Informal document No. **GRRF-56-5**
(56th GRRF, 20-22 September 2004,
agenda item 1.1.)

ECONOMIC COMMISSION FOR EUROPE

INLAND TRANSPORT COMMITTEE

World Forum for Harmonization of Vehicle Regulations (WP.29)

Working Party on Brakes and Running Gear (GRRF)
Fifty-sixth session, 20-22 September 2004,

PROPOSAL FOR DRAFT AMENDMENTS TO REGULATION No. 13

(Braking)

Transmitted by the expert from the United Kingdom

Note: The text reproduced below has been prepared by the expert from the United Kingdom and proposes amendments to the paragraphs in Annex 13 of Regulation 13 that need to be amended in order to delete category M_1 vehicles.

Note: This document is distributed to the Experts on Brakes and Running Gear only.

Annex 13

TEST REQUIREMENTS FOR VEHICLES FITTED WITH ANTI-LOCK SYSTEMS

1. GENERAL.

1.1. This Annex defines the required braking performance for road vehicles fitted with anti-lock systems. In addition, power-driven vehicles which are authorized to tow a trailer, and trailers equipped with compressed-air braking systems, shall, when the vehicles are laden, meet the requirements for compatibility set out in **Annex 10** to this Regulation.

1.2. The anti-lock 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 an anti-lock system within the meaning of this Annex and **Annex 10** to this Regulation, if it provides performance equal to that prescribed by this Annex.

2. DEFINITIONS.

2.1. An "**anti-lock system**" is a part of a service braking system which automatically controls the degree of slip, in the direction of rotation of the wheel(s), on one or more wheels of the vehicle during braking.

2.2. "**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.

2.3. "**Controller**" means a component designed to evaluate the data transmitted by the sensor(s) and to transmit a signal to the modulator.

2.4. "**Modulator**" means a component designed to vary the braking force(s) in accordance with the signal received from the controller.

2.5. " **Directly controlled wheel** " means a wheel whose braking force is modulated according to data provided at least by its own sensor. 1/

2.6. "**Indirectly controlled wheel** " means a wheel whose braking force is modulated according to data provided by the sensor(s) of other wheel(s). 1/

2.7. "**Full cycling**" means that the anti-lock system is repeatedly modulating the brake force to prevent the directly controlled wheels from locking. Brake applications where modulation only occurs once during the stop shall not be considered to meet this definition.

In the case of trailers 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 **1 bar** above the maximum cycling pressure throughout a given test. The supply pressure available may not be increased above **8 bar**.

3. TYPES OF ANTI-LOCK SYSTEMS.

3.1. A power-driven vehicle is deemed to be equipped with an anti-lock system within the meaning of paragraph **1.** of **Annex 10** to this Regulation, if one of the following systems is fitted:

All footnotes to Annex 13 can be found at the end of this Annex (p8)

3.1.1. Category 1 anti-lock system

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

3.1.2. Category 2 anti-lock system

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

3.1.3. Category 3 anti-lock system

A vehicle equipped with a category **3** anti-lock system shall meet all the relevant requirements of this Annex, except those of paragraphs **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 must fulfil the conditions of adhesion utilization and the wheel-locking sequence of **Annex 10** to this Regulation, with regard to the braking rate and the load respectively. These requirements may be checked on high- and low-adhesion road surfaces (about **0.8** and **0.3** maximum) by modulating the service braking control force.

3.2. A trailer is deemed to be equipped with an anti-lock system within the meaning of paragraph **1.** of **Annex 10** to this Regulation 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 system. In the case of full trailers, at least **2** wheels on one front axle and **2** wheels on one rear axle are directly controlled with each of these axles having at least **one** independent modulator and all remaining wheels being either directly or indirectly controlled. In addition, the anti-lock equipped trailer shall meet one of the following conditions:

3.2.1. Category A anti-lock system.

A trailer equipped with a category **A** anti-lock system shall meet all the relevant requirements of this Annex.

