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| ６．７． | United Nations | ECE/TRANS/WP.29/GRPE/2020/3 | |
| _unlogo | **Economic and Social Council** | | Distr.: General  5 November 2019  Original: English |

**Economic Commission for Europe**

Inland Transport Committee

**World Forum for Harmonization of Vehicle Regulations**

**Working Party on Pollution and Energy**

**Eightieth session**

Geneva, 14-17 January 2020

Item 3(a) of the provisional agenda

**Light vehicles: UN Regulations Nos. 68 (Measurement of the   
maximum speed, including electric vehicles), 83 (Emissions of   
M1 and N1 vehicles), 101 (CO2 emissions/fuel consumption) and   
103 (Replacement pollution control devices)**

**Proposal for a new 00 series of amendments to a new UN Regulation on uniform provisions concerning the approval of light duty passenger and commercial vehicles with regards to criteria emissions, emissions of carbon dioxide and fuel consumption and/or the measurement of electric energy consumption and electric range (WLTP)**

**Submitted by the Informal Working Group on Worldwide harmonized Light vehicles Test Procedure (WLTP)**[[1]](#footnote-2)\*

The text reproduced below was prepared by the Transposition Task Force of the Informal Working Group (IWG) on Worldwide harmonized Light vehicles Test Procedure (WLTP) in line with Phase 2 of its mandate (ECE/TRANS/WP.29/AC.3/44).

The 00 series of amendments contains two levels against which approvals can be granted; Level 1A which relates to vehicles tested using a 4-phase WLTC; and Level 1B for vehicles tested on a 3-phase WLTC.

Annex B4

Road load and dynamometer setting

4.2.1.1.2. Using an interpolation method

At the request of the manufacturer, an interpolation method may be applied.

In this case, two test vehicles shall be selected from the family complying with the respective family requirement.

Test vehicle H shall be the vehicle producing the higher, and preferably highest, cycle energy demand of that selection, test vehicle L the one producing the lower, and preferably lowest, cycle energy demand of that selection.

All items of optional equipment and/or body shapes that are chosen not to be considered when applying the interpolation method shall be identical for both test vehicles H and L such that these items of optional equipment produce the highest combination of the cycle energy demand due to their road load relevant characteristics (i.e. mass, aerodynamic drag and tyre rolling resistance).

In the case where individual vehicles can be supplied with a complete set of standard wheels and tyres and in addition a complete set of snow tyres (marked with 3 Peaked Mountain and Snowflake – 3PMS) with or without wheels, the additional wheels/tyres shall not be considered as optional equipment.

[4.2.1.1.2.1. The following requirements between vehicles H and L shall be fulfilled for that road load relevant characteristic:

(a) The following minimum differences between the vehicles H and L shall be fulfilled to allow extrapolating road load coefficients and/or test mass.

(i) To allow for the extrapolation of test mass within the constraints described in paragraph 2.3.2.3. of Annex B6 and paragraph 4.5.1.4. of Annex B8, the following minimum difference between H and L is required:

Mass of at least 30 kg;

(ii) To allow for the extrapolation of road load coefficient f0 within the constraints described in paragraph 2.3.2.3. of Annex B6 and paragraph 4.5.1.4. of Annex B8, the following minimum differences between H and L are required:

Rolling resistance of at least 1.0 kg/tonne and a mass of at least 30 kg; in case of RR between 0 and 1.0, the minimum of the mass difference is replaced with 100 kg instead of 30 kg;

(iii) To allow for the extrapolation of road load coefficient f2 within the constraints described in paragraph 2.3.2.3. of Annex B6 and paragraph 4.5.1.4. of Annex B8, the following minimum difference between H and L is required:

Aerodynamic drag (CD × Af) of at least 0.05 m².

If the manufacturer can demonstrate that the results after an extrapolation are still rational, the minimum criteria in points (i) to (iii) above can be waived.

(b) For each road load characteristic (i.e. mass, aerodynamic drag and tyre rolling resistance) as well as for the road load coefficients f0 and f2, the value of vehicle H shall be higher than that of vehicle L, otherwise the worst case shall be applied for that road load relevant characteristic. At the request of the manufacturer and upon approval by the responsible authority the requirements of this point can be waived.

4.2.1.1.2.2. To achieve a sufficient difference between vehicle H and vehicle L on a particular road load relevant characteristic, or in order to fulfil criteria of paragraph 4.2.1.1.2.1. of this annex, the manufacturer may artificially worsen vehicle H, e.g. by applying a higher test mass.]

