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PROPOSAL FOR DRAFT AMANDMENTS TO REGULATION No. 90
(Replacement brake linings)

Transmitted by the expert of the Federation of
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Note: The text reproduced below was prepared by the expert from FEMFM in order to strengthen some prescriptions of the Regulation.

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

A. PROPOSAL

Annex 3,

Paragraph 2.1.2.1., amend to read:

" ... from each of the following speeds:

Front axle: 65 km/h down to 30 km/h
100 km/h down to 50 km/h
135 km/h down to 65 km/h (where v_{max} exceeds 150 km/h).

Rear axle: 45 km/h down to 20 km/h
65 km/h down to 30 km/h
90 km/h down to 45 km/h (where v_{max} exceeds 150 km/h)."

Paragraph 2.2.4.1., amend to read:

" ... corresponding to vehicle linear speeds as given in the table below:

Vehicle category	Test speed in km/h	
	Front axle	Rear axle
M1	75 down to 35 115 down to 60	80 down to 35 115 down to 55
	where vmax exceeds 150 km/h:	
	150 down to 65	150 down to 60
M2	80 down to 40 120 down to 60	70 down to 35 100 down to 50
	where vmax exceeds 150 km/h:	
	150 down to 45	135 down to 65
N1	80 down to 35 120 down to 55	70 down to 25 105 down to 50
	where vmax exceeds 150 km/h:	
	150 down to 35	145 down to 75

"

Annex 4,

Paragraphs 2.1.1.1. and 2.1.1.2. (including the addition of a footnote 1/), amend to read:

"2.1.1.1. The rotational mass of the dynamometer shall correspond to half the axle portion of 0.55 of the maximum vehicle mass and the dynamic rolling radius of the tyre 1/.

2.1.1.2. The initial dynamometer rotational speed shall correspond to the linear vehicle speed as stated in paragraphs below and shall be based on the dynamic rolling radius of the tyre 1/.

1/ The condition to cover the worst case as agreed with the technical service responsible for conducting the approval tests".

Paragraph 2.2.3.1., amend to read:

" ... from each of the following speeds:

55 km/h down to 30 km/h
80 km/h down to 50 km/h and
110 km/h down to 85 km/h (if $v_{max} \geq 90$ km/h)."

* * *

B. JUSTIFICATION

Re. annex 3 paras. 2.1.2.1.,2.2.4.1. and annex 4 paragraph 2.2.3.1.:

A significant number of approvals to Regulation No.90 have been granted. As the tests for these approvals were carried out, it became apparent that some simplifications of the requirements introduced to facilitate the practical use of the Regulation were too extreme, particularly in the speed sensitivity tests. To demonstrate these unacceptable simplifications, the following mathematical solutions should be examined.

Symbols

v_t	Vehicle test speed
v_{tB}	Vehicle test speed at the beginning of braking
v_{tE}	Vehicle test speed at the end of braking
v_p	Speed on the dynamometer
v_{pB}	Speed on the dynamometer at the start of braking
v_{pE}	Speed on the dynamometer at the end of braking
M	Total vehicle mass
m_a	Mass assigned to the test axle on the dynamometer
I	Inertia of the dynamometer
r	Tyre rolling radius
ω	Angular speed on dynamometer
E_v	Energy destroyed by the vehicle test
E_D	Energy destroyed by the dynamometer test

From:

$$E_V = E_D = ½ M v_t^2 = ½ m_a v_p^2 \qquad (1)$$

results:

$$v_t = v_p (m_a/M)^{½} \qquad (2)$$

we can say:

$$\frac{1}{2} M v_t^2 = \frac{1}{2} I \omega^2 \qquad (3)$$

Insert (2) in (3) and use (4):

$$I = m_a r^2 \qquad (4)$$

to give:

$$\frac{1}{2} M v_p^2 m_a/M = \frac{1}{2} m_a r^2 \omega^2 \qquad (5)$$

or:

$$v_p^2 = r^2 \omega^2 \qquad (6)$$

or:

$$v_p = r \omega \qquad (7)$$

This is valid.

No contradictions between vehicle and dynamometer tests can occur, if the test conditions in Regulation No. 90 are calculated on the basis of these equations.

This would also be valid for "check-braking". In this case:

$$E_V = \frac{1}{2} M (v_{tB}^2 - v_{tE}^2) \qquad (8)$$

and

$$E_D = \frac{1}{2} m_a (v_{pB}^2 - v_{pE}^2) = \frac{1}{2} I (\omega_B^2 - \omega_E^2) \qquad (9)$$

We introduce a Factor F, which is the quotient of the real energy levels destroyed by the Vehicle test E_V and on the Dynamometer test E_D. This means:

$$F = E_V / E_D \qquad (10)$$

From (10), which under ideal conditions would equate to "1", from (8) and (9) the following can be derived:

$$F = [(v_{tB}^2 - v_{tE}^2)/(v_{pB}^2 - v_{pE}^2)] : (m_a/M) \qquad (11)$$

The designated axle portions m_a/M are listed in the table under paragraph 2.2.2.1. of annex 3 and under paragraph 2.1.1.1. of annex 4. The relevant speeds are listed in paragraphs 2.1.1.1., 2.1.2.1., 2.2.3.1.,and 2.2.4.1 of annex 3 and in paragraphs 1.2.2.1.1., 1.2.2.2.1., 2.2.1.1., and 2.2.3.1. of annex 4. Using these values in equation (11), table 1 can be generated.