3.2.2. Category B anti-lock system.

A trailer equipped with a category **B** anti-lock system shall meet all the relevant requirements of this Annex, except paragraph **6.3.2.**

4. GENERAL REQUIREMENTS.

4.1. Any **electrical failure** or sensor anomaly that affects the system with respect to the functional and performance requirements in this Annex, including those in the supply of electricity, the external wiring to the controller(s), the controller(s) [2/] and the modulator(s) shall be signalled to the driver by a specific optical warning signal. The yellow warning signal specified in paragraph **5.2.1.29.1.2.** of this Regulation, shall be used for this purpose.

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**. [3/] However, to prevent erroneous fault indication when a sensor is not generating a speed output signal, due to non-rotation of a wheel, verification may be delayed but (*must be*)detected not later than when the vehicle speed exceeds **15 km/h**.

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.

All footnotes to Annex 13 can be found at the end of this Annex (p8)

4.2. Power-driven vehicles equipped with an anti-lock system and authorized to tow a trailer equipped with such a system, with the exception of vehicles of category **N_1** , shall be fitted with a separate optical warning signal for the anti-lock system of the trailer, meeting the requirements of paragraph

4.1. of this Annex. The separate **yellow** warning signals specified in paragraph **5.2.1.29.2.** of this Regulation, shall be used for this purpose, activated via **pin 5** of the electrical connector conforming to **ISO 7638:1997** [4/].

4.3. In the event of failure in the anti-lock system, the residual braking performance shall be that prescribed for the vehicle in question in the event of a failure of part of the transmission of the service braking system (see paragraph **5.2.1.4.** of this Regulation). This requirement shall not be construed as a departure from the requirements concerning secondary braking. In the case of trailers, the residual braking performance in the event of a defect in the anti-lock system according to paragraph **4.1.** of this Annex, shall be at least **80%** of the prescribed laden performance for the service braking system of the relevant trailer.

4.4. The operation of the anti-lock system shall not be adversely affected by magnetic or electrical fields. This shall be demonstrated by compliance with Regulation No. **10, 02** series of amendments.

4.5. A manual device may **not** be provided to **disconnect or change the control mode** [5/] of the anti-lock system, **except on off-road power-driven vehicles of categories N_2 and N_3** as defined in **Annex 7** to the Consolidated Resolution on the Construction of Vehicles (R.E.3) ; where a device is fitted to **N_2 or N_3** category vehicles, the following conditions must be met:

4.5.1. the power-driven vehicle with the anti-lock system disconnected or the control mode changed by the device referred to in paragraph **4.5.** above must satisfy all the relevant requirements in **Annex 10** to this Regulation;

4.5.2. an **optical warning** signal shall inform the driver that the anti-lock system has been disconnected or the control mode changed; the **yellow** anti-lock failure warning signal specified in paragraph **5.2.1.29.1.2.** of this Regulation, may be used for this purpose. The warning signal may be **constant or flashing**.

4.5.3. the anti-lock system must automatically be reconnected/returned to 'on-road' mode when the ignition (start) device is again set to the "on" (run) position;

4.5.4. the vehicles user's handbook provided by the manufacturer should warn the driver of the consequences of manual disconnection or mode change of the anti-lock system;

4.5.5. the device referred to in paragraph **4.5.** above may, in conjunction with the towing vehicle, disconnect/change the control mode of the anti-lock system of the trailer. A separate device for the trailer alone is not permitted.

5. SPECIAL PROVISIONS CONCERNING POWER-DRIVEN VEHICLES.

5.1. Energy consumption

Power-driven vehicles equipped with anti-lock systems must maintain their performance when the service braking control device is fully applied for long periods. Compliance with this requirement shall be verified by means of the following tests:

All footnotes to Annex 13 can be found at the end of this Annex (p8)

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 must be isolated.

5.1.1.2. From an initial speed of not less than **50 km/h**, on a surface with a coefficient of **adhesion** of **0.3** [6/] 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 must remain under control of the anti-lock system throughout that time.

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

5.1.1.4. The service braking control device shall then be **fully** actuated **4** times in succession with the vehicle stationary.