4.3. Measurement and calculation of road load using the coastdown method

The road load shall be determined by using either the stationary anemometry (paragraph 4.3.1. of this annex) or the on-board anemometry (paragraph 4.3.2. of this annex) method.

4.3.1. Coastdown method using stationary anemometry

4.3.1.1. Selection of reference speeds for road load curve determination

Reference speeds for road load determination shall be selected according to paragraph 2.2. of this annex.

4.3.1.2. Data collection

During the test, elapsed time and vehicle speed shall be measured at a minimum frequency of 10 Hz.

4.3.1.3. Vehicle coastdown procedure

4.3.1.3.1. Following the vehicle warm-up procedure described in paragraph 4.2.4. of this annex and immediately prior to each coastdown run, the vehicle shall be accelerated to 10 to 15 km/h above the highest reference speed and shall be driven at that speed for a maximum of 1 minute. After that, the coastdown run shall be started immediately.

4.3.1.3.2. During a coastdown run, the transmission shall be in neutral. Any movement of the steering wheel shall be avoided as much as possible, and the vehicle brakes shall not be operated.

4.3.1.3.3. The test shall be repeated until the coastdown data satisfy the statistical precision requirements as specified in paragraph 4.3.1.4.2. of this annex.

4.3.1.3.4. Although it is recommended that each coastdown run should be performed without interruption, if data cannot be collected in a single run for all the reference speed points, the coastdown test may be performed with coastdown runs where the first and last reference speeds are not necessarily the highest and lowest reference speeds. In this case, the following additional requirements shall apply:

(a) At least one reference speed in each coastdown run shall overlap with the immediately higher speed range coastdown run. This reference speed shall be referred to as a split point;

(b) At each overlapped reference speed, the average force of the immediately lower speed coastdown run shall not deviate from the average force of the immediately higher speed coastdown run by ±10 N or ± 5 per cent, whichever is greater;

(c) Overlapped reference speed data of the lower speed coastdown run shall be used only for checking criterion (b) and shall be excluded from evaluation of the statistical precision as defined in paragraph 4.3.1.4.2. of this annex;

(d) The overlapped speed may be less than 10 km/h but shall not be less than 5 km/h. In this case, overlap criterion (b) shall be checked by either extrapolating the polynomial curves for the lower and higher speed segment to a 10 km/h overlap, or by comparing the average force in the specific speed range.

4.3.1.3.5. It is recommended that coastdown runs should be conducted successively without undue delay between runs. If there is a delay between runs (e.g. for a driver break, checking vehicle integrity, etc.), the vehicle shall be warmed up again as described in paragraph 4.2.4. and the coastdown runs shall be re-commenced from this point.

4.3.1.4. Coastdown time measurement

4.3.1.4.1. The coastdown time corresponding to reference speed as the elapsed time from vehicle speed () to () shall be measured.

4.3.1.4.2. These measurements shall be carried out in opposite directions until a minimum of three pairs of measurements have been obtained that satisfy the statistical precision pj defined in the following equation:

where:

is the statistical precision of the measurements made at reference speed vj;

is the number of pairs of measurements;

is the harmonic average of the coastdown time at reference speed vj in seconds given by the following equation:

where:

is the harmonic average coastdown time of the ith pair of measurements at velocity vj, seconds, s, given by the following equation:

where:

and are the coastdown times of the ith measurement at reference speed vj, in seconds, s, in the respective directions a and b;

is the standard deviation, expressed in seconds, s, defined by:

σj

is a coefficient given in Table A4/4.

Table A4/4

**Coefficient h as a function of n**

|  |  |  |  |
| --- | --- | --- | --- |
| *n* | *h* | *n* | *h* |
| 3 | 4.3 | 17 | 2.1 |
| 4 | 3.2 | 18 | 2.1 |
| 5 | 2.8 | 19 | 2.1 |
| 6 | 2.6 | 20 | 2.1 |
| 7 | 2.5 | 21 | 2.1 |
| 8 | 2.4 | 22 | 2.1 |
| 9 | 2.3 | 23 | 2.1 |
| 10 | 2.3 | 24 | 2.1 |
| 11 | 2.2 | 25 | 2.1 |
| 12 | 2.2 | 26 | 2.1 |
| 13 | 2.2 | 27 | 2.1 |
| 14 | 2.2 | 28 | 2.1 |
| 15 | 2.2 | 29 | 2.0 |
| 16 | 2.1 | 30 | 2.0 |

4.3.1.4.3. If during a measurement in one direction any external factor or driver action occurs that obviously influences the road load test, that measurement and the corresponding measurement in the opposite direction shall be rejected. All the rejected data and the reason for rejection shall be recorded, and the number of rejected pairs of measurement shall not exceed 1/3 of the total number of measurement pairs. In the case of split runs, the rejection criteria shall be applied at each split run speed range.

