 km/h or 15 km/h, as appropriate, when no defect is present.

4.1.2. When the anti-lock braking system is energized with the vehicle stationary, electrically controlled pneumatic modulator valve(s) shall cycle at least once.

4.2. Tractors equipped with an anti-lock braking system and authorised to tow a towed vehicle equipped with such a system shall be fitted with a separate optical warning signal for the anti-lock braking system of the towed vehicle, meeting the requirements of point 4.1. The separate warning signals specified in point 2.2.1.29.2. of Annex I shall be used for this purpose, activated via pin 5 of the electrical connector conforming to ISO 7638:2003. The ISO 7638:2003 connector may be used for 5 pin or 7 pin applications, as appropriate.

4.2.1. The warning signal shall not light up when a towed vehicle without an anti-lock braking system is coupled or when no towed vehicle is coupled. This function shall be automatic.

4.3. In the event of a failure as described in point 4.1., the following requirements shall apply:

Tractors: The residual braking performance in the event of a failure of part of the transmission of the service braking system shall be 1.3 m/s². That requirement shall not be construed as a departure from the requirements concerning secondary braking.

Towed vehicles: The residual braking performance shall be of at least 30 per cent of the prescribed performance for the service braking system of the relevant towed vehicle.

4.4. The operation of the system shall not be adversely affected by magnetic or electrical fields. That requirement shall be demonstrated by compliance with the technical requirements laid down on the basis of Article 17 (2) (g) and (5) of Regulation (EU) 167/2013.

4.5. A manual device shall not be provided to disconnect or change the control mode of the anti-lock braking system, except on tractors of category T or C. Where a device is fitted to tractors of category T or C, the following conditions shall be met:

4.5.1. An optical warning signal shall inform the driver that the anti-lock braking system has been disconnected or the control mode changed; the anti-lock failure warning signal specified in point 2.2.1.29.1.2. of Annex I may be used for this purpose.

The warning signal shall be constant or flashing.

4.5.2. The anti-lock braking system shall automatically be reconnected/returned to on-road mode when the ignition (start) device is again set to the 'on' (run) position or the vehicle speed exceeds 30 km/h.

4.5.3. The vehicle user's handbook provided by the manufacturer should warn the driver of the consequences of manual disconnection or mode change of the anti-lock braking system.

4.5.4. The device referred to in point 4.5. may, in conjunction with the tractor, disconnect/change the control mode of the anti-lock braking system of the towed vehicle. A separate device for the towed vehicle alone is not permitted.

4.5.5. Devices changing the control mode of the anti-lock braking system are not subject to point 4.5. if in the changed control mode condition all requirements for the category of anti-lock braking system with which the vehicle is equipped are fulfilled. However, in such a case, points 4.5.1., 4.5.2., and 4.5.3. shall be met.

4.6. In the case of vehicles which are equipped with an anti-lock braking system and with an integrated endurance braking system, the anti-lock braking system shall act at least on the service brakes of the endurance braking system's controlled axle and on the endurance braking system itself, and shall fulfil the relevant requirements of this Annex.

4.7. In the case of towed vehicles with pneumatic braking systems, full cycling of the anti-lock braking system is only assured when the pressure available at any brake actuator of a directly controlled wheel is more than 100 kPa above the maximum cycling pressure throughout a given test. The supply pressure available may not be increased above 800 kPa.

In the case of towed vehicles with hydraulic braking systems, full cycling of the anti-lock braking system is only assured when the pressure available at any brake actuator of a directly controlled wheel is more than 1,750 kPa above the maximum cycling pressure throughout a given test. The available energy level provided to the anti-lock braking system may not be increased above 14,200 kPa.

5. Special provisions concerning tractors

5.1. Energy consumption

Tractors equipped with anti-lock braking systems shall maintain their performance when the service braking control device is fully applied for long periods. Compliance with the requirement shall be verified by means of the procedure referred to in points 5.1.1., 5.2.3., 5.2.4., 5.2.5., 5.3., 6.1.1., 6.1.3., 6.1.4., 6.3.:

5.1.1. Test procedure

5.1.1.1. The initial energy level in the energy storage device(s) shall be that specified by the manufacturer. This level shall be at least such as to ensure the efficiency prescribed for service braking when the vehicle is laden. The energy storage device(s) for pneumatic auxiliary equipment shall be isolated.

5.1.1.2. From an initial speed of not less than 50 km/h (or v_{max}, whichever is lower), on a surface with a coefficient of adhesion of 0.3 or less, the brakes of the laden vehicle shall be fully applied for a time t, during which time the energy consumed by the indirectly controlled

wheels shall be taken into consideration and all directly controlled wheels shall remain under control of the anti-lock braking system throughout that time.

Until such test surfaces become generally available, tyres at the limit of wear, and higher values up to 0.4 may be used at the discretion of the technical service. The actual value obtained and the type of tyres and surface shall be recorded.

5.1.1.3. The vehicle's engine shall be then stopped or the supply to the energy storage device(s) cut off.

5.1.1.4. The service braking control device shall be then fully actuated four times in succession with the vehicle stationary.

5.1.1.5. When the control device is applied for the fifth time, it shall be possible to brake the vehicle with at least the performance prescribed for secondary braking of the laden vehicle.

5.1.1.6. During the tests, in the case of a vehicle authorised to tow a vehicle equipped with a compressed-air braking system, the supply line shall be blocked off and an energy storage device of 0.5 litre capacity shall be connected to the control line (in accordance with point 1.2.2.3. of Annex IV, section A). When the brakes are applied for the fifth time, as provided in point 5.1.1.5. of this Annex, the energy level supplied to the control line shall not be below half the level obtained at a full application starting with the initial energy level.

5.1.2. Additional requirements

5.1.2.1. The coefficient of adhesion of the road surface is measured with the vehicle in question, by the method described in point 1.1. of Appendix 2.

5.1.2.2. The braking test shall be conducted with the engine disconnected and idling, and with the vehicle laden.

5.1.2.3. The braking time t shall be 15 seconds.

5.1.2.4. If the time t cannot be completed in a single braking phase, further phases may be used, up to a maximum of four in all.

5.1.2.5. If the test is conducted in several phases, no fresh energy shall be supplied between the phases of the test. From the second phase, the energy consumption corresponding to the initial brake application may be taken into account, by subtracting one full brake application from the four full applications prescribed in points 5.1.1.4., 5.1.1.5., 5.1.1.6. and 5.1.2.6. for each of the second, third and fourth phases used in the test procedure prescribed in point 5.1.1. as applicable.

5.1.2.6. The performance prescribed in point 5.1.1.5. shall be deemed to be satisfied if, at the end of the fourth application, with the vehicle stationary, the energy level in the storage device(s) is at or above that required for secondary braking with the laden vehicle.

5.2. Utilisation of adhesion

5.2.1. The utilisation of adhesion by the anti-lock braking system takes into account the actual increase in braking distance beyond the theoretical minimum. The anti-lock braking system shall be deemed to be satisfactory when the condition

$$\varepsilon \geq 0.75$$

is satisfied, where ε represents the adhesion utilised, as described in point 1.2. of Appendix 2.

5.2.2. The adhesion utilisation (*ε)* shall be measured on road surfaces with a coefficient of adhesion of 0.3 or less, and of about 0.8 (dry road), with an initial speed of 50 km/h or v_{max}, whichever is the lower. To eliminate the effects of differential brake temperatures it is recommended that z_{AL} (see Appendix 1) be determined prior to the determination of k.

Until such test surfaces become generally available, tyres at the limit of wear, and higher values up to 0.4 may be used at the discretion of the technical service. The actual value obtained and the type of tyres and surface shall be recorded.

5.2.3. The test procedure to determine the coefficient of adhesion (k) and the formulae for calculation of the adhesion utilisation (*ε)* shall be those laid down in Appendix 2.

5.2.4. The utilisation of adhesion by the anti-lock braking system shall be checked on complete vehicles equipped with anti-lock braking systems of categories 1 or 2. In the case of vehicles equipped with category 3 anti-lock braking systems, only the axle(s) with at least one directly controlled wheel shall satisfy this requirement.

5.2.5. The condition $\varepsilon \geq 0.75$ shall be checked with the vehicle laden and unladen. The laden test on the high-adhesion surface may be omitted if the prescribed force on the control device does not achieve full cycling of the anti-lock braking system. For the unladen test, the control force may be increased up to 1,000 N if no cycling is achieved with its full force value. A higher force value than the one of the full force may be used if required to activate the anti-lock braking system. If 1,000 N is insufficient to make the system cycle, then this test may be omitted. For air braking systems, the air pressure may not be increased above the cut-out pressure for the purpose of this test.

5.3. Additional checks

The following additional checks shall be carried out with the engine disconnected, with the vehicle laden and unladen:

5.3.1. The wheels directly controlled by an anti-lock braking system shall not lock when the full force is suddenly applied on the control device, on the road surfaces specified in point 5.2.2., at an initial speed of 40 km/h and at a high initial speed as indicated in the table below:

Condition	Maximum test speed
High adhesion surface	0.8 $v_{max} \leq 80$ km/h
Low adhesion surface	0.8 $v_{max} \leq 70$ km/h

5.3.2. When an axle passes from a high-adhesion surface (k_H) to low-adhesion surface (k_L) where $k_H \geq 0.5$ and $k_H/k_L \geq 2$, with the full force applied on the control device, the directly controlled wheels shall not lock. . The running speed and the instant of applying the brakes shall be so calculated that, with the anti-lock braking system fully cycling on the high-adhesion surface, the passage from one surface to the other is made at high and at low speed, under the conditions laid down in point 5.3.1. above.

5.3.3. When a vehicle 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 the full force applied on the control device, the deceleration of the vehicle shall rise to the appropriate high value within a reasonable time and the vehicle shall not deviate from its initial course. The running speed and the instant of applying the brakes shall be so calculated that, with the anti-lock braking system fully cycling on the low-adhesion surface, the passage from one surface to the other occurs at approximately 50 km/h or 0.8 v_{max}, whichever is the lower.

5.3.4. In the case of vehicles equipped with anti-lock braking systems of categories 1 and 2, when the right and left wheels of the vehicle are situated on surfaces with differing coefficients of adhesion (k_H and k_L) where $k_H \geq 0.5$ and $k_H/k_L \geq 2$ the directly controlled wheels shall not lock when the full force is suddenly applied on the control device at a speed of 50 km/h or 0.8 v_{max}, whichever is the lower.

5.3.5. Furthermore, laden vehicles equipped with anti-lock braking systems of category 1 shall, under the conditions of point 5.3.4., satisfy the braking rate prescribed in Appendix 3.