5.1.1.5. When the control device is applied for the **5th** time, it must 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 power-driven vehicle authorized to draw a trailer equipped with a compressed-air braking system, the supply line shall be stopped and an energy storage device of **0.5 litre** capacity shall be connected to the pneumatic control line - if fitted - (in accordance with paragraph **1.2.2.3.** of **Annex 7A** to this Regulation). When the brakes are applied for the **5th** time, as provided in paragraph **5.1.1.5.** above, the energy level supplied to the pneumatic 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 shall be measured with the vehicle under test, by the method described in paragraph **1.1.** of **Appendix 2** to this Annex.

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 determined by the formula:

$$t = \frac{V_{max}}{7}$$ (but not less than **15 seconds**)

where t is expressed in seconds and v_{max} represents the maximum design speed of the vehicle expressed in km/h, with an upper limit of **160 km/h**.

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 **4** in all.

All footnotes to Annex 13 can be found at the end of this Annex (p8)

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 **2nd** 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 paragraph **5.1.1.4.** (and **5.1.1.5.** , **5.1.1.6.** and **5.1.2.6.**) of this Annex for each of the **2nd , 3rd and 4th** phases used in the test prescribed in paragraph **5.1.1**. of this Annex, as applicable.

5.1.2.6. The performance prescribed in paragraph **5.1.1.5.** of this Annex 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. Utilization of adhesion

5.2.1. The utilization of adhesion by the anti-lock system takes into account the actual increase in braking distance beyond the theoretical minimum. The anti-lock system shall be deemed to be satisfactory when the condition $\varepsilon \geq 0.75$ is satisfied, where ε represents the adhesion utilized, as defined in paragraph **1.2.** of **Appendix 2** to this Annex.

5.2.2. The adhesion utilization ε shall be measured on road surfaces with a coefficient of adhesion of **0.3** [6/] **or less**, and of about **0.8** (dry road), with an initial speed of **50 km/h**. To eliminate the effects of differential brake temperatures it is recommended that z_{AL} be determined prior to the determination of **k**.

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

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

5.2.5. The condition $\varepsilon \geq 0.75$ shall be checked with the vehicle **laden and unladen**.[13/]
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 system.
For the unladen test, the control force may be increased up to **100 daN** if no cycling is achieved with its full force value [7/]. **If 100 daN** 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 system must not lock when the **full force** [7/] is suddenly applied on the control device, on the road surfaces specified in paragraph **5.2.2.** of this Annex, at an initial speed of **40 km/h** and at a high initial speed as indicated in the table below: [9/]

All footnotes to Annex 13 can be found at the end of this Annex (p8)

	Vehicle category	**Maximum test speed**
High-Adhesion	- All categories except N_2 , N_3 laden	$0.8\ V_{MAX} \leq 120$ km/h

Surface	- N_2 , N_3 laden	0.8 V_{MAX} ≤ 80 km/h
Low-Adhesion Surface	- N_1	0.8 V_{MAX} ≤ 120 km/h
	-M_2 , M_3 N_2 except semi-trailer Tractors	0.8 V_{MAX} ≤ 80 km/h
	- N_3 and semi-trailer tractors N_2	0.8 V_{MAX} ≤ 70 km/h

5.3.2. When an axle passes from a high-adhesion surface (k_H) to a low-adhesion surface (k_L) where **$k_H \geq 0.5$** and **$k_H / k_L \geq 2$**, [10/] with the full force [7/] applied on the control device, the directly controlled wheels must not lock. The running speed and the instant of applying the brakes shall be so calculated that, with the anti-lock 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 paragraph **5.3.1.** of this Annex [9/].

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 $k_H / k_L \geq 2$**, [10/] with the full force [7/] applied on the control device, the deceleration of the vehicle must rise to the appropriate high value within a reasonable time and the vehicle must 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 system fully cycling on the low-adhesion surface, the passage from one surface to the other occurs at approximately **50 km/h**.

5.3.4. In the case of vehicles equipped with anti-lock systems of **categories 1 or 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 $k_H / k_L \geq 2$**,[10/] the directly controlled wheels must not lock when the full force [7/] is suddenly applied on the control device at a speed of **50 km/h**.

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

5.3.6. However, in the tests provided in paragraphs **5.3.1.** , **5.3.2.** , **5.3.3.** , **5.3.4.** and **5.3.5.** of this Annex, brief periods of wheel-locking shall be 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 must not be affected.

5.3.7. During the tests provided in paragraphs **5.3.4.** and **5.3.5.** of this Annex, steering correction is permitted, if the angular rotation of the steering control is within **120° during the initial 2 seconds**, and not more than **240° in all**. Furthermore, at the beginning of these tests the longitudinal median plane of the vehicle must pass over the boundary between the high- and low-adhesion surfaces and during these tests no part of the (outer) tyres must cross this boundary [13/].

All footnotes to Annex 13 can be found at the end of this Annex (p8)

6. SPECIAL PROVISIONS CONCERNING TRAILERS.

6.1. Energy consumption.

Trailers equipped with anti-lock 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 11/ and with the brakes adjusted as closely as possible and with the proportioning/load- sensing valve (if fitted) held in the "**laden**" **position** throughout the test.

6.1.2. In the case of compressed-air braking systems, the initial energy level in the energy transmission storage device(s) shall be equivalent to a pressure of **8.0 bar** at the coupling head of the trailer'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 all wheels shall remain under control of the anti-lock system. During this test, the supply to the energy transmission 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 transmission storage device(s) and, as from the **2nd** 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 paragraph **6.1.2.** of this Annex At the beginning of the following phase(s) the pressure in the reservoir(s) after application of the brakes must 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 braking, with the vehicle stationary, the service braking control device shall be fully actuated **4** times. During the **5th** application, the pressure in the operating circuit must 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 system.

6.2. Utilization of adhesion

6.2.1. Braking systems equipped with an anti-lock system shall be deemed acceptable when the condition $\varepsilon \geq 0.75$ is satisfied, where ε represents the adhesion utilized, as defined in paragraph **1.2.** of **Appendix 2** to this Annex. This condition shall be verified with the vehicle **unladen**, on a straight and level road with a surface having a good coefficient of adhesion.11/ , 12/

6.2.2. To eliminate the effects of differential brake temperatures it is **recommended to determine z_{RAL} 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 system must not lock when the full force 7/ is suddenly applied on the control device of the towing vehicle. This shall be checked, under the conditions prescribed in paragraph **6.2.** of this Annex, at initial speeds of **40 km/h and 80 km/h.**

All footnotes to Annex 13 can be found at the end of this Annex (p8)

6.3.2. The provisions of this paragraph shall only apply to trailers equipped with an anti-lock 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: $z_{RALH} / \varepsilon_H \geq 0.5$ and $z_{RALH} / z_{RALL} \geq 2$

the directly controlled wheels must not lock when the full force [5/] is suddenly applied on the control device of the towing vehicle at a speed of **50 km/h**. The ratio z_{RALH} / z_{RALL} may be ascertained by the procedure in paragraph **2.** of **Appendix 2** to this Annex or by calculating the ratio z_{RALH} / z_{RALL}. Under this condition the unladen vehicle shall satisfy the prescribed rate in **Appendix 3** to this Annex. [9/]

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, but in all cases, stability must not be affected.

FOOTNOTES to this **ANNEX :**

1/ Anti-lock 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/ The manufacturer shall provide the Technical Service with **documentation** relating to the controller(s) which follows the format set out in **Annex 18**.

3/ 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/ The **ISO 7638-1997** connector may be used for **5 pin** or **7 pin** applications, as appropriate.

5/ It is understood that devices changing the control mode of the anti-lock system are not subject to paragraph **4.5.**of this Annex if, in the changed control mode condition, all requirements for the category of anti-lock systems, with which the vehicle is equipped, are fulfilled. However in this case paragraphs **4.5.2.** , **4.5.3.** and **4.5.4.** of this Annex shall be met.

6/ 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.

7/ "**Full force**" means the maximum force laid down in **Annex 4** to this Regulation for the category of vehicle; a higher force may be used if required to activate the anti-lock system.

9/ The purpose of these tests is to check that the wheels do not lock and that the vehicle remains stable; it is not necessary, therefore, to make complete stops and bring the vehicle to a halt on the low-adhesion surface.

10/ k_H is the high-adhesion surface coefficient.
k_L is the low-adhesion surface coefficient.
k_H and k_L are measured as laid down in **Appendix 2** to this Annex.

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

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

13/ Until a uniform test procedure is established, the tests required by paragraphs **5.2.5**.& **5.3.7**. may have to be **repeated** for vehicles equipped with **electrical regenerative braking systems**, in order to determine the effect of different braking distribution values provided by automatic functions on the vehicle.

Annex 13 - Appendix 1

SYMBOLS AND DEFINITIONS

	TABLE: SYMBOLS AND DEFINITIONS
SYMBOL	NOTES
E	Wheelbase.
E_R	Distance between king-pin and centre of axle or axles of semi-trailer (or distance between drawbar coupling and centre of axle or axles of centre-axle trailer).
ε	the adhesion utilized of the vehicle: quotient of the maximum braking rate with the anti-lock system operative (Z_{AL}) and the coefficient of adhesion (k).
ε_i	the ε - value measured on axle i (in the case of a power-driven vehicle with a category 3 anti-lock system).
ε_H	the ε - value on the high-adhesion surface.
ε_L	The ε - value on the low-adhesion surface.
F	force (N).
F_{bR}	Braking force of the trailer with the anti-lock system inoperative.
F_{bRmax}	Maximum value of F_{bR}.
F_{bRmaxi}	value of F_{bRmax} with only axle i of the trailer braked.
F_{bRAL}	Braking force of the trailer with the anti-lock system operative.
F_{Cnd}	total normal reaction of road surface on the unbraked and non-driven axles of the vehicle combination under static conditions.
F_{Cd}	total normal reaction of road surface on the unbraked and driven axles of the vehicle combination under static conditions.
F_{dyn}	Normal reaction of road surface under dynamic conditions with the anti-lock system operative.
F_{idyn}	F_{dyn} on axle i in case of power-driven vehicles or full trailers.
F_i	Normal reaction of road surface on axle i under static conditions.

	TABLE: SYMBOLS AND DEFINITIONS
SYMBOL	NOTES
F_M	total normal static reaction of road surface on all wheels of power-driven (towing) vehicle.
F_{Mnd} */	total normal static reaction of road surface on the unbraked and non-driven axles of the power-driven vehicle.
F_{Md} */	total normal static reaction of road surface on the unbraked and driven axles of the power-driven vehicle.
F_R	total normal static reaction of road surface on all wheels of trailer.
F_{Rdyn}	total normal dynamic reaction of road surface on the axle(s) of semi-trailer or centre-axle trailer.
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 trailer).
h_K	Height of fifth wheel coupling (king pin).
h_R	Height of centre of gravity of the trailer.
K	Coefficient of adhesion between tyre and road.
k_f	k-factor of one front axle.
k_H	k-value determined on the high-adhesion surface.
k_i	k-value determined on axle i for a vehicle with a category 3 anti-lock system.
k_L	k-value determined on the low-adhesion surface.
k_{lock}	Value of adhesion for 100 % slip.
k_M	k – factor of the power-driven vehicle.
k_{peak}	Maximum value of the curve "adhesion versus slip".
k_r	k – factor of one rear axle.
k_R	k – factor of the trailer.

*/ F_{Mnd} and F_{Md} in case of two-axled motor vehicles: these may be simplified to corresponding F_i - symbols.

	TABLE: SYMBOLS AND DEFINITIONS
SYMBOL	NOTES
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.
z_{AL}	Braking rate z of the vehicle with the anti-lock system operative.
z_c	Braking rate z of the vehicle combination, with the trailer only braked and the anti-lock system inoperative.
z_{CAL}	Braking rate z of the vehicle combination, with the trailer only braked and the anti-lock system operative.
z_{cmax}	Maximum value of z_c .
z_{cmaxi}	Maximum value of z_c with only axle i of the trailer braked.
z_m	Mean braking rate.
z_{max}	Maximum value of z.
z_{MALS}	z_{AL} of the power-driven vehicle on a "split surface".
z_R	Braking rate z of the trailer with the anti-lock system inoperative.
z_{RAL}	z_{AL} of the trailer obtained by braking all the axles, the towing vehicle unbraked and its engine disengaged.
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.

Annex 13 - Appendix 2

UTILIZATION OF ADHESION

1. METHOD OF MEASUREMENT FOR POWER-DRIVEN VEHICLES.

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 on only 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 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 will 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:

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

z_{max} is the maximum value of z and **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 **3** 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 **3** values defined above cannot be obtained, then the minimum time **t_{min} may be utilized**. However, the requirements of paragraph **1.3.** below shall still apply.

1.1.4. The braking forces shall be calculated from the measured braking rate and the **rolling resistance** of the unbraked 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 that given by the formulae in **Annex 10** to this Regulation.

1.1.6. The value of k shall be rounded to **3** decimal places.

1.1.7. Then, the test will be repeated for the other axle(s) as defined in paragraphs **1.1.1.** to **1.1.6.** above (for exemptions see paragraphs **1.4.** and **1.5.** below).

1.1.8. For example, in the case of a two-axle rear-wheel drive vehicle, with the front axle (1) being braked, the coefficient of adhesion (k) is given by:

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

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

1.2. Determination of the adhesion utilized (ε)

1.2.1. The adhesion utilized (ε) is defined as the quotient of the maximum braking rate with the anti-lock 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**, the maximum braking rate (z_{AL}) shall be measured with **full cycling** of the anti-lock braking system and based on the average value of **3** tests, as in paragraph **1.1.3.** of this Appendix, 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.

$$k_M = \frac{k_f \cdot F_{f\,dyn} + k_r \cdot F_{r\,dyn}}{P \cdot g}$$

where:

$$F_{f\,dyn} = F_f + \frac{h}{E} \cdot z_{AL} \cdot P \cdot g$$

$$F_{r\,dyn} = F_r - \frac{h}{E} \cdot z_{AL} \cdot P \cdot g$$

1.2.4. The value of ε shall be rounded to **2** decimal places.

1.2.5. In the case of a vehicle equipped with an anti-lock system of categories **1 or 2**, the value of z_{AL} will be based on the whole vehicle, with the anti-lock system in operation, and the adhesion utilized (ε) is given by the same formula quoted in paragraph **1.2.1.** of this Appendix.

1.2.6. In the case of a vehicle equipped with an anti-lock system of **category 3**, the value of z_{AL} will be measured on each axle which has at least one directly controlled wheel. For example, for a two-axle rear-wheel drive vehicle with an anti-lock system acting only on the rear axle (2), the adhesion utilized (ε) is given by:

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

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

1.3. If **ε > 1.00** the measurements of coefficients of adhesion shall be repeated.
A tolerance of **10%** is accepted.

1.4. For **power-driven vehicles** equipped with three axles, only the axle not associated with a close-coupled bogie will be used to establish a k value for the vehicle. 1/

1.5. For vehicles of categories **N_2 and N_3** with a wheelbase less than **3.80 m** and with **h/E ≥ 0.25** the determination of the coefficient of adhesion for the rear axle will be omitted.

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

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

2. METHOD OF MEASUREMENT FOR TRAILERS.

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 trailer 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 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 trailer only braked. During each test, a constant input force shall be maintained and the braking rate will 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**.

1/ Until a uniform test procedure is agreed, vehicles with more than three axles and special vehicles will be subject to consultation with the Technical Service.

2.1.3.2. Starting from the minimum measured value of t, called t_{min} , select **3 values of t** comprised within t_{min} and 1.05 t_{min} and calculate their arithmetical mean value t_m , then calculate

$$z_{Cmax} = \frac{0.566}{t_m}$$

If it is demonstrated that for practical reasons the **3** values defined above cannot be obtained, then the minimum time t_{min} may be utilized.

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

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

The k value has to be determined according to paragraph **2.2.3.** of this Appendix for full trailers or paragraph **2.3.1.** of this Appendix for semi-trailers respectively.

2.1.5. If ε **> 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 towing vehicle unbraked, based on the average value of **3 tests**, as in paragraph **2.1.3.** of this Appendix.

2.2. Full trailers

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

For one **front axle** i:

$$F_{bRmaxi} = z_{Cmaxi}(F_M + F_R) - 0.01\,F_{Cnd} - 0.015\,F_{Cd}$$

$$F_{i\,dyn} = F_i + \frac{z_{Cmax\,i}\,(F_M \cdot h_D + g \cdot P \cdot h_R) - F_{WM} \cdot h_D}{E}$$

$$k_f = \frac{F_{bRmaxi}}{F_{idyn}}$$

For **one rear axle** i:

$$F_{bRmaxi} = z_{Cmaxi}(F_M + F_R) - 0.01\,F_{Cnd} - 0.015\,F_{Cd}$$

$$F_{i\,dyn} = F_i - \frac{z_{Cmaxi}\,(F_M \cdot h_D + g \cdot P \cdot h_R) - F_{WM} \cdot h_D}{E}$$

$$k_r = \frac{F_{bRmaxi}}{F_{i\,dyn}}$$

2.2.2. The values of k_f and k_r will be rounded to **3** decimal places.

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

$$k_R = \frac{k_f \cdot F_{f\,dyn} + k_r \cdot F_{r\,dyn}}{P \cdot g}$$

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

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

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

2.3. Semi-trailers and centre-axle trailers

2.3.1. The measurement of k (with the anti-lock 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.

$$F_{bRmax} = z_{Cmax} \cdot (F_M + F_R) - F_{WM}$$

$$F_{Rdyn} = F_R - \frac{F_{bRmax} \cdot h_K + z_{C\,max} \cdot g \cdot P(h_R - h_K)}{E_R}$$

$$k = \frac{F_{bRmax}}{F_{Rdyn}}$$

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

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

$$F_{Rdyn} = F_R - \frac{F_{bRAL} \cdot h_K + z_{C\,AL} \cdot g \cdot P(h_R - h_K)}{E_R}$$

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

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

Lucas Note : (z_{RAL} values are determined for use in paragraph **2.2.** of **Appendix 3**.)

Annex 13 - Appendix 3

PERFORMANCE ON DIFFERING-ADHESION SURFACES

1. Power-driven vehicles

1.1. The prescribed braking rate referred to in paragraph **5.3.5.** 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 must satisfy the conditions prescribed in paragraph **5.3.4.** 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 paragraph **1.1.** of Appendix 2 to this Annex.

1.3. The braking rate (z_{MALS}) for laden power-driven vehicles shall be:

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

2. Trailers

2.1. The braking rate referred to in paragraph **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 system operative. These two surfaces must satisfy the conditions prescribed in paragraph **6.3.2.** of this Annex.

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

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

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

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

Annex 13 - Appendix 4

METHOD OF SELECTION OF THE LOW-ADHESION SURFACES

1. Details of the coefficient of adhesion of the surface selected, as defined in paragraph **5.1.1.2.** of this Annex, must be given to the Technical Service.

1.1. These data must include a curve of the coefficient of adhesion versus slip (from 0 to 100% slip) for a speed of approximately **40 km/h**. 1/

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 **1** decimal place.

1.1.4. The surface to be used must have a ratio **R** between **1.0** and **2.0**. 11/

2. Prior to the tests, the Technical Service shall ensure that the selected surface meets the specified requirements and shall be informed of the following:

(a) test method to determine R,
(b) type of vehicle (power-driven vehicle, trailer, ...),
(c) 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.

1/ 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 such vehicles, the ratio k_{peak} to k_{lock} shall be established using a value of k_{peak} as defined in **Appendix 2** of this Annex.
With the consent of the Technical Service the coefficient of adhesion described in this paragraph may be determined by another method provided that the equivalence of the values of k_{peak} and k_{lock} are demonstrated.