Due to uncertainty of data validity and for practical reasons, more than the minimum number of run pairs required in paragraph 4.3.1.4.2. of this annex may be performed, but the total number of run pairs shall not exceed 30 runs including the rejected pairs as described in this paragraph. In this case, data evaluation shall be carried out as described in paragraph 4.3.1.4.2. of this annex starting from the first run pair, then including as many consecutive run pairs as needed to reach the statistical precision on a data set containing no more than 1/3 of rejected pairs. The remaining run pairs shall be disregarded.

4.3.1.4.4. The following equation shall be used to compute the arithmetic average of the road load where the harmonic average of the alternate coastdown times shall be used:

where:

Δv is 5 km/h;

is the harmonic average of alternate coastdown time measurements at velocity , seconds, s, given by:

where:

and are the harmonic average coastdown times in directions a and b, respectively, corresponding to reference speed , in seconds, s, given by the following two equations:

and:

.

where:

is the arithmetic average of the test vehicle masses at the beginning and end of road load determination, kg;

is the equivalent effective mass of rotating components according to paragraph 2.5.1. of this annex;

The coefficients, , and in the road load equation shall be calculated with a least squares regression analysis.

In the case that the tested vehicle is the representative vehicle of a road load matrix family, the coefficient f1 shall be set to zero and the coefficients f0 and f2 shall be recalculated with a least squares regression analysis.

4.5. Correction to reference conditions and measurement equipment

4.5.1. Air resistance correction factor

The correction factor for air resistance K2 shall be determined using the following equation:

where:

is the arithmetic average atmospheric temperature of all individual runs, Kelvin (K);

is the arithmetic average atmospheric pressure, kPa.

4.5.2. Rolling resistance correction factor

The correction factor for rolling resistance, in Celsius-1 (°C-1), may be determined based on empirical data and approved by the responsible authority for the particular vehicle and tyre combination to be tested, or may be assumed to be as follows:

4.5.3. Wind correction

4.5.3.1. Wind correction when using stationary anemometry

Wind correction may be waived when the arithmetic average wind speed for each valid run pair is 2 m/s or less. In the case that wind speed is measured at more than one part of the test track, such as when the test is performed on an oval test track (see paragraph 4.1.1.1.1. of this annex), the wind speed shall be averaged at each measurement location and the higher of two average wind speeds shall be used to determine whether a wind speed correction is to be applied or may be waived.

4.5.3.1.1. The wind correction resistance for the coastdown method or for the torque meter method shall be calculated using the following equations:

or:

where:

is the wind correction resistance for the coastdown method, N;

is the coefficient of the aerodynamic term determined according to paragraph 4.3.1.4.4. of this annex;

in the case that wind speed is measured at only one point, vw is the arithmetic average vector component of the wind speed parallel to the test road during all valid run pairs m/s;

in the case that the wind speed is measured at two points, vw is the lower of the two arithmetic average vector components of the wind speed parallel to the test road during all valid run pairs, m/s;

is the wind correction resistance for the torque meter method, Nm;

is the coefficient of the aerodynamic term for the torque meter method determined according to paragraph 4.4.4. of this annex.

4.5.3.2. Wind correction when using on-board anemometry

In the case that the coastdown method is based on on-board anemometry, w1 and w2 in the equations in paragraph 4.5.3.1.1. of this annex shall be set to zero, as the wind correction is already applied according to paragraph 4.3.2. of this annex.

4.5.4. Test mass correction factor

The correction factor for the test mass of the test vehicle shall be determined using the following equation:

where:

is the test mass of the test vehicle, kg;

is the arithmetic average of the test vehicle masses at the beginning and end of road load determination, kg.

4.5.5. Road load curve correction

4.5.5.1. The curve determined in paragraph 4.3.1.4.4. of this annex shall be corrected to reference conditions as follows:

where:

is the corrected road load, N;

is the constant road load coefficient, N;

is the first order road load coefficient, N/(km/h);

is the second order road load coefficient, N/(km/h)2;

is the correction factor for rolling resistance as defined in paragraph 4.5.2. of this annex;

is the test mass correction as defined in paragraph 4.5.4. of this annex;

is the correction factor for air resistance as defined in paragraph 4.5.1. of this annex;

is the arithmetic average atmospheric temperature during all valid run pairs, °C;

is vehicle velocity, km/h;

is the wind resistance correction as defined in paragraph 4.5.3. of this annex, N.