In table 1 - Type of Test Column:

‘C’ denotes cold performance test
‘S’ denotes speed sensitivity test
‘F’ denotes front conditions
‘R’ denotes rear conditions

Table 1

Vehicle category	Type of Test	v_{tB} [km/h]	v_{tE} [km/h]	v_{pB} [km/h]	v_{pE} [km/h]	m_a/M	F
M1	C,F	70	0	80	0	0,77	0,994
M1	C,R	45	0	80	0	0,32	0,989
M2	C,F	50	0	60	0	0,69	1,006
M2	C,R	40	0	60	0	0,44	1,010
N1	C,F	65	0	80	0	0,66	1,000
N1	C,R	50	0	80	0	0,39	1,002
M1	S,F	65	0	75	0	0,77	0,975
M1	S,R	45	0	75	0	0,32	1,125
M1	S,F	100	0	120	0	0,77	0,902
M1	S,R	65	0	120	0	0,32	0,917
M1	S,F	135	0	160	0	0,77	0,925
M1	S,R	90	0	160	0	0,32	0,989
M2	S,F	65	0	75	0	0,69	1,089
M2	S,R	45	0	75	0	0,44	0,818
M2	S,F	100	0	120	0	0,69	1,006
M2	S,R	65	0	120	0	0,44	0,667
M2	S,F	135	0	160	0	0,69	1,032
M2	S,R	90	0	160	0	0,44	0,719
N1	S,F	65	0	75	0	0,66	1,138
N1	S,R	45	0	75	0	0,39	0,923
N1	S,F	100	0	120	0	0,66	1,052
N1	S,R	65	0	120	0	0,39	0,752
N1	S,F	135	0	160	0	0,66	1,079
N1	S,R	90	0	160	0	0,39	0,811
M3,N2,N3	C, F and R	45	0	60	0	0,55	1,023
M3,N2,N3	S, F and R	40	20	60	30	0,55	0,808
M3,N2,N3	S, F and R	60	40	80	60	0,55	1,299
M3,N2,N3	S, F and R	80	60	110	80	0,55	0,893

By inspection the conditions for the "cold performance equivalence test (C)" are acceptable, the results for the "speed sensitivity test (S)" suggest a modification is necessary because they do not approach the ideal value of “1” in many cases.

Modification is called for on four counts:

I The deviation which occurs between energy levels, encountered from time to time, during a stop on a vehicle and the equivalent stop on dynamometer; even though the brake friction material tested on the dynamometer should be experiencing the same level of work as on the vehicle during a specific test.

II It is well understood that pure speed sensitivity is not quantifiable because of the overlap of speed and temperature effects. To minimise this effect „check braking“ is commonly employed during speed sensitivity testing rather than full stops.

III In Regulation No. 90, Annex 4 "check braking“ is specified for speed sensitivity evaluation. Following the reason in “II” it is logical and consistent to change Regulation No 90, annex 3 to the „check braking“ method for speed sensitivity evaluation as in annex 4.

IV It has been observed that even some OE materials fail to meet speed sensitivity requirements in annex 3. It therefore appears logical to rationalise the energy levels called for.

In the revised test it is proposed that:

i Cold performance tests, C, remain unchanged.

ii Initial vehicle test speeds, v_{tB}, in all tests remain unchanged.

iii The final speed, v_{tE}, in the "speed sensitivity" test on the vehicle is half the initial speed, v_{tB}, rounded up to nearest 5 km/h in the direction of greatest energy consumption, except for M3, N2 and N3 vehicles where the final speed given in Regulation No. 90 is still utilised.

iv The proposed change from full vehicle stops to „check-braking“ results in an energy reduction on each brake application of some 25 per cent. We consider this to be acceptable because deviations of more than 30% occur between vehicle and dynamometer tests, as shown in table 1.

v The initial dynamometer speeds, v_{pB}, were calculated from equation 2 using initial vehicle speed, v_{tB}, [unchanged], and also m_a/M values, except for initial speeds where v_{max} exceeds 150km/h. In these cases v_{max} of 150 km/h should be used and not the 160 km/h currently specified in Regulation No. 90. All values of v_{pB} have been rounded up to the nearest 5 km/h.

vi The final dynamometer speeds, v_{pE}, have been calculated to ensure that the energy dissipated on vehicle and dynamometer tests correspond as closely as possible to each other by resolving equation 11 and equating the factor “F“ (Energy destroyed on vehicle/Energy destroyed on dynamometer) to “1” and rounding the speed up to the nearest 5 km/h.