5.3.6. However, in the tests provided for in points 5.3.1., 5.3.2., 5.3.3., 5.3.4. and 5.3.5., brief periods of wheel-locking are allowed. Furthermore, wheel-locking is permitted when the vehicle speed is less than 15 km/h; likewise, locking of indirectly controlled wheels is permitted at any speed, but stability and steerability shall not be affected.

5.3.7. During the tests provided for in points 5.3.4. and 5.3.5., steering correction is permitted if the angular rotation of the steering control device is within 120º during the initial 2 seconds and not more than 240º in all. Furthermore, at the beginning of these tests the longitudinal median plane of the vehicle shall pass over the boundary between the high- and low-adhesion surfaces and during these tests no part of the (outer) tyres shall cross this boundary.

5.3.8. The following notes are taken into account:

5.3.8.1. k_H and k_L are measured as laid down in Appendix 2 to this Annex.

5.3.8.2. The purpose of the tests in the following points 5.3.1., 5.3.2., 5.3.3. and 5.3.4. is to check that the directly controlled wheels do not lock and that the vehicle remains stable. In these tests a higher force value than the one of the full force may be used if required to activate the anti-lock braking system.

5.3.8.3. With regard to points 5.3.1. and 5.3.2. it is not necessary, therefore, to make complete stops and bring the vehicle to a complete halt on the low-adhesion surface.

6. Special provisions concerning towed vehicles

6.1. Energy consumption

Towed vehicles equipped with anti-lock braking systems shall be so designed that, even after the service braking control device has been fully applied for some time, the vehicle retains sufficient energy to bring it to a halt within a reasonable distance.

6.1.1. Compliance with the above requirement shall be checked by the procedure specified below, with the vehicle unladen, on a straight and level road with a surface having a good coefficient of adhesion, and with the brakes adjusted as closely as possible and with the brake load sensing device (if fitted) held in the 'laden' position throughout the test.

If the coefficient of adhesion of the test track is too high, preventing the anti-lock braking system from cycling then the test may be carried out on a surface with a lower coefficient of adhesion.

6.1.2. In the case of compressed-air braking systems, the initial energy level in the energy storage device(s) shall be equivalent to a pressure of 800 kPa at the coupling head of the towed vehicle's supply line.

6.1.3. With an initial vehicle speed of at least 30 km/h, the brakes shall be fully applied for a time t = 15 s, during which time the energy consumed by the indirectly controlled wheels shall be taken into consideration and all directly controlled wheels shall remain under control of the anti-lock braking system. During this test, the supply to the energy storage device(s) shall be cut off. If the time t = 15 s cannot be completed in a single braking phase, further phases may be used. During these phases, no fresh energy shall be supplied to the energy storage device(s) and, as from the second phase, the additional energy consumption for filling the actuators is to be taken into account, e.g. by the following test procedure. The pressure in the reservoir(s) when starting the first phase is to be that stated in point 6.1.2. At the beginning of the following phase(s), the pressure in the reservoir(s) after application of the brakes shall be not less than the pressure in the reservoir(s) at the end of the preceding phase. At the subsequent phase(s), the only time to be taken into account is from the point at which the pressure in the reservoir(s) is equal to that at the end of the preceding phase.

6.1.4. At the end of the braking, with the vehicle stationary, the service braking control device shall be fully actuated four times. During the fifth application, the pressure in the operating circuits shall be sufficient to provide a total braking force at the periphery of the wheels equal to not less than 22.5 % of the maximum stationary wheel load and without causing an automatic application of any braking system not being under the control of the anti-lock braking system.

6.2. Utilisation of adhesion

6.2.1. Towed vehicles equipped with an anti-lock braking system shall be deemed acceptable when the condition $\varepsilon \geq 0.75$ is satisfied, where ε represents the adhesion utilised, as defined in point 2. of Appendix 2. This condition shall be verified with the vehicle unladen, on a straight and level road with a surface having a good coefficient of adhesion.

If the coefficient of adhesion of the test track is too high, preventing the anti-lock braking system from cycling then the test may be carried out on a surface with a lower coefficient of adhesion.

In the case of trailers fitted with a brake load sensing device the pressure setting may be increased to ensure full cycling.

6.2.2. To eliminate the effects of differential brake temperatures, it is recommended that z_{RAL} be determined prior to the determination of k_R.

6.3. Additional checks

6.3.1. At speeds exceeding 15 km/h, the wheels directly controlled by an anti-lock braking system shall not lock when the full force is suddenly applied on the control device of the tractor. This shall be checked, under the conditions prescribed in point 6.2., at initial speeds of 40 km/h and 60 km/h.

6.3.2. The provisions of this point shall only apply to towed vehicles equipped with an anti-lock braking system of category A. When the right and left wheels are situated on surfaces which produce differing maximum braking rates (z_{RALH} and z_{RALL}), where

$$\frac{z_{RALH}}{\varepsilon_H} \geq 0.5 \text{ and } \frac{z_{RALH}}{z_{RALL}} \geq 2$$

the directly controlled wheels shall not lock when the force is suddenly applied on the control device of the tractor at a speed of 50 km/h. The ratio z_{RALH}/z_{RALL} may be ascertained by the procedure in point 2 of Appendix 2 or by calculating the ratio z_{RALH}/z_{RALL}. Under this condition, the unladen vehicle shall satisfy the prescribed braking rate in Appendix 3.

In the case of towed vehicle equipped with a brake load sensing device, the pressure setting of the device may be increased to ensure full cycling.

6.3.3. At vehicle speeds ≥15 km/h, the directly controlled wheels are permitted to lock for brief periods, but at speeds < 15 km/h, any locking is permissible. Indirectly controlled wheels are permitted to lock at any speed. In all cases, stability shall not be affected.

Appendix 1

Symbols

The following symbols are used in Appendices 2, 3 and 4:

Symbol	Notes
E	wheelbase
E_R	distance between coupling point and centre of axle(s) of rigid drawbar towed vehicle (or distance between coupling point and centre of axle(s) of centre-axle towed vehicle)
ε	the adhesion utilised by the vehicle: quotient of the maximum braking rate with the anti-lock braking system operative (z_{AL}) and the coefficient of adhesion (k)
ε_i	the ε-value measured on axle i (in the case of a tractor with a category 3 anti-lock braking system)
ε_H	the ε-value on the high-friction surface
ε_L	the ε-value on the low-friction surface
F	force [N]
F_{bR}	braking force of the towed vehicle with the anti-lock braking system inoperative
F_{bRmax}	maximum value of F_{bR}
F_{bRmaxi}	value of F_{bRmax} with only axle i of the towed vehicle braked
F_{bRAL}	braking force of the towed vehicle with the anti-lock braking system operative
F_{Cnd}	total normal reaction of road surface on the un-braked and non-driven axles of the vehicle combination under static conditions
F_{Cd}	total normal reaction of road surface on the un-braked and driven axles of the vehicle combination under static conditions
F_{dyn}	normal reaction of road under dynamic conditions with the anti-lock braking system operative
F_{idyn}	F_{dyn} on axle i in case of tractors or drawbar towed vehicle
F_i	normal reaction of road surface on axle i under static conditions
F_M	total normal static reaction of road surface on all wheels of the tractor
F_{Mnd} [2]	total normal static reaction of road surface on the un-braked and non-driven axles of the tractor

[2] F_{Mnd} and F_{Md} in case of two-axled power-driven vehicles: these symbols may be simplified to corresponding F_i-symbols.

F_{Md}	total normal static reaction of road surface on the un-braked and driven axles of the power-driven vehicle
F_R	total normal static reaction of road surface on all wheels of towed vehicle
F_{Rdyn}	total normal dynamic reaction of road surface on the axle(s) of rigid drawbar towed vehicle or centre-axle towed vehicle
F_{wM}	$0.01\ F_{Mnd} + 0.015\ F_{Md}$
g	acceleration due to gravity (9.81 m/s^2)
h	height of centre of gravity specified by the manufacturer and agreed by the technical service conducting the approval test
h_D	height of drawbar (hinge point on towed vehicle)
h_K	height of fifth wheel coupling (king pin)
h_R	height of centre of gravity of the towed vehicle
k	coefficient of adhesion between tyre and road
k_f	k-factor of one front axle
k_H	k-value determined on the high-friction surface
k_i	k-value determined on axle i for a vehicle with a category 3 anti-lock braking system
k_L	k-value determined on the low-friction surface
k_{lock}	value of adhesion for 100 % slip
k_M	k-factor of the tractor
k_{peak}	maximum value of the curve ‘adhesion versus slip’
k_r	k-factor of one rear axle
k_R	k-factor of the towed vehicle
P	mass of individual vehicle [kg]
R	ratio of k_{peak} to k_{lock}
t	time interval [s]
t_m	mean value of t
t_{min}	minimum value of t
z	braking rate [m/s^2]
z_{AL}	braking rate z of the vehicle with the anti-lock braking system operative
z_C	braking rate z of the vehicle combination, with the towed vehicle only braked and the anti-lock braking system inoperative

z_{CAL}	braking rate z of the vehicle combination, with the towed vehicle only braked and the anti-lock braking system operative
z_{Cmax}	maximum value of z_C
z_{Cmaxi}	maximum value of z_C, with only axle i of the towed vehicle braked
z_m	mean braking rate
z_{max}	maximum value of z
z_{MALS}	z_{AL} of the tractor on a 'split surface'
z_R	braking rate z of the towed vehicle with the anti-lock braking system inoperative
z_{RAL}	z_{AL} of the towed vehicle obtained by braking all the axles, the tractor un-braked and its engine disconnected
z_{RALH}	z_{RAL} on the surface with the high coefficient of adhesion
z_{RALL}	z_{RAL} on the surface with the low coefficient of adhesion
z_{RALS}	z_{RAL} on the split surface
z_{RH}	z_R on the surface with the high coefficient of adhesion
z_{RL}	z_R on the surface with the low coefficient of adhesion
z_{RHmax}	maximum value of z_{RH}
z_{RLmax}	maximum value of z_{RL}
z_{Rmax}	maximum value of z_R

Appendix 2

Utilisation of adhesion

1. Method of measurement for tractors

1.1. Determination of the coefficient of adhesion (k)

1.1.1. The coefficient of adhesion (k) shall be determined as the quotient of the maximum braking forces without locking the wheels and the corresponding dynamic load on the axle being braked.

1.1.2. The brakes shall be applied only on one axle of the vehicle under test, at an initial speed of 50 km/h. The braking forces shall be distributed between the wheels of the axle to reach maximum performance. The anti-lock braking system shall be disconnected, or inoperative, between 40 km/h and 20 km/h.

1.1.3. A number of tests at increments of line pressure shall be carried out to determine the maximum braking rate of the vehicle (z_{max}). During each test, a constant input force shall be maintained and the braking rate shall be determined by reference to the time (t) taken for the speed to reduce from 40 km/h to 20 km/h using the formula:

$$z = \frac{0.566}{t}$$

z_{max} is the maximum value of z in m/s^2,

t is in seconds.

1.1.3.1. Wheel-lock may occur below 20 km/h.

1.1.3.2. Starting from the minimum measured value of t, called t_{min}, then select three values of t comprised within t_{min} and 1.05 t_{min} and calculate their arithmetical mean value t_m, then calculate

$$z_m = \frac{0.566}{t_m}$$

If it is demonstrated that for practical reasons the three values determined above cannot be obtained, then the minimum time t_{min} may be utilised. However, the requirements of point 1.3. still apply.

1.1.4. The braking forces shall be calculated from the measured braking rate and the rolling resistance of the un-braked axle(s) which is equal to 0.015 and 0.010 of the static axle load for a driven axle and a non-driven axle, respectively.

1.1.5. The dynamic load on the axle shall be calculated from the braking rate, static axle load, wheelbase and centre of gravity height.

1.1.6. The value of k shall be rounded to three decimal places.

1.1.7. Then, the test shall be repeated for the other axles(s) as defined in points 1.1.1. to 1.1.6. (for exemptions, see points 1.4 and 1.5).

1.1.8. For example, in the case of a two-axle rear-wheel drive vehicle, with the front axle being braked, the coefficient of adhesion (k) is given by:

$$k_f = \frac{z_m \times P \times g - 0.015\, F_2}{F_1 + \frac{h}{E} z_m \times P \times g}$$

1.1.9. One coefficient shall be determined for the front axle k_f and one for the rear axle k_r.

1.2. Determination of the adhesion utilised (ε)

1.2.1. The adhesion utilised (*ε)* is defined as the quotient of the maximum braking rate with the anti-lock braking system operative (z_{AL}) and the coefficient of adhesion k_M, i.e.

$$\varepsilon = \frac{z_{AL}}{k_M}$$

1.2.2. From an initial vehicle speed of 55 km/h, or v_{max} whichever is lower, the maximum value for the braking rate (z_{AL}) shall be measured with full cycling of the anti-lock braking system. This value for z_{AL} shall be based on the average value of three tests, as previously described in point 1.1.3, using the time taken for the speed to reduce from 45 km/h to 15 km/h, according to the following formula:

$$z_{AL} = \frac{0.849}{t_m}$$

1.2.3. The coefficient of adhesion k_M shall be determined by weighting with the dynamic axle loads:

$$k_M = \frac{k_f \times F_{fdyn} + k_r \times F_{rdyn}}{P \times g}$$

Where:

$$F_{fdyn} = F_f + \frac{h}{E} \times z_{AL} \times P \times g$$

$$F_{rdyn} = F_r - \frac{h}{E} \times z_{AL} \times P \times g$$

1.2.4. The value of *ε* shall be rounded to two decimal places.

1.2.5. In the case of a vehicle equipped with an anti-lock braking system of category 1 or 2, the value of z_{AL} is based on the whole vehicle, with the anti-lock braking system in operation, and the adhesion utilised (*ε)* shall be given by the same formula quoted in point 1.2.1.

1.2.6. In the case of a vehicle equipped with an anti-lock braking system of category 3, the value of z_{AL} shall be measured on each axle which has at least one directly controlled wheel.

Example: for a two-axle vehicle with an anti-lock braking system acting only on the rear axle (2), the adhesion utilised (ε) is given by:

$$\varepsilon_2 = \frac{z_{AL} \times P \times g - 0.010 \times F_1}{k_2\left(F_2 - \frac{h}{E} z_{AL} \times P \times g\right)}$$

This calculation shall be made for each axle having at least one directly controlled wheel.

1.3. If $\varepsilon > 1.00$, the measurements of coefficients of adhesion shall be repeated. A tolerance of 10 % is acceptable.

1.4. For tractors equipped with three axles, any axles that are interconnected by either suspension components and thereby react to weight transfer under braking or driveline may be disregarded in establishing a k value for the vehicle.

Until a uniform test procedure is agreed, vehicles with more than three axles and special vehicles shall be subject to consultation with the technical service.

1.5. For tractors with a wheel base less than 3.80 m and with h/E > 0.25, the determination of the coefficient of adhesion for the rear axle shall be omitted

1.5.1. In that case, the adhesion utilised (ε) is defined as the quotient of the maximum braking rate with the anti-lock braking system operative (z_{AL}) and the coefficient of adhesion (k_f), i. e.

$$\varepsilon = \frac{z_{AL}}{k_f}$$

2. Method of measurement for towed vehicles

2.1. General

2.1.1. The coefficient of adhesion (k) shall be determined as the quotient of the maximum braking forces without locking the wheels and the corresponding dynamic load on the axle being braked.

2.1.2. The brakes shall be applied on only one axle of the towed vehicle under test, at an initial speed of 50 km/h. The braking forces shall be distributed between the wheels of the axle to reach maximum performance. The anti-lock braking system shall be disconnected or inoperative between 40 km/h and 20 km/h.

2.1.3. A number of tests at increments of line pressure shall be carried out to determine the maximum braking rate of the vehicle combination (z_{Cmax}) with the towed vehicle only braked. During each test, a constant input force shall be maintained and the braking rate shall be determined by reference to the time taken (t) for the speed to reduce from 40 km/h to 20 km/h using the formula:

$$z_c = \frac{0.566}{t}$$

2.1.3.1. Wheel-lock may occur below 20 km/h.

2.1.3.2. Starting from the minimum measured value of t, called t_{min}, then select three values of t comprised within t_{min} and 1.05 t_{min} and calculate their arithmetical mean value t_m.

then calculate:

$$z_{C\max} = \frac{0.566}{t_m}$$

If it is demonstrated that for practical reasons the three values determined above cannot be obtained, then the minimum time t_{min} may be utilised.

2.1.4. The adhesion utilised (ε) shall be calculated by means of the formula:

$$\varepsilon = \frac{z_{AL}}{k_R}$$

The k value shall be determined according to point 2.2.3 for drawbar towed vehicles or point 2.3.1 for rigid drawbar towed vehicles and centre-axle towed vehicles, respectively.

2.1.5. If $\varepsilon > 1.00$ the measurements of coefficients of adhesion shall be repeated. A tolerance of 10 % is accepted.

2.1.6. The maximum braking rate (z_{RAL}) shall be measured with full cycling of the anti-lock braking system and the tractor unbraked, based on the average value of three tests, as in point 2.1.3.

2.2. Drawbar towed vehicles

2.2.1. The measurement of k (with the anti-lock braking system being disconnected, or inoperative, between 40 km/h and 20 km/h) shall be performed for the front and rear axles.

For one front axle i:

For one front axle i:

$$F_{bR\max i} = z_{c\max i}\left(F_M + F_R\right) - 0{,}01\, F_{Cnd} - 0.015\, F_{Cd}$$

$$F_{idyn} = F_i + \frac{z_{C\max}\left(F_M \times h_D + g \times P \times h_R\right) - F_{WM} \times h_D}{E}$$

$$k_r = \frac{F_{bR\max i}}{F_{idyn}}$$

For one rear axle i:

$$F_{bR\max i} = z_{C\max i}\left(F_M + F_R\right) - 0{,}01\, F_{Cnd} - 0.015\, F_{Cd}$$

$$F_{idyn} = F_i - \frac{z_{C\max}\left(F_M \times h_D + g \times P \times h_R\right) - F_{WM} \times h_D}{E}$$

$$k_r = \frac{F_{bR\max i}}{F_{idyn}}$$

2.2.2. The values of k_f and k_r shall be rounded to three decimal places.

2.2.3. The coefficient of adhesion k_R shall be determined proportionally according to the dynamic axle loads.

$$k_R = \frac{k_f \times F_{fdyn} + k_r \times F_{rdyn}}{P \times g}$$

2.2.4. Measurement of z_{RAL} (with the anti-lock braking system operative)

$$z_{RAL} = \frac{z_{CAL} \times \left(F_M + F_R\right) - 0.01\ F_{Cnd} - 0.015\ F_{Cd}}{F_R}$$

z_{RAL} shall be determined on a surface with a high coefficient of adhesion and, for vehicles with a category A anti-lock braking system, also on a surface with a low coefficient of adhesion.

2.3. Rigid drawbar towed vehicles and centre-axle towed vehicles

2.3.1. The measurement of k (with the anti-lock braking system being disconnected, or inoperative, between 40 km/h and 20 km/h) shall be carried out with wheels fitted only on one axle, the wheels of the other axle(s) are removed.

$$F_{bR\max} = z_{C\max}\left(F_M + F_R\right) - F_{WM}$$

$$F_{Rdyn} = F_R - \frac{F_{bR\max} \times h_k + z_c \times g \times P \times \left(h_R - h_k\right)}{E_R}$$

$$k = \frac{F_{bR\max}}{F_{rdyn}}$$

2.3.2. The measurement of z_{RAL} (with the anti-lock braking system operative) shall be carried out with all wheels fitted.

$$F_{bRAL} = z_{CAL} \times \left(F_M + F_R\right) - F_{WM}$$

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

$$z_{RAL} = \frac{F_{bRAL}}{F_{Rdyn}}$$

z_{RAL} shall be determined on a surface with a high coefficient of adhesion and, for vehicles with a category A anti-lock braking system, also on a surface with a low coefficient of adhesion.

Appendix 3

Performance on differing adhesion surfaces

1. Tractors

1.1. The prescribed braking rate referred to in point 6.3.5. of this Annex may be calculated by reference to the measured coefficient of adhesion of the two surfaces on which this test is carried out.

These two surfaces shall satisfy the conditions prescribed in point 6.3.4. of this Annex.

1.2. The coefficient of adhesion (k_H and k_L) of the high- and low-adhesion surfaces, respectively, shall be determined in accordance with the provisions in point 1.1. of Appendix 2.

1.3. The braking rate (z_{MALS}) for laden tractors shall be:

$$z_{MALS} \geq 0.75 \frac{4k_L + k_H}{5} \text{ and } z_{MALS} \geq k_L$$

2. Towed vehicles

2.1. The braking rate referred to in point 6.3.2. of this Annex may be calculated by reference to the measured braking rates z_{RALH} and z_{RALL} on the two surfaces on which the tests are carried out with the anti-lock braking system operative. These two surfaces shall satisfy the conditions prescribed in point 6.3.2. of this Annex.

2.2. The braking rate z_{RALS} shall be:

$$z_{RALS} \geq \frac{0.75}{\varepsilon_H} \times \frac{4z_{RALL} + z_{RALH}}{5} \text{ and}$$

$$z_{RALS} > \frac{z_{RALL}}{\varepsilon_H}$$

If $\varepsilon_H > 0.95$ use $\varepsilon_H = 0.95$.

Appendix 4

Method of selection of the low-adhesion surface

1. Details of the coefficient of adhesion of the surface selected, as determined in point 5.1.1.2. of this Annex, shall be given to the technical service.

1.1. These data shall include a curve of the coefficient of adhesion versus slip (from 0 % to 100 % slip) for a speed of approximately 40 km/h.

Until a uniform test procedure is established for the determination of the adhesion curve for vehicles with a maximum mass exceeding 3.5 tonnes, the curve established for passenger cars may be used. In this case, for vehicles with a maximum mass exceeding 3.5 tonnes, the ratio k_{peak} to k_{lock} shall be established using a value of k_{peak} as defined in Appendix 2. With the consent of the technical service, the coefficient of adhesion described in this item may be determined by another method provided that the equivalence of the values of k_{peak} and k_{lock} are demonstrated.

1.1.1. The maximum value of the curve will represent k_{peak} and the value at 100 % slip will represent k_{lock}.

1.1.2. The ratio R shall be determined as the quotient of the k_{peak} and k_{lock}.

$$R = \frac{k_{peak}}{k_{lock}}$$

1.1.3. The value of R shall be rounded to one decimal place.

1.1.4. The surface to be used shall have a ratio R between 1.0 and 2.0.

Until such test surfaces become generally available, a ratio R up to 2.5 is acceptable, subject to discussion with the technical service.

2. Prior to the tests, the technical service shall ensure that the selected surface meets the specified requirements and shall be informed of the test method to determine R, the type of vehicle (tractor, etc.) and the axle load and tyres (different loads and different tyres have to be tested and the results shown to the technical service which will decide if they are representative for the vehicle to be approved).

2.1. The value of R shall be mentioned in the test report.

The calibration of the surface has to be carried out at least once a year with a representative vehicle to verify the stability of R.

ANNEX XII

Requirements applying to EBS of vehicles with compressed-air braking systems or of vehicles with data communication via pin 6 and 7 of ISO 7638 connector and to vehicles fitted with such EBS

1. Definitions

For the purposes of this Annex:

1.1. 'point-to-point' means a topology of a communication network with only two units. Each unit has an integrated termination resistor for the communication line;

1.2. 'braking signal' means a logic signal indicating brake activation.

2. General requirements

2.1. The electric control line shall conform to ISO 11992-1 and 11992-2:2003 including Amd.1:2007 and be a point-to-point type using the seven pin connector according to ISO 7638-1 or 7638-2:2003. The data contacts of the ISO 7638 connector shall be used to transfer information exclusively for braking (including ABS) and running gear (steering, tyres and suspension) functions as specified in ISO 11992-2:2003 including Amd.1:2007. The braking functions have priority and shall be maintained in the normal and failed modes. The transmission of running gear information shall not delay braking functions. The power supply, provided by the ISO 7638 connector, shall be used exclusively for braking and running gear functions and that required for the transfer of towed vehicle related information not transmitted via the electric control line. However, in all cases the provisions of point 5.2.1. shall apply. The power supply for all other functions shall use other measures.

2.2. The support of messages defined within ISO 11992-2:2003 including Amd.1:2007 is specified in Appendix 1 to this Annex for the tractor and towed vehicle as appropriate.

2.3. The functional compatibility of tractors and towed vehicles equipped with electric control lines shall be assessed at the time of type approval by checking that the relevant provisions of ISO 11992:2003, including ISO 11992-2:2003 and its Amd.1:2007 parts 1 and 2, are fulfilled. Appendix 2 to this Annex provides an example of tests that may be used to perform this assessment.

2.4. When a tractor is equipped with an electric control line and electrically connected to a towed vehicle equipped with an electric control line, a continuous failure (> 40 ms) within the electric control line shall be detected in the tractor and shall be signaled to the driver by the yellow warning signal specified in point 2.2.1.29.1.2. of Annex I, when such vehicles are connected via the electric control line.

3. Special requirements for the connections between tractors and towed vehicles for compressed-air braking systems

3.1. The electric control line of the tractor shall provide information as to whether the requirements of point 2.2.1.29.1.2. of Annex I can be satisfied by the electric control line, without assistance from the pneumatic control line. It shall also provide

information as to whether it is equipped according to point 2.1.4.1.2. of Annex I with two control lines or according to point 2.1.4.1.3. of Annex I with only an electric control line.

3.2. A tractor equipped according to point 2.1.4.1.3. of Annex I shall recognize that the coupling of a towed vehicle equipped according to point 2.1.4.1.1. of Annex I is not compatible. When such vehicles are electrically connected via the electric control line of the tractor, the driver shall be warned by the red optical warning signal specified in point 2.2.1.29.1.1. of Annex I and when the system is energized, the brakes on the tractor shall be automatically applied. This brake application shall provide at least the prescribed parking braking performance required by points 3.1.3.1. and 3.1.3.2. of Annex II respectively.

3.3. In the case of a tractor equipped with two control lines as described in point 2.1.4.1.2. of Annex I, when electrically connected to a towed vehicle which is also equipped with two control lines, all of the following conditions shall be fulfilled:

3.3.1. both signals shall be present at the coupling head and the towed vehicle shall use the electric control signal unless this signal is deemed to have failed. In this case the towed vehicle shall automatically switch to the pneumatic control line;

3.3.2. each vehicle shall conform to the relevant provisions of Appendix 1 of Annex II for both electric and pneumatic control lines;

3.3.3. when the electric control signal has exceeded the equivalent of 100 kPa for more than 1 second, the towed vehicle shall verify that a pneumatic signal is present; should no pneumatic signal be present, the driver shall be warned from the towed vehicle by the separate yellow warning signal specified in point 2.1.4.1.2. of Annex I.

3.4. A towed vehicle may be equipped as described in point 2.1.4.1.3. of Annex I, provided that it can only be operated in conjunction with a tractor with an electric control line which satisfies the requirements of point 2.2.1.17.1. of Annex I. In any other case, the towed vehicle, when electrically connected, shall automatically apply the brakes or remain braked. The driver shall be warned by the separate yellow warning signal specified in point 2.2.1.29.2. of Annex I.

3.5. If the operation of the parking braking system on the tractor also operates a braking system on the towed vehicle, as permitted by point 2.1.2.3. of Annex I, then the following additional requirements shall be met:

3.5.1. When the tractor is equipped according to point 2.1.4.1.1. of Annex I, the actuation of the parking braking system of the tractor shall actuate a braking system on the towed vehicle via the pneumatic control line.

3.5.2. When the tractor is equipped according to point 2.1.4.1.2. of Annex I, the actuation of the parking braking system on the tractor shall actuate a braking system on the towed vehicle as prescribed in point 3.5.1. In addition, the actuation of the parking braking system may also actuate a braking system on the towed vehicle via the electric control line.

3.5.3. When the tractor is equipped according to point 2.1.4.1.3, of Annex I or, if it satisfies the requirements of point 2.2.1.17.1. of Annex I without assistance from the pneumatic control line, point 2.1.4.1.2. of Annex I, the actuation of the parking braking system on the tractor shall actuate a braking system on the towed vehicle via the electric control line. When the electrical energy for the braking equipment of the tractor is switched off, the braking of the towed vehicle shall be effected by evacuation of the supply line (in addition, the pneumatic control line may remain pressurized); the supply line may only remain evacuated until the electrical energy for the braking equipment of the tractor is restored and simultaneously the braking of the towed vehicle via the electric control line is restored.

4. Special additional requirements for service braking systems with electric control transmission

4.1. Tractors

4.1.1. With the parking braking system released, the service braking system shall be able to generate a static total braking force at least equivalent to that required by the prescribed Type-0 test, even when the ignition/start switch has been switched off and/or the key has been removed. In the case of tractors authorized to tow vehicles of category R3b or R4b, such vehicles shall provide a full control signal for the service braking system of the towed vehicle. It should be understood that sufficient energy is available in the energy transmission of the service braking system.

4.1.2. In the case of a single temporary failure (< 40 ms) within the electric control transmission, excluding its energy supply, (e.g. non-transmitted signal or data error) there shall be no distinguishable effect on the service braking performance.

4.1.3. A failure within the electric control transmission, not including its energy reserve, that affects the function and performance of systems addressed in this Regulation shall be indicated to the driver by the red or yellow warning signal specified in points 2.2.1.29.1.1. and 2.2.1.29.1.2. of Annex I, respectively, as appropriate. When the prescribed service braking performance can no longer be achieved (warning signal), failures resulting from a loss of electrical continuity (e.g. breakage, disconnection) shall be signalled to the driver as soon as they occur, and the prescribed residual braking performance shall be fulfilled by operating the service braking control in accordance with point 3.1.4. of Annex II.

The manufacturer shall provide the Technical Service with an analysis of potential failures within the control transmission and their effects. This information shall be subject to discussion and agreement between the Technical Service and the vehicle manufacturer.

These requirements shall not be construed as a departure from the requirements concerning secondary braking.

4.1.4. A tractor electrically connected to a towed vehicle via an electric control line, shall provide a clear warning to the driver whenever the towed vehicle provides the failure information that the stored energy in any part of the service braking system on the

towed vehicle falls below the warning level, as specified in point 5.2.4. A similar warning shall also be provided when a continuous failure (> 40 ms) within the electric control transmission of the towed vehicle, excluding its energy reserve, precludes achievement of the prescribed service braking performance of the towed vehicle, as specified in point 4.2.3. The warning signal specified in point 2.2.1.29.2.1. of Annex I shall be used for this purpose.

4.1.5. In the event of a failure of the energy source of the electric control transmission, starting from the nominal value of the energy level, the full control range of the service braking system shall be guaranteed after twenty consecutive full stroke actuations of the service braking control device. During the test, the braking control device shall be fully applied for 20 seconds and released for 5 seconds on each actuation. It should be understood that during the above test, sufficient energy is available in the energy transmission to ensure full actuation of the service braking system. This requirement shall not be construed as a departure from the requirements of Annex IV.

4.1.6. When the battery voltage falls below a value nominated by the manufacturer at which the prescribed service braking performance can no longer be guaranteed and/or which precludes at least two independent service braking circuits from each achieving the prescribed secondary or residual braking performance, the warning signal specified in point 2.2.1.29.1.1. of Annex I shall be activated. After the warning signal has been activated, it shall be possible to apply the service braking control device and obtain at least the performances prescribed for residual and secondary braking in the case of tractor with maximum design speed exceeding 60 km/h or the performance prescribed for secondary braking in the case of tractor with maximum design speed not exceeding 60 km/h. It should be understood that sufficient energy is available in the energy transmission of the service braking system. This requirement shall not be construed as a departure from the requirement concerning secondary braking.

4.1.7. If auxiliary equipment is supplied with energy from the same reserve as the electric control transmission, it shall be ensured that, with the engine running at a speed not greater than 80% of the maximum power speed, the supply of energy is sufficient to fulfil the prescribed deceleration values by either provision of an energy supply which is able to prevent discharge of this reserve when all auxiliary equipment is functioning or by automatically switching off pre-selected parts of the auxiliary equipment at a voltage above the critical level referred to in point 4.1.6. such that further discharge of this reserve is prevented. Compliance may be demonstrated by calculation or by a practical test. For vehicles authorized to tow a vehicle of category R3b or R4b the energy consumption of the towed vehicle shall be taken into account by a load of 400 W. This point does not apply to vehicles where the prescribed deceleration values can be reached without the use of electrical energy.

4.1.8. If the auxiliary equipment is supplied with energy from the electric control transmission, the following requirements shall be fulfilled.

4.1.8.1. In the event of a failure in the energy source, whilst the vehicle is in motion, the energy in the reservoir shall be sufficient to actuate the brakes when the control device is applied.

4.1.8.2. In the event of a failure in the energy source, whilst the vehicle is stationary and the parking braking system applied, the energy in the reservoir shall be sufficient to actuate the lights even when the brakes are applied.

4.1.9. In the case of a failure in the electric control transmission of the service braking system of a tractor equipped with an electric control line according to point 2.1.4.1.2. or 2.1.4.1.3. of Annex I, the full actuation of the brakes of the towed vehicle shall remain ensured.

4.1.10. In the case of a failure in the electric control transmission of a towed vehicle, electrically connected via an electric control line only, according to point 2.1.4.1.3. of Annex I, braking of the towed vehicle shall be ensured according to point 2.2.1.17.3.1. of Annex I. This shall be the case whenever the towed vehicle provides the "supply line braking request" signal via the data communication part of the electric control line or in the event of the continuous absence of this data communication. This point shall not apply to tractors which cannot be operated with towed vehicles connected via an electric control line only, as described in point 3.4.

4.2. Trailers

4.2.1. In the case of a single temporary failure (< 40 ms) within the electric control transmission, excluding its energy supply, (e.g. non-transmitted signal or data error) there shall be no distinguishable effect on the service braking performance.

4.2.2. In the case of a failure within the electric control transmission (e.g. breakage, disconnection), of at least 30% of the prescribed performance for the service braking system of the relevant towed vehicle shall be maintained.

Until uniform test procedures have been agreed, the manufacturer shall provide the Technical Service with an analysis of potential failures within the control transmission, and their effects. This information shall be subject to discussion and agreement between the Technical Service and the vehicle manufacturer.

For towed vehicles, electrically connected via an electric control line only, according to point 2.1.4.1.3. of Annex I, and fulfilling 2.2.1.17.3.2. of Annex I with the performance prescribed in point 3.2.3. of Annex II, it is sufficient that the provisions of point 4.1.10. are invoked, when a braking performance of at least 30% of the prescribed performance for the service braking system of the towed vehicle can no longer be ensured, by either providing the "supply line braking request" signal via the data communication part of the electric control line or by the continuous absence of this data communication.

4.2.3. A failure within the electric control transmission of the towed vehicle that affects the function and performance of systems addressed by this Regulation and failures of energy supply available from the ISO 7638:2003 connector shall be indicated to the driver by the separate warning signal specified in point 2.2.1.29.2. of Annex I via pin 5 of the electrical connector conforming to ISO 7638:2003. In addition, towed

vehicles equipped with an electric control line, when electrically connected to a tractor with an electric control line, shall provide the failure information for activation of the warning signal specified in point 2.2.1.29.2.1. of Annex I via the data communication part of the electric control line, when the prescribed service braking performance of the towed vehicle can no longer be ensured.

However, in the case of any failure of the energy supply available from the ISO 7638:2003 connector, the indication of the yellow warning signal via pin 5 of the electrical connector conforming to ISO 7638:2003 is sufficient under the condition that the full braking force is still available.

5. Additional requirements

5.1. Tractors

5.1.1. Generation of a braking signal to illuminate stop lamps

5.1.1.1. Activation of the service braking system by the driver shall generate a signal that will be used to illuminate the stop lamps.

5.1.1.2. Requirements for vehicles that utilize electronic signalling to control initial application of the service braking system and equipped with an endurance braking system:

Deceleration by the endurance braking system	
≤ 1.3 m/sec^2	> 1.3 m/sec^2
May generate the signal	Shall generate the signal

5.1.1.3. In the case of vehicles equipped with a braking system of a specification different to that laid down in point 5.1.1.2. , the operation of the endurance braking system may generate the signal irrespective of the deceleration produced.

5.1.1.4. The signal shall not be generated when deceleration is produced by the natural braking effect of the engine alone.

5.1.1.5. Activation of the service braking system by automatically commanded braking shall generate the signal mentioned above. However, when the deceleration generated is less than 0.7 m/s^2, the signal may be suppressed

At the time of type approval, compliance with this requirement shall be confirmed by the vehicle manufacturer.

5.1.1.6. Activation of part of the service braking system by selective braking shall not generate the signal mentioned above.

During a selective braking event, the function may change to automatically commanded braking.

5.1.1.7. In the case of vehicles equipped with an electric control line the signal shall be generated by the tractor when a message “illuminate stop lamps” is received via the electric control line from the towed vehicle.

5.2. Towed vehicles

5.2.1. Whenever power supplied by the ISO 7638:2003 connector is used for the functions referred to in point 2.1., the braking system shall have priority and be protected from an overload external to the braking system. This protection shall be a function of the braking system.

5.2.2. In the case of a failure in one of the control lines connecting two vehicles equipped according to point 2.1.4.1.2. of Annex I the towed vehicle shall use the control line not affected by the failure to ensure, automatically, the braking performance prescribed for the towed vehicle in point 3.2.1. of Annex II.

5.2.3. When the supply voltage to the towed vehicle falls below a value nominated by the manufacturer at which the prescribed service braking performance can no longer be guaranteed, the separate yellow warning signal specified in point 2.2.1.29.2. of Annex I shall be activated via pin 5 of the ISO 7638:2003 connector. In addition, towed vehicles equipped with an electrical control line, when electrically connected to a tractor with an electric control line, shall provide the failure information for actuation of the warning signal specified in point 2.2.1.29.2.1. of Annex I via the data communication part of the electric control line.

5.2.4. When the stored energy in any part of the service braking system of a towed vehicle equipped with an electric control line and electrically connected to a tractor with an electronic control line, falls to the value determined in accordance with point 5.2.4.1., a warning shall be provided to the driver of the tractor. The warning shall be provided by activation of the red signal specified in point 2.2.1.29.2.1. of Annex I and the towed vehicle shall provide the failure information via the data communication part of the electric control line. The separate yellow warning signal specified in point 2.2.1.29.2. of Annex I shall also be activated via pin 5 of the electrical connector conforming to ISO 7638:2003, to indicate to the driver that the low-energy situation is on the towed vehicle.

5.2.4.1. The low energy value referred to in point 5.2.4. shall be that at which, without re-charging of the energy reservoir and irrespective of the load condition of the towed vehicle, it is not possible to apply the service braking control device a fifth time after four full-stroke actuations and obtain at least 50% of the prescribed performance of the service braking system of the relevant towed vehicle.

5.2.5. Activation of the service braking system

5.2.5.1. In the case of towed vehicles equipped with an electric control line the message "illuminate stop lamps" shall be transmitted by the towed vehicle via the electric control line when the towed vehicle braking system is activated during "automatically commanded braking" initiated by the towed vehicle. However, when the retardation generated is less than 0.7 m/s^2, the signal may be suppressed.

At the time of type approval, compliance with this requirement shall be confirmed by the vehicle manufacturer.

5.2.5.2. In the case of towed vehicles equipped with an electric control line the message "illuminate stop lamps" shall not be transmitted by the towed vehicle via the electrical control line during selective braking initiated by the towed vehicle.

During a selective braking event, the function may change to automatically commanded braking.

6. Suppression of automatic braking

In the case of towed vehicles equipped with an electric control line and electrically connected to a tractor with an electric control line the automatic braking action specified in point 2.2.1.17.2.2. of Annex I may be suppressed as long as the pressure in the compressed air reservoirs of the towed vehicle is sufficient to ensure the braking performance specified in point 3.2.3. of Annex II.

Appendix 1

Compatibility between tractors and towed vehicles with respect to ISO 11992 data communications

1. General

1.1. The requirements of this Appendix shall only apply to tractors and towed vehicles equipped with an electric control line.

1.2. The ISO 7638 connector provides a power supply for the braking system or anti-lock braking system of the towed vehicle. In the case of vehicles equipped with an electric control line this connector also provides a data communication interface via Pins 6 and 7 as in point 2.1. of this Annex.

1.3. This Appendix lays down requirements applicable to the tractor and towed vehicle with respect to the support of messages defined within ISO 11992-2:2003 including Amd.1:2007.

2. The parameters defined within ISO 11992-2:2003 including Amd.1:2007 that are transmitted by the electric control line shall be supported as follows:

2.1. The following functions and associated messages are those specified within this Regulation that shall be supported by the tractor or towed vehicle as appropriate:

2.1.1. Messages transmitted from the tractor to the towed vehicle:

Function / Parameter	*ISO 11992-2:2003 Reference*	*Reference in this Regulation*
Service/secondary brake demand value	EBS11 Byte 3-4	Appendix 1 to Annex II, point 3.1.3.2.
Two electrical circuits brake demand value	EBS12 Byte 3 Bit 1-2	Annex XII, point 3.1.
Pneumatic control line	EBS12 Byte 3 Bit 5-6	Annex XII, point 3.1.

2.1.2. Messages transmitted from the towed vehicle to the tractor:

Function / Parameter	*ISO 11992-2:2003 Reference*	*Reference in this Regulation*
Vehicle electrical supply sufficient / insufficient	EBS22 Byte 2 Bit 1-2	Annex XII, point 5.2.3.
Warning signal request	EBS22 Byte 2 Bit 3-4	Annex XII, point 4.2.3., 5.2.4. and 5.2.3.
Supply line braking request	EBS22 Byte 4 Bit 3-4	Annex XII , point 4.2.2.
Stop lamps request	EBS22 Byte 4 Bit 5-6	Annex XII, point 5.2.5.1.
Vehicle pneumatic supply sufficient / insufficient	EBS23 Byte 1 Bit 7-8	Annex XII, point 5.2.4.

2.2. When the towed vehicle transmits the following message, the tractor shall provide a warning to the driver:

Function / Parameter	*ISO 11992-2:2003 Reference*	*Driver Warning Required*
Warning signal request	EBS22 Byte 2 Bit 3-4	point 2.2.1.29.2.1. of Annex I

2.3. The following messages defined in ISO 11992-2:2003 including Amd.1:2007 shall be supported by the tractor or towed vehicle:

2.3.1. Messages transmitted from the tractor to the towed vehicle:

No messages currently defined.

2.3.2. Messages transmitted from the towed vehicle to the tractor:

Function / Parameter	*ISO 11992-2:2003 Reference*
Vehicle service brake active / passive	EBS22 Byte 1, Bit 5-6
Braking via electric control line supported	EBS22 Byte 4, Bit 7-8
Geometric data index	EBS24 Byte 1
Geometric data index content	EBS24 Byte 2

2.4. The following messages shall be supported by the tractor or towed vehicle as appropriate when the vehicle is installed with a function associated with that parameter:

2.4.1. Messages transmitted from the tractor to the towed vehicle:

Function / Parameter	*ISO 11992-2:2003 Reference*
Vehicle type	EBS11 Byte 2, Bit 3-4
VDC (Vehicle Dynamic Control) Active / passive	EBS11 Byte 2, Bit 5-6
Brake demand value for front or left side of vehicle	EBS11 Byte 7
Brake demand value for rear or right side of vehicle	EBS11 Byte 8
ROP (Roll Over Protection) system enabled/disabled	EBS12 Byte 1, Bit 3-4
YC (Yaw Control) system enabled/disabled	EBS12 Byte 1, Bit 5-6
Enable/disable towed vehicle ROP (Roll Over Protection) system	EBS12 Byte 2, Bit 1-2
Enable/disable towed vehicle YC (Yaw Control) system	EBS12 Byte 2, Bit 3-4
Traction help request	RGE11 Byte 1, Bit 7-8
Lift axle 1 - position request	RGE11 Byte 2, Bit 1-2
Lift axle 2 - position request	RGE11 Byte 2, Bit 3-4
Steering axle locking request	RGE11 Byte 2, Bit 5-6
Seconds	TD11 Byte 1
Minutes	TD11 Byte 2
Hours	TD11 Byte 3
Months	TD11 Byte 4
Day	TD11 Byte 5
Year	TD11 Byte 6
Local minute offset	TD11 Byte 7
Local hour offset	TD11 Byte 8

2.4.2. Messages transmitted from the towed vehicle to the tractor:

Function / Parameter	*ISO 11992-2:2003 Reference*
Support of side or axle wise brake force distribution	EBS21 Byte 2, Bit 3-4
Wheel based vehicle speed	EBS21 Byte 3-4
Lateral acceleration	EBS21 Byte 8
Vehicle ABS active / passive	EBS22 Byte 1, Bit 1-2

Function / Parameter	*ISO 11992-2:2003 Reference*
Amber warning signal request	EBS22 Byte 2, Bit 5-6
Vehicle type	EBS22 Byte 3, Bit 5-6
Loading ramp approach assistance	EBS22 Byte 4, Bit 1-2
Axle load sum	EBS22 Byte 5-6
Tyre pressure sufficient / insufficient	EBS23 Byte 1, Bit 1-2
Brake lining sufficient / insufficient	EBS23 Byte 1, Bit 3-4
Brake temperature status	EBS23 Byte 1, Bit 5-6
Tyre / wheel identification (pressure)	EBS23 Byte 2
Tyre / wheel identification (lining)	EBS23 Byte 3
Tyre / wheel identification (temperature)	EBS23 Byte 4
Tyre pressure (actual tyre pressure)	EBS23 Byte 5
Brake lining	EBS23 Byte 6
Brake temperature	EBS23 Byte 7
Brake cylinder pressure first axle left wheel	EBS25 Byte 1
Brake cylinder pressure first axle right wheel	EBS25 Byte 2
Brake cylinder pressure second axle left wheel	EBS25 Byte 3
Brake cylinder pressure second axle right wheel	EBS25 Byte 4
Brake cylinder pressure third axle left wheel	EBS25 Byte 5
Brake cylinder pressure third axle right wheel	EBS25 Byte 6
ROP (Roll Over Protection) system enabled/disabled	EBS25 Byte 7, Bit 1-2
YC (Yaw Control) system enabled/disabled	EBS25 Byte 7, Bit 3-4
Traction help	RGE21 Byte 1, Bit 5-6
Lift axle 1 position	RGE21 Byte 2, Bit 1-2
Lift axle 2 position	RGE21 Byte 2, Bit 3-4
Steering axle locking	RGE21 Byte 2, Bit 5-6
Tyre wheel identification	RGE23 Byte 1
Tyre temperature	RGE23 Byte 2-3
Air leakage detection (Tyre)	RGE23 Byte 4-5
Tyre pressure threshold detection	RGE23 Byte 6, Bit 1-3

2.5. The support of all other messages defined within ISO 11992-2:2003 including Amd.1:2007 is optional for the tractor and towed vehicle.

Appendix 2

Test procedure to assess the functional compatibility of vehicles equipped with electric control lines

1. General

1.1. This Appendix lays down a procedure that may be used by the Technical Service to check tractors and towed vehicles equipped with an electric control line against the functional and performance requirements referred to in point 2.2. of Annex XII.

1.2. The references to ISO 7638 within this Appendix apply to ISO 7638-1:2003 for 24V applications and ISO 7638-2:2003 for 12V applications.

2. Tractors

2.1. ISO 11992 towed vehicle simulator

The simulator shall:

2.1.1. Have a connector meeting ISO 7638:2003 (7 pin) to connect to the vehicle under test. Pins 6 and 7 of the connector shall be used to transmit and receive messages complying with ISO 11992:2003 including ISO 11992-2:2003 and its Amd.1:2007;

2.1.2. Be capable of receiving all of the messages transmitted by the motor vehicle to be type approved and be capable of transmitting all towed vehicle messages defined within ISO 11992-2:2003 and its Amd.1:2007;

2.1.3. Provide a direct or indirect readout of messages, with the parameters in the data field shown in the correct order relative to time; and

2.1.4. Include a facility to measure coupling head response time in accordance with point 2.6 of Annex III.

2.2. Checking procedure

2.2.1. Confirm that the manufacturer's/supplier's information document demonstrates compliance with the provisions of ISO 11992 with respect to the physical layer, data link layer and application layer.

2.2.2. Check the following, with the simulator connected to the motor vehicle via the ISO 7638 interface and whilst all towed vehicle messages relevant to the interface are being transmitted:

2.2.2.1. Control line signalling:

2.2.2.1.1. The parameters defined in EBS 12 byte 3 of ISO 11992-2:2003 and its Amd.1:2007 shall be checked against the specification of the vehicle as follows:

Control Line Signalling	*EBS 12 Byte 3*	
	Bits 1 - 2	*Bits 5 - 6*
Service braking demand generated from one electrical circuit	00_b	
Service braking demand generated from two electrical circuits	01_b	
Vehicle is not equipped with a pneumatic control line [1]		00_b
Vehicle is equipped with a pneumatic control line		01_b

2.2.2.2. Service/Secondary brake demand:

2.2.2.2.1 The parameters defined in EBS 11 of ISO 11992-2:2003 and its Amd.1:2007 shall be checked as follows:

Test condition	*Byte reference*	*Electrical control line signal value*
Service brake pedal and secondary brake control released	3 - 4	0
Service brake pedal fully applied	3 - 4	33280_d to 43520_d (650 to 850 kPa)
Secondary brake fully applied [2]	3 - 4	33280_d to 43520_d (650 to 850 kPa)

2.2.2.3. Failure warning:

2.2.2.3.1. Simulate a permanent failure in the communication line to pin 6 of the ISO 7638 connector and check that the yellow warning signal specified in point 2.2.1.29.1.2. of Annex I is displayed.

2.2.2.3.2. Simulate a permanent failure in the communication line to pin 7 of the ISO 7638 connector and check that the yellow warning signal specified in point 2.2.1.29.1.2. of Annex I is displayed.

2.2.2.3.3. Simulate message EBS 22, byte 2 with bits 3 - 4 set to 01_b and check that the warning signal specified in point 2.2.1.29.1.1. of Annex I is displayed.

2.2.2.4. Supply line braking request:

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[1] This specification of vehicle is prohibited following point 2.1.4.1.3. of Annex I.

[2] Optional on tractors with electric and pneumatic control lines when the pneumatic control line fulfils the relevant requirements for secondary braking.

For power-driven vehicles which can be operated with towed vehicles connected via an electric control line only:

Only the electric control line shall be connected.

Simulate message EBS 22, byte 4 with bits 3 - 4 set to 01_b and check that when the service brake, secondary brake or parking braking system is fully actuated the pressure in the supply line falls to 150 kPa within the following two seconds.

Simulate a continuous absence of data communication and check that when the service brake, secondary brake or parking braking system is fully actuated the pressure in the supply line falls to 150 kPa within the following two seconds.

2.2.2.5. Response time:

2.2.2.5.1. Check that, with no faults present, the control line response requirements laid down in point 2.6. of Annex III are met.

2.2.2.6. Illumination of stop lamps

Simulate message EBS 22 byte 4 bits 5 to 6 set to 00 and check that the stop lamps are not illuminated.

Simulate message EBS 22 byte 4 bits 5 to 6 set to 01 and check that the stop lamps are illuminated.

2.2.3. Additional checks

2.2.3.1. At the discretion of the Technical Service the checking procedures laid down in points 2.2.1. and 2.2.2. may be repeated with the non-braking functions relevant to the interface in different states or switched off.

2.2.3.2. Point 2.4.1. of Appendix 1 defines additional messages that shall under specific circumstances be supported by the tractor. Additional checks may be carried out to verify the status of supported messages to ensure the requirements of point 2.3. are fulfilled.

3. Towed vehicles

3.1. ISO 11992 tractor simulator

The simulator shall:

3.1.1. Have a connector meeting ISO 7638:2003 (7 pin) to connect to the vehicle under test. Pins 6 and 7 of the connector shall be used to transmit and receive messages complying with ISO 11992:2003 including ISO 11992-2:2003 and its Amd.1:2007;

3.1.2. Have a failure warning display and an electrical power supply for the towed vehicle;

3.1.3. Shall be capable of receiving all of the messages transmitted by the towed vehicle to be type approved and be capable of transmitting all motor vehicle messages defined within ISO 11992-2:2003 and its Amd.1:2007.

3.1.4. Provide a direct or indirect readout of messages with the parameters in the data field shown in the correct order relative to time; and

3.1.5. Include a facility to measure brake system response time in accordance with point 4.5.2. of Annex III.

3.2. Checking procedure

3.2.1. Confirm that the manufacturer's or supplier's Information Document, demonstrates compliance with the provisions of ISO 11992:2003 including ISO 11992-2:2003 and its Amd.1:2007 with respect to the physical layer, data link layer and application layer.

3.2.2. Check the following, with the simulator connected to the towed vehicle via the ISO 7638 interface and whilst all tractor messages relevant to the interface are being transmitted:

3.2.2.1. Service brake system function:

3.2.2.1.1. The towed vehicle response to the parameters defined in EBS 11 of ISO 11992-2:2003 and its Amd.1:2007 shall be checked as follows:

The pressure in the supply line at the start of each test shall be $\geq$ 700 kPa and the vehicle shall be laden (the loading condition may be simulated for the purpose of this check).

3.2.2.1.1.1. For towed vehicles equipped with pneumatic and electric control lines:

Both control lines shall be connected;

Both control lines shall be signalled simultaneously;

The simulator shall transmit message byte 3, bits 5-6;

Of EBS 12 set to 01_b to indicate to the towed vehicle that a pneumatic control line should be connected.

Parameters to be checked:

Message transmitted by the simulator		*Pressure at the brake chambers*
Byte reference	Digital demand value	
3 - 4	0	0 kPa
3 - 4	33280_d (650 kPa)	As defined in the vehicle manufacturer's brake calculation

3.2.2.1.1.2. Towed vehicles equipped with pneumatic and electric control lines or an electric control line only:

Only the electric control line shall be connected

The simulator shall transmit the following messages:

Byte 3, bits 5 - 6 of EBS 12 set to 00_b to indicate to the towed vehicle that a pneumatic control line is not available, and byte 3, bits 1 - 2 of EBS 12 set to 01_b to indicate to the towed vehicle that the electric control line signal is generated from two electric circuits.

Parameters to be checked:

Message transmitted by the simulator		*Pressure at the brake chambers*
Byte reference	Digital demand value	
3 - 4	0	0 kPa
3 - 4	33280_d (650 kPa)	As defined in the vehicle manufacturer's brake calculation

3.2.2.1.2. For towed vehicles equipped with only an electric control line, the response to messages defined in EBS 12 of ISO 11992-2:2003 and its Amd.1:2007 shall be checked as follows:

The pneumatic supply line at the start of each test shall be $\geq$ 700 kPa.

The electric control line shall be connected to the simulator.

The simulator shall transmit the following messages:

Byte 3, bits 5 - 6 of EBS 12 set to 01_b to indicate to the towed vehicle that a pneumatic control line is available.

Byte 3-4 of EBS 11 shall be set to 0 (no service brake demand)

The response to the following messages shall be checked:

EBS 12, Byte 3, Bit 1-2	*Pressure in the brake chambers or reaction of the towed vehicle*
01_b	0 kPa (service brake released)
00_b	The towed vehicle is automatically braked to demonstrate that the combination is not compatible. A signal should also be transmitted via Pin 5 of the ISO 7638:2003 connector (yellow warning).

3.2.2.1.3. For towed vehicles connected with only an electrical control line, the response of the towed vehicle to a failure in the electric control transmission of the towed vehicle which results in a reduction in braking performance to at least 30% of the prescribed value shall be checked by the following procedure:

The pneumatic supply line at the start of each test shall be ≥ 700 kPa.

The electric control line shall be connected to the simulator.

Byte 3, bits 5-6 of EBS 12 set to 00_b to indicate to the towed vehicle that a pneumatic control line is not available.

Byte 3, bits 1-2 of EBS 12 set to 01_b to indicate to the towed vehicle that the electric control line signal is generated from two independent circuits.

The following shall be checked:

Test condition	*Braking system response*
With no faults present in the towed vehicle braking system	Check that the braking system is communicating with the simulator and that Byte 4, bits 3-4 of EBS 22 is set to 00_b.
Introduce a failure in the electric control transmission of the towed vehicle braking system that prevents at least 30 per cent of the prescribed braking performance from being maintained	Check that Byte 4, bits 3-4 of EBS 22 is set to 01_b or The data communications to the simulator has been terminated

3.2.2.2. Failure warning

3.2.2.2.1. Check that the appropriate warning message or signal is transmitted under the following conditions:

3.2.2.2.1.1. Where a permanent failure within the electric control transmission of the towed vehicle braking system precludes the service braking performance being met, simulate such a failure and check that byte 2, bits 3 - 4 of EBS 22 transmitted by the towed vehicle is set to 01_b. A signal should also be transmitted via pin 5 of the ISO 7638 connector (yellow warning).

3.2.2.2.1.2. Reduce the voltage on pins 1 and 2 of the ISO 7638 connector to below a value nominated by the manufacturer which precludes the service braking system performance from being fulfilled and check that byte 2, bits 3 - 4 of EBS 22 transmitted by the towed vehicle are set to 01_b. A signal should also be transmitted via pin 5 of the ISO 7638 connector (yellow warning).

3.2.2.2.1.3. Check compliance with the provisions of point 5.2.4. of this Annex by isolating the supply line. Reduce the pressure in the towed vehicle pressure storage system to the value nominated by the manufacturer. Check that byte 2, bits 3 - 4 of EBS 22 transmitted by the towed vehicle is set to 01_b and that byte 1, bits 7 - 8 of

EBS 23 is set to 00. A signal should also be transmitted via pin 5 of the ISO 7638 connector (yellow warning).

3.2.2.2.1.4. When the electrical part of the braking equipment is first energised check that byte 2, bits 3 - 4 of EBS 22 transmitted by the towed vehicle is set to 01_b. After the braking system has checked that no defects that require identification by the warning signal are present the above message should be set to 00_b.

3.2.2.3. Response time checking

3.2.2.3.1. Check that, with no faults present, the braking system response time requirements laid down in point 4.5.2. of Annex III are met.

3.2.2.4. Automatically commanded braking

In case the towed vehicle includes a function where its operation results in an automatically commanded braking intervention, the following shall be checked:

If no automatically commanded braking intervention is generated, check that message EBS 22 byte 4 bits 5 to 6 are set to 00.

Simulate an automatically commanded braking intervention, when the resulting deceleration is ≥ 0.7 m/sec^2, check that message EBS 22 byte 4 bits 5 to 6 are set to 01.

3.2.2.5. Vehicle stability function

In the case of a towed vehicle equipped with a vehicle stability function, the following checks shall be carried out:

When the vehicle stability function is inactive, check that message EBS 21 byte 2 bits 1 to 2 are set to 00.

3.2.2.6. Support of the electric control line

Where the towed vehicle braking system does not support braking via the electric control line check that message EBS 22 byte 4 bits 7 to 8 are set to 00.

Where the towed vehicle braking system supports the electric control line, check that message EBS 22 byte 4 bits 7 to 8 are set to 01.

3.2.3. Additional checks

3.2.3.1. At the discretion of the Technical Service the checking procedures laid down in points 3.2.1. and 3.2.2. may be repeated with the non-braking messages relevant to the interface in different states or switched off.

Where repeat measurements of the brake system response time are carried out, variations in the value recorded may occur due to the reaction of the vehicle pneumatics. In all cases the prescribed response time requirements shall be met.

3.2.3.2. Point 2.4.2. of Appendix 1 defines additional messages that shall under specific circumstances be supported by the towed vehicle. Additional checks may be carried out to verify the status of supported messages to ensure the requirements of point 2.3. of this Annex are fulfilled.

ANNEX XIII
Requirements applying to hydraulic connections of the single-line type and to vehicles fitted with them

1. General

1.1. In addition to at least one type of connection as defined in point 2.1.4. of Annex I or points 2.1.5.1.1. to 2.1.5.1.3. of that Annex, a hydraulic connection of the single line type may be installed on the tractor.

1.2 Hydraulic connections of the single-line type shall be so designed as to ensure that the braking systems covered by the provisions of Annexes I to XII are not to be adversely affected by any operation of this equipment or in the event of any failure of this equipment.

1.3. The service braking system of the tractor shall be fitted with a device so designed that if the towed vehicle braking system should fail, or the control line between the tractor and towed vehicle should break, it will still be possible to brake the tractor with the effectiveness prescribed for the secondary braking system in this Regulation.

2. Hydraulic connections of the single-line type between tractors and towed vehicles equipped with hydraulic braking systems shall fulfil the following requirements:

2.1. Type of connection: hydraulic control line with the male connector on the tractor and the female connector on the towed vehicle. The connectors shall comply with ISO 5676:1983.

2.2. With the engine running and the control device of the service braking system of the tractor fully applied a pressure between 10,000 kPa and 15,000 kPa shall be generated on the control line.

2.3. With the engine running and no brake control device on the tractor applied (driving or stand-by condition), the pressure supplied at the coupling head of the control line shall be 0^{+200} kPa.

2.4. The response time requirements of Annex III do not apply to this type of connection.

2.5. The compatibility requirements according to Appendix 1 to Annex II do not apply to this type of connection.

3. Alternative requirements

As an alternative to the requirements of points 1 and 2, hydraulic connection of the single line type installed on tractors shall fulfil all the requirements of the current point, in addition to the provisions of points 1.2. and 2.1.

3.1. The hydraulic circuit shall be provided with a relief valve to prevent hydraulic pressures exceeding 15,000 kPa.

3.2. With no brake control device (including parking brake) applied on the tractor, at any engine revolutions per minute (RPM) between low idle and rated speed, pressure at coupling head shall be between 1,000 and 1,500 kPa.

3.3. Applying tractor service brakes gradually, pressure at coupling head shall increase progressively and reach the maximum specified value, which shall be between 12,000 and 14,000 kPa. Requirement shall be fulfilled at any engine RPM, as described in point 3.2.

3.4. Permissible relationship between braking rate TM/FM and the coupling head pressure p_m shall be lower than line AAA of Figure 1. Requirement shall be fulfilled by the unladen vehicle.

3.5. The response time at the coupling head, measured connecting the towed vehicle simulator (as described in point 3.10.) to the tractor, shall not be higher than 0.6 seconds. The response time shall be measured at the coupling head, starting from the moment of the pedal actuation until the moment when pressure reaches the value of 7,500 kPa. During the test, engine RPM shall be set to 2/3 of the rated speed. The ambient and vehicle temperature shall be stabilized between 10°C and 30°C. The pedal actuation time necessary to reach a pressure of 10,000 kPa at the coupling head, shall be not less than 0.2 seconds.

3.6. In case of failure of the towed vehicle braking system part, located on the tractor side, a pressure drop to 0 kPa (measured at the coupling head) shall be generated within 1 second, in order to apply the brakes of the towed vehicle. The same provision applies in case of shut off or low efficiency of the energy source.

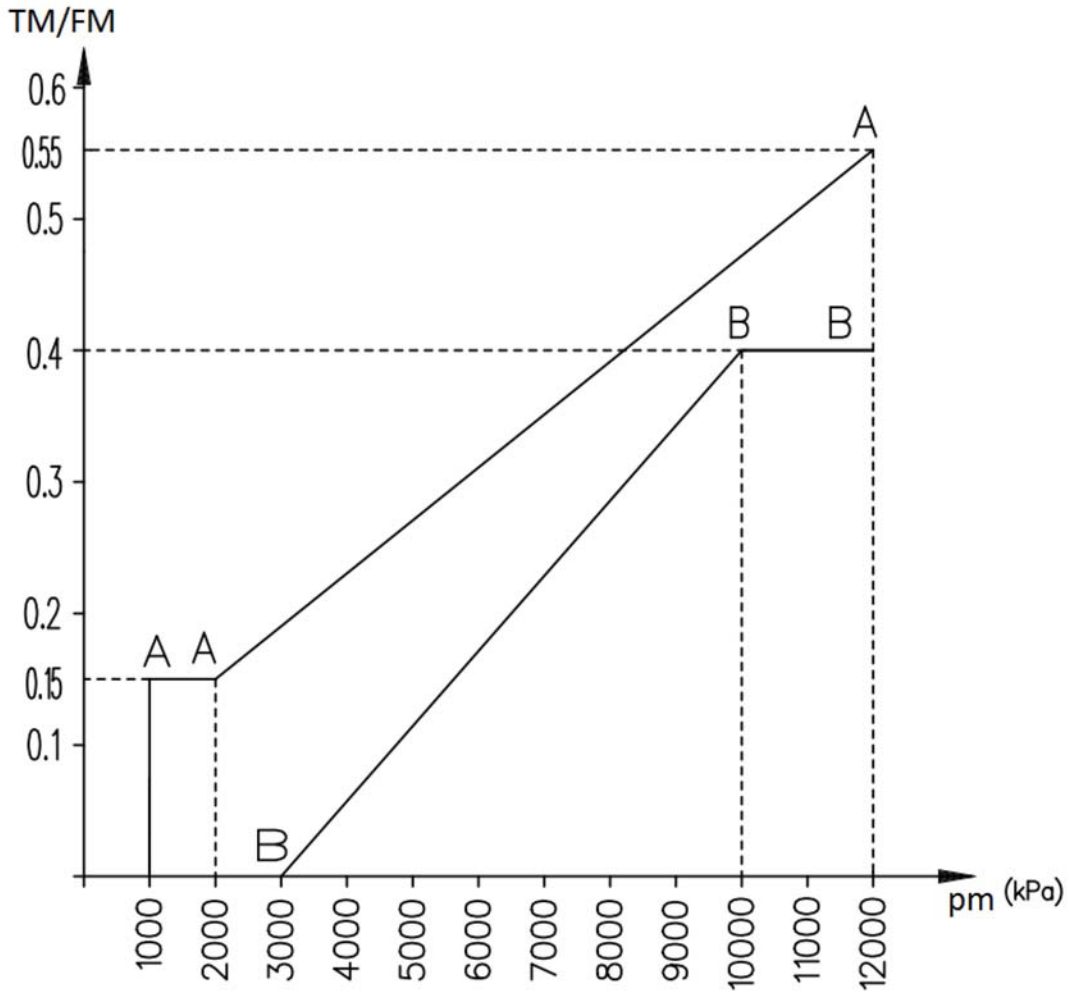
3.7. In case of failure of the tractor service brakes, operator shall be able to drop the pressure at the coupling head to 0 kPa. This requirement may be achieved by an auxiliary manual control device.

3.8. The tractor shall be equipped with the warning signal specified in point 2.2.1.29.1.1. of Annex I; it shall be activated when the pressure in the towed vehicle braking system drops below 1,000 $^{(+0\ -\ 200)}$ kPa.

3.9. Braking valve and energy source shall be marked in accordance with the requirements laid down on the basis of Article 17 (2) (k) and (5) of Regulation (EU) 167/2013.

3.10. Towed vehicle simulator: The device simulating the towed vehicle braking system shall include a hydraulic circuit provided with one female coupler as per ISO 5676-1983 and two identical hydraulic energy storage devices, fitted with spring elements and fulfilling the requirements reported in Figure 2. The simulator shall be manufactured according to the provisions of Figure 3.

Figure 1 - Relationship between braking rate TM/FM and coupling head pressure pm

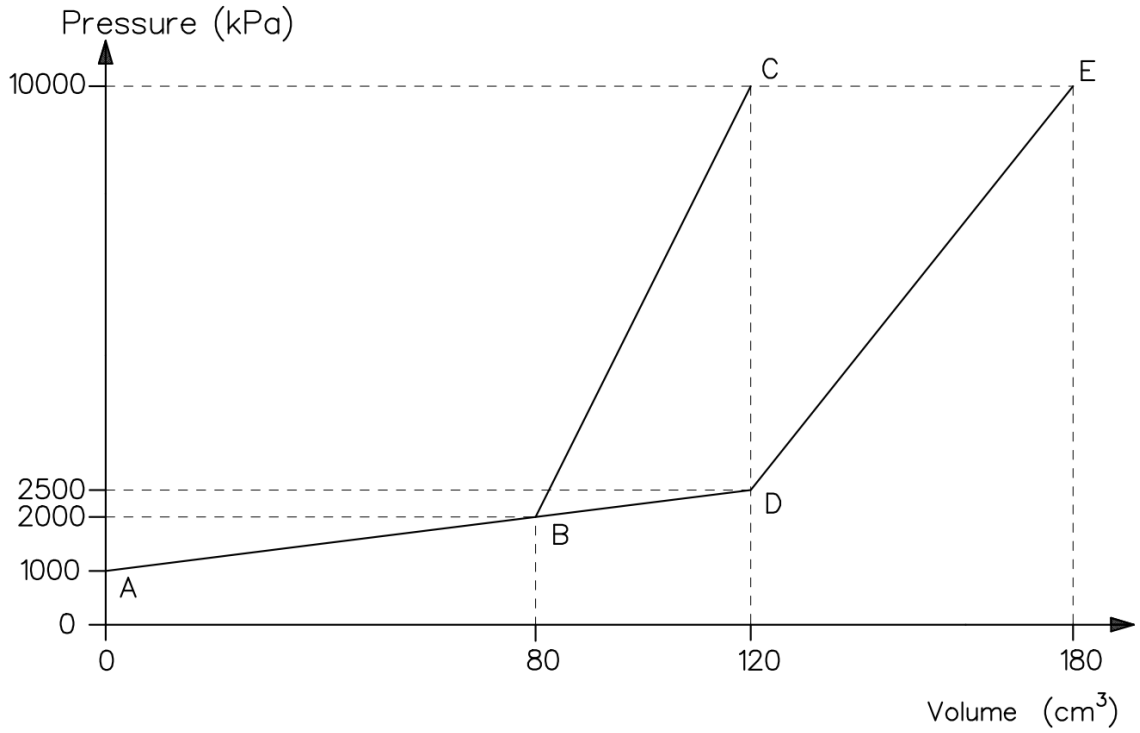


pm = stabilized hydraulic pressure at the coupling head (kPa).

TM = sum of braking forces at the periphery of all wheels of tractors

FM = total normal static reaction of road surface on wheels of tractors

Figure 2 – Characteristic of the towed vehicle simulator, depending on its maximum permissible mass

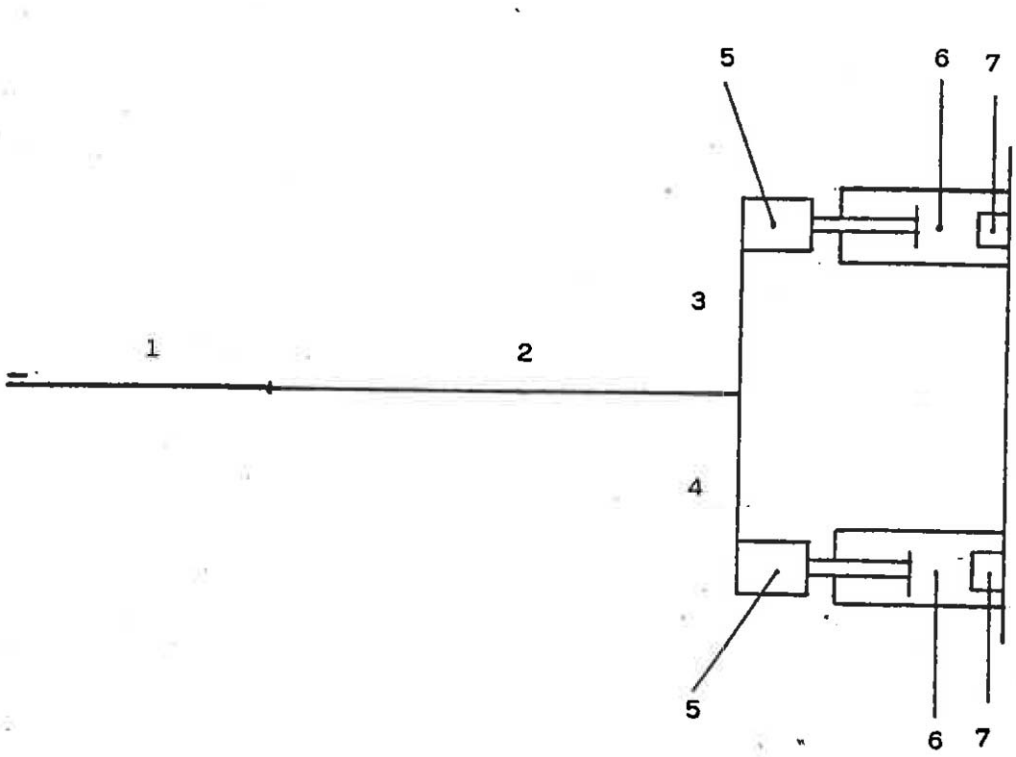


- diagram A B C for maximum permissible mass up to 14 tons.

- diagram A D E for maximum permissible mass higher than 14 tons

Note: tolerance admitted ± 2%

Figure 3 - Towed vehicle simulator layout



1 = hose of 2,000 mm length with one female coupler as per ISO 5676-1983;

2 = tube of internal diameter 8 mm and length of 4,000 mm;

3 = tube of internal diameter 8 mm and length of 1,000 mm;

4 = tube of internal diameter 8 mm and length of 1,000 mm;

5 = piston brake simulating elements;

6 = spring adjusted elements acting on the total stroke of the piston;

7 = spring adjusted elements acting only at the end of the pistons stroke.