The result of the calculation below shall be used as the target road load coefficient At in the calculation of the chassis dynamometer load setting described in paragraph 8.1. of this annex:

The result of the calculation below shall be used as the target road load coefficient Bt in the calculation of the chassis dynamometer load setting described in paragraph 8.1. of this annex:

(f1 × (1 + K0 × (T-20))).

The result of the calculation below shall be used as the target road load coefficient Ct in the calculation of the chassis dynamometer load setting described in paragraph 8.1. of this annex:

(K2 × f2).

4.5.5.2. The curve determined in paragraph 4.4.4. of this annex shall be corrected to reference conditions and measurement equipment installed according to the following procedure.

4.5.5.2.1. Correction to reference conditions

where:

is the corrected running resistance, Nm;

is the constant term as determined in paragraph 4.4.4. of this annex, Nm;

is the coefficient of the first order term as determined in paragraph 4.4.4. of this annex, Nm/(km/h);

is the coefficient of the second order term as determined in paragraph 4.4.4. of this annex, Nm/(km/h)2;

is the correction factor for rolling resistance as defined in paragraph 4.5.2. of this annex;

is the test mass correction as defined in paragraph 4.5.4. of this annex;

is the correction factor for air resistance as defined in paragraph 4.5.1. of this annex;

is the vehicle velocity, km/h;

T is the arithmetic average atmospheric temperature during all valid run pairs, °C;

is the wind correction resistance as defined in paragraph 4.5.3. of this annex.

4.5.5.2.2. Correction for installed torque meters

If the running resistance is determined according to the torque meter method, the running resistance shall be corrected for effects of the torque measurement equipment installed outside the vehicle on its aerodynamic characteristics.

The running resistance coefficient c2 shall be corrected using the following equation:

c2corr = K2 × c2 × (1 + (∆(CD × Af))/(CD’ × Af’))

where:

∆(CD × Af) = (CD × Af) - (CD’ × Af’) ;

CD’ × Af’ is the product of the aerodynamic drag coefficient multiplied by the frontal area of the vehicle with the torque meter measurement equipment installed measured in a wind tunnel fulfilling the criteria of paragraph 3.2. of this annex, m²;

CD × Af is the product of the aerodynamic drag coefficient multiplied by the frontal area of the vehicle with the torque meter measurement equipment not installed measured in a wind tunnel fulfilling the criteria of paragraph 3.2. of this annex, m².

4.5.5.2.3. Target running resistance coefficients

The result of the calculation below shall be used as the target running resistance coefficient at in the calculation of the chassis dynamometer load setting described in paragraph 8.2. of this annex:

The result of the calculation below shall be used as the target running resistance coefficient bt in the calculation of the chassis dynamometer load setting described in paragraph 8.2. of this annex:

(c1 × (1 + K0 × (T-20))).

The result of the calculation below shall be used as the target running resistance coefficient ct in the calculation of the chassis dynamometer load setting described in paragraph 8.2. of this annex:

(c2corr × r).

6. Wind tunnel method

The wind tunnel method is a road load measurement method using a combination of a wind tunnel and a chassis dynamometer or of a wind tunnel and a flat belt dynamometer. The test benches may be separate facilities or integrated with one another.

6.1. Measurement method

6.1.1. The road load shall be determined by:

(a) adding the road load forces measured in a wind tunnel and those measured using a flat belt dynamometer; or

(b) adding the road load forces measured in a wind tunnel and those measured on a chassis dynamometer.

6.1.2. Aerodynamic drag shall be measured in the wind tunnel.

6.1.3. Rolling resistance and drivetrain losses shall be measured using a flat belt or a chassis dynamometer, measuring the front and rear axles simultaneously.

6.2. Approval of the facilities by the responsible authority

The results of the wind tunnel method shall be compared to those obtained using the coastdown method to demonstrate qualification of the facilities and recorded.

6.2.1. Three vehicles shall be selected by the responsible authority. The vehicles shall cover the range of vehicles (e.g. size, weight) planned to be measured with the facilities concerned.

6.2.2. Two separate coastdown tests shall be performed with each of the three vehicles according to paragraph 4.3. of this annex, and the resulting road load coefficients, f0, f1 and f2, shall be determined according to that paragraph and corrected according to paragraph 4.5.5. of this annex. The coastdown test result of a test vehicle shall be the arithmetic average of the road load coefficients of its two separate coastdown tests. If more than two coastdown tests are necessary to fulfil the approval of facilities' criteria, all valid tests shall be averaged.

6.2.3. Measurement with the wind tunnel method according to paragraphs 6.3. to 6.7. inclusive of this annex shall be performed on the same three vehicles as selected in paragraph 6.2.1. of this annex and in the same conditions, and the resulting road load coefficients, f0, f1 and f2, shall be determined.

If the manufacturer chooses to use one or more of the available alternative procedures within the wind tunnel method (i.e. paragraph 6.5.2.1. on preconditioning, paragraphs 6.5.2.2. and 6.5.2.3. on the procedure, including paragraph 6.5.2.3.3. on dynamometer setting), these procedures shall also be used also for the approval of the facilities.

6.2.4. Approval criteria

The facility or combination of facilities used shall be approved if both of the following two criteria are fulfilled:

1. The difference in cycle energy, expressed as εk, between the wind tunnel method and the coastdown method shall be within ±0.05 for each of the three vehicles k according to the following equation:

where:

εk is the difference in cycle energy over a complete Class 3 WLTC for vehicle k between the wind tunnel method and the coastdown method, per cent;

Ek,WTM is the cycle energy over a complete Class 3 WLTC for vehicle k, calculated with the road load derived from the wind tunnel method (WTM) calculated according to paragraph 5. of Annex B7, J;

Ek,coastdown is the cycle energy over a complete Class 3 WLTC for vehicle k, calculated with the road load derived from the coastdown method calculated according to paragraph 5. of Annex B7, J.; and

1. The arithmetic average of the three differences shall be within 0.02.

The approval shall be recorded by the responsible authority including measurement data and the facilities concerned.

The facility may be used for road load determination for a maximum of two years after the approval has been granted.

Each combination of roller chassis dynamometer or moving belt and wind tunnel shall be approved separately.

Every combination of wind speeds (see paragraph 6.4.3. of this annex) used for the determination of road load values shall be validated separately.

6.3. Vehicle preparation and temperature

Conditioning and preparation of the vehicle shall be performed according to paragraphs 4.2.1. and 4.2.2. of this annex and applies to both the flat belt or roller chassis dynamometers and the wind tunnel measurements.

In the case that the alternative warm-up procedure described in paragraph 6.5.2.1. of this annex is applied, the target test mass adjustment, the weighing of the vehicle and the measurement shall all be performed without the driver in the vehicle.

The flat belt or the chassis dynamometer test cells shall have a temperature set point of 20 °C with a tolerance of ±3 °C. At the request of the manufacturer, the set point may also be 23 °C with a tolerance of ±3 °C.

6.4. Wind tunnel procedure

6.4.1. Wind tunnel criteria

The wind tunnel design, test methods and the corrections shall provide a value of (CD × Af) representative of the on-road (CD × Af) value and with a repeatability of ±0.015 m².

For all (CD × Af) measurements, the wind tunnel criteria listed in paragraph 3.2. of this annex shall be met with the following modifications:

(a) The solid blockage ratio described in paragraph 3.2.4. of this annex shall be less than 25 per cent;

(b) The belt surface contacting any tyre shall exceed the length of that tyre's contact area by at least 20 per cent and shall be at least as wide as that contact patch;

(c) The standard deviation of total air pressure at the nozzle outlet described in paragraph 3.2.8. of this annex shall be less than 1 per cent;

(d) The restraint system blockage ratio described in paragraph 3.2.10. of this annex shall be less than 3 per cent;

(e) Additionally to the requirement defined in paragraph 3.2.11. of this annex, when measuring Class 1 vehicles, the precision of the measured force shall not exceed ±2.0 N.

6.4.2. Wind tunnel measurement

The vehicle shall be in the condition described in paragraph 6.3. of this annex.

The vehicle shall be placed parallel to the longitudinal centre line of the tunnel with a maximum tolerance of ±10 mm.

The vehicle shall be placed with a yaw angle of 0 ° within a tolerance of ±0.1°.

Aerodynamic drag shall be measured for at least for 60 seconds and at a minimum frequency of 5 Hz. Alternatively, the drag may be measured at a minimum frequency of 1 Hz and with at least 300 subsequent samples. The result shall be the arithmetic average of the drag.

Prior to a test it shall be checked that at the aerodynamic force measured at a wind speed of 0 km/h yields a result equal to 0 Newtons.

In the case that the vehicle has movable aerodynamic body parts, paragraph 4.2.1.5. of this annex shall apply. Where movable parts are velocity-dependent, every applicable position shall be measured in the wind tunnel and evidence shall be provided to the responsible authority indicating the relationship between reference speed, movable part position, and the corresponding (CD × Af).

6.4.3. Wind speeds for wind tunnel measurement

The aerodynamic force shall be measured at two wind speeds under the following speed conditions:

(a) Class 1 vehicles

Lower wind speed *vlow* to measure aerodynamic force shall be *vlow* < 80 km/h;

Higher wind speed *vhigh* shall be (*vlow*+ 40 km/h*≤* *vhigh* *≤* 150 km/h).

(b) Class 2 and 3 vehicles

Lower wind speed *vlow* to measure aerodynamic force shall be 80 km/h*≤* *vlow* *≤* 100 km/h;

Higher wind speed shall be (*vlow*+ 40 km/h*≤* *vhigh* *≤* 150 km).

6.5. Flat belt applied for the wind tunnel method

6.5.1. Flat belt criteria

6.5.1.1. Description of the flat belt test bench

The wheels shall rotate on flat belts that do not change the rolling characteristics of the wheels compared to those on the road. The measured forces in the x-direction shall include the frictional forces in the drivetrain.

6.5.1.2. Vehicle restraint system

The dynamometer shall be equipped with a centring device aligning the vehicle within a tolerance of ±0.5 degrees of rotation around the z-axis. The restraint system shall maintain the centred drive wheel position throughout the coastdown runs of the road load determination within the following limits:

6.5.1.2.1. Lateral position (y-axis)

The vehicle shall remain aligned in the y-direction and lateral movement shall be minimised.

6.5.1.2.2. Front and rear position (x-axis)

Additional to the requirement of paragraph 6.5.1.2.1. of this annex, both wheel axes shall be within ±10 mm of the belt’s lateral centre lines.

6.5.1.2.3. Vertical force

The restraint system shall be designed so as to impose no vertical force on the drive wheels.

6.5.1.3. Accuracy of measured forces

Only the reaction force for turning the wheels shall be measured. No external forces shall be included in the result (e.g. force of the cooling fan air, vehicle restraints, aerodynamic reaction forces of the flat belt, dynamometer losses, etc.).

The force in the x-direction shall be measured with an accuracy of ±5 N.

6.5.1.4. Flat belt speed control

The belt speed shall be controlled with an accuracy of ±0.1 km/h.

6.5.1.5. Flat belt surface

The flat belt surface shall be clean, dry and free from foreign material that might cause tyre slippage.

6.5.1.6. Cooling

A current of air of variable speed shall be blown towards the vehicle. The set point of the linear velocity of the air at the blower outlet shall be equal to the corresponding dynamometer speed above measurement speeds of 5 km/h. The linear velocity of the air at the blower outlet shall be within ±5 km/h or ±10 per cent of the corresponding measurement speed, whichever is greater.

6.5.2. Flat belt measurement

The measurement procedure may be performed according to either paragraph 6.5.2.2. or paragraph 6.5.2.3. of this annex.

6.5.2.1. Preconditioning

The vehicle shall be conditioned on the dynamometer as described in paragraphs 4.2.4.1.1. to 4.2.4.1.3. inclusive of this annex.

The dynamometer load setting Fd for the preconditioning shall be:

where:

ad = 0

bd = f1a;

The equivalent inertia of the dynamometer shall be the test mass.

The aerodynamic drag used for the load setting shall be taken from paragraph 6.7.2. of this annex and may be set directly as input. Otherwise, ad, bd, and cd from this paragraph shall be used.

At the request of the manufacturer, as an alternative to paragraph 4.2.4.1.2. of this annex, the warm-up may be conducted by driving the vehicle with the flat belt.

In this case, the warm-up speed shall be 110 per cent of the maximum speed of the applicable WLTC. The warm up is considered complete when the vehicle has been driven for at least 1,200 seconds and the change of measured force over a period of 200 seconds is less than 5 N.

6.5.2.2. Measurement procedure with stabilised speeds

6.5.2.2.1. The test shall be conducted from the highest to the lowest reference speed point.

6.5.2.2.2. Immediately after the measurement at the previous speed point, the deceleration from the current to the next applicable reference speed point shall ­be performed in a smooth transition of approximately 1 m/s².

6.5.2.2.3. The reference speed shall be stabilised for at least 4 seconds and for a maximum of 10 seconds. The measurement equipment shall ensure that the signal of the measured force is stabilised after that period.

6.5.2.2.4. The force at each reference speed shall be measured for at least 6 seconds while the vehicle speed is kept constant. The resulting force for that reference speed point FjDyno shall be the arithmetic average of the force during the measurement.

6.5.2.2.5. The steps in paragraphs 6.5.2.2.2. to 6.5.2.2.4. inclusive of this annex shall be repeated for each reference speed.

6.5.2.3. Measurement procedure by deceleration

6.5.2.3.1. Preconditioning and dynamometer setting shall be performed according to paragraph 6.5.2.1. of this annex. Prior to each coastdown, the vehicle shall be driven at the highest reference speed or, in the case that the alternative warm-up procedure is used at 110 per cent of the highest reference speed, for at least 1 minute. The vehicle shall be subsequently accelerated to at least 10 km/h above the highest reference speed and the coastdown shall be started immediately.

6.5.2.3.2. The measurement shall be performed according to paragraphs 4.3.1.3.1. to 4.3.1.4.4. inclusive of this annex but exclusive 4.3.1.4.2.. and are considered since coasting down is performed in only one directions. The measurement shall be stopped after two decelerations if the force of both coastdowns at each reference speed point is within ±10 N, otherwise at least three coastdowns shall be performed using the criteria set out in paragraph 4.3.1.4.2. of this annex.

6.5.2.3.3. The force fjDyno at each reference speed vj shall be calculated by removing the dynamometer set force:

where:

fjDecel is the force determined according to the equation calculating Fj in paragraph 4.3.1.4.4. of this annex at reference speed point j, N;

is the force determined to the equation calculating Fj in paragraph 6.5.2.1. of this annex at reference speed point j, N.

Alternatively, at the request of the manufacturer, cd may be set to zero during the coastdown and for calculating fjDyno.

6.5.2.4. Measurement conditions

The vehicle shall be in the condition described in paragraph 4.3.1.3.2. of this annex.

6.5.3. Measurement result of the flat belt method

The result of the flat belt dynamometer fjDyno shall be referred to as fj for the further calculations in paragraph 6.7. of this annex.

6.6. Chassis dynamometer applied for the wind tunnel method

6.6.1. Criteria

In addition to the descriptions in paragraphs 1. and 2. of Annex B5, the criteria described in paragraphs 6.6.1.1. to 6.6.1.6. shall apply.

6.6.1.1. Description of a chassis dynamometer

The front and rear axles shall be equipped with a single roller with a diameter of not less than 1.2 metres.

6.6.1.2. Vehicle restraint system

The dynamometer shall be equipped with a centring device aligning the vehicle. The restraint system shall maintain the centred drive wheel position within the following recommended limits throughout the coastdown runs of the road load determination:

6.6.1.2.1. Vehicle position

The vehicle to be tested shall be installed on the chassis dynamometer roller as defined in paragraph 7.3.3. of this annex.

6.6.1.2.2. Vertical force

The restraint system shall fulfil the requirements of paragraph 6.5.1.2.3. of this annex.

6.6.1.3. Accuracy of measured forces

The accuracy of measured forces shall be as described in paragraph 6.5.1.3. of this annex apart from the force in the x-direction that shall be measured with an accuracy as described in paragraph 2.4.1. of Annex B5.

6.6.1.4. Dynamometer speed control

The roller speeds shall be controlled with an accuracy of ±0.2 km/h.

6.6.1.5. Roller surface

The roller surface shall be clean, dry and free from foreign material that might cause tyre slippage.

6.6.1.6. Cooling

The cooling fan shall be as described in paragraph 6.5.1.6. of this annex.

6.6.2. Dynamometer measurement

The measurement shall be performed as described in paragraph 6.5.2. of this annex.

6.6.3. Correcting measured chassis dynamometer forces to those on a flat surface

The measured forces on the chassis dynamometer shall be corrected to a reference equivalent to the road (flat surface) and the result shall be referred to as fj.

where:

c1 is the tyre rolling resistance fraction of fjDyno;

c2 is a chassis dynamometer-specific radius correction factor;

fjDyno is the force calculated in paragraph 6.5.2.3.3. of this annex for each reference speed j, N;

RWheel is one-half of the nominal design tyre diameter, m;

RDyno is the radius of the chassis dynamometer roller, m.

The manufacturer and the responsible authority shall agree on the factors c1 and c2 to be used, based on correlation test evidence provided by the manufacturer for the range of tyre characteristics intended to be tested on the chassis dynamometer.

As an alternative the following conservative equation may be used:

C2 shall be 0.2 except that 2.0 shall be used if the road load delta method (see paragraph 6.8. of this annex) is used and the road load delta calculated according to paragraph 6.8.1. of this annex is negative.

6.7. Calculations

6.7.1. Correction of the flat belt and chassis dynamometer results

The measured forces determined in paragraphs 6.5. and 6.6. of this annex shall be corrected to reference conditions using the following equation:

where:

is the corrected resistance measured at the flat belt or chassis dynamometer at reference speed j, N;

is the measured force at reference speed j, N;

is the correction factor for rolling resistance as defined in paragraph 4.5.2. of this annex, K-1;

is the test mass correction as defined in paragraph 4.5.4. of this annex, N;

T is the arithmetic average temperature in the test cell during the measurement, K.

6.7.2. Calculation of the aerodynamic force

The calculation in paragraph 6.7.2.1. shall be applied considering the results of both wind speeds. However, if the difference of the product of the drag coefficient and frontal area measured at the wind speeds vlow and vhigh is less than 0.015 m², the calculation in paragraph 6.7.2.2. may be applied at the request of the manufacturer.

6.7.2.1. The aerodynamic force of each wind speed , , and shall be calculated using the equation below.

where:

is the product of the drag coefficient and frontal area measured in the wind tunnel at a certain reference speed point j, if applicable, m²;

is the dry air density defined in paragraph 3.2.10. of this Regulation, kg/m³;

is the aerodynamic force calculated at wind speed w, N;

vw is the applicable wind speed, km/h.

is the reference to the applicable wind speed "0wind", "low" and "high";

is the aerodynamic force at 0 km/h, N;

is the aerodynamic force at vlow, N;

is the aerodynamic force at vhigh, N.

The aerodynamic force coefficients and shall be calculated with a least square regression analysis using , , and and the equation below:

The final result for the aerodynamic force FAj shall be calculated with the equation below at each reference speed point vj. If the vehicle is equipped with velocity-dependent movable aerodynamic body parts, the corresponding aerodynamic force shall be applied for the reference speed points concerned.

6.7.2.2. The aerodynamic force shall be calculated using the equation below, where the final of that wind speed shall be used, that is also used for determination of optional equipment within the interpolation method. If the vehicle is equipped with velocity-dependent movable aerodynamic body parts, the corresponding (CD × Af) values shall be applied for the reference speed points concerned.

where:

is the aerodynamic force calculated at reference speed j, N;

is the product of the drag coefficient and frontal area measured in the wind tunnel at a certain reference speed point j, if applicable, m²;

is the dry air density defined in paragraph 3.2.10. of this Regulation, kg/m³;

vj is the reference speed j, km/h.

6.7.3. Calculation of road load values

The total road load as a sum of the results of paragraphs 6.7.1 and 6.7.2. of this annex shall be calculated using the following equation:

for all applicable reference speed points j, N.

For all calculated, the coefficients f0, f1 and f2 in the road load equation shall be calculated with a least squares regression analysis and shall be used as the target coefficients in paragraph 8.1.1. of this annex.

In the case that the vehicle tested according to the wind tunnel method is representative of a road load matrix family vehicle, the coefficient f1 shall be set to zero and the coefficients f0 and f2 shall be recalculated with a least squares regression analysis.

8. Chassis dynamometer load setting

8.1. Chassis dynamometer load setting using the coastdown method

This method is applicable when the road load coefficients f0, f1 and f2 have been determined.

In the case of a road load matrix family, this method shall be applied when the road load of the representative vehicle is determined using the coastdown method described in paragraph 4.3. of this annex. The target road load values are the values calculated using the method described in paragraph 5.1. of this annex.

8.1.1. Initial load setting

For a chassis dynamometer with coefficient control, the chassis dynamometer power absorption unit shall be adjusted with the arbitrary initial coefficients, , and , of the following equation:

where:

is the chassis dynamometer setting load, N;

is the speed of the chassis dynamometer roller, km/h.

The following are recommended coefficients to be used for the initial load setting:

(a)

for single-axis chassis dynamometers, or

for dual-axis chassis dynamometers, where , and are the target road load coefficients;

(b) Empirical values, such as those used for the setting for a similar type of vehicle.

For a chassis dynamometer of polygonal control, adequate load values at each reference speed shall be set to the chassis dynamometer power absorption unit.

8.1.2. Coastdown

The coastdown test on the chassis dynamometer shall be performed with the procedure given in paragraphs 8.1.3.4.1. or 8.1.3.4.2. of this annex and shall start no later than 120 seconds after completion of the