From these considerations table 2 can be generated.

Table 2

Vehicle category	Type of Test	v_{tB} [km/h]	v_{tE} [km/h]	v_{pB} [km/h]	v_{pE} [km/h]	m_a/M	F
M1	C,F	70	0	80	0	0,77	0,994
M1	C,R	45	0	80	0	0,32	0,989
M2	C,F	50	0	60	0	0,69	1,006
M2	C,R	40	0	60	0	0,44	1,010
N1	C,F	65	0	80	0	0,66	1,000
N1	C,R	50	0	80	0	0,39	1,002
M1	S,F	65	30	75	35	0,77	0,981
M1	S,R	45	20	80	35	0,32	0,981
M1	S,F	100	50	115	60	0,77	1,012
M1	S,R	65	30	115	55	0,32	1,019
M1	S,F	135	65	150	65	0,77	0,995
M1	S,R	90	45	150	60	0,32	1,004
M2	S,F	65	30	80	40	0,69	1,004
M2	S,R	45	20	70	35	0,44	1,005
M2	S,F	100	50	120	60	0,69	1,006
M2	S,R	65	30	100	50	0,44	1,008
M2	S,F	135	65	150	45	0,69	0,991
M2	S,R	90	45	135	65	0,44	0,986
N1	S,F	65	30	80	35	0,66	0,974
N1	S,R	45	20	70	25	0,39	0,975

N1	S,F	100	50	120	55	0,66	0,999
N1	S,R	65	30	105	50	0,39	1,000
N1	S,F	135	65	150	35	0,66	0,997
N1	S,R	90	45	145	75	0,39	1,011
M3,N2,N3	C, F and R	45	0	60	0	0,55	1,023
M3,N2,N3	S, F and R	40	20	55	30	0,55	1,027
M3,N2,N3	S, F and R	60	40	80	50	0,55	0,932
M3,N2,N3	S, F and R	80	60	110	85	0,55	1,044

By inspection, table 2 shows a significantly converging Factor “F”. In addition, it must be remembered that the temperature influence on the speed sensitivity has been reduced, annexes 3 and 4 correspond better and the danger of a failure for OE materials is diminished. On these grounds, it is recommended that the amendments be introduced to Regulation No. 90.

Re. annex 4 paras. 2.1.1.1. and 2.1.1.2.:

The current wording of the Regulation was drafted in order to cover a theoretical worst case condition by combining the highest inertia with the highest rotational speed instead of considering the different braking energy, torque and rotational speed conditions resulting from the different wheel sizes authorized for the vehicle type(s) in question. However, it was found that in cases of big differences in the tire radius this leads to unrealistic severe test conditions compared to a vehicle test that even original equipment brake linings would fail the test.

The following mathematical derivation shall explain the issue:

The dissipation of energy E_R by stopping braking of a vehicle on the road loaded with the mass M and at an initial speed v is:

$E_R = ½ M x v^2$ (1)

The relevant energy on a dyno is:

$E_D = ½ I x ù^2$ (2)

I is the inertia and ù the angular speed. It is valid:

$I = M x r^2$ (3)

and

$v= ù x r$ (4)

where r is the tyre radius. We now transfer our considerations to the largest radius r_L and to the smallest radius r_S. From (2), (3) and (4) we can introduce the relevant angular speeds, inertias and energies corresponding to the formulas:

$ù_L = v/r_L$ (5)

$I_L = M x r_L^2$ (6)

$E_{DL} = ½ I_L x ù_L^2$ (7)

$\grave{u}_s = v/r_s$ (8)

$I_s = M \times r_s^2$ (9)

$E_{DS} = ½\, I_s \times \grave{u}_s^2$ (10)

Comparison leads to the result:

$E_R = E_D = E_{DL} = E_{DS}$ (11)

This is always valid because in the case of a lower angular speed this is consistently compensated by a higher inertia and the other way round.

Now we introduce the worst cast energy E_w as it is required by the current text of the regulation:

$E_w = ½\, I_L \times \grave{u}_s^2$ (12)

By insertion of (6) and (8) in (12) we get:

$E_w = ½\, M \times v^2 \times (r_L/r_s)^2 = E_R \times f^2$ (13)

In a typical example for a N_3 truck the tyre radius may vary between 0,441m (smallest tyre) and 0,546 m (largest tyre). This means a factor f = 1,238 or an energy increase by f^2 = 1,533 equal to 53,3% which must be seen as an unacceptable correlation to the vehicle test on the road.

The proposed amendments shall provide the possibility to agree with the Technical Service on more realistic worst case conditions for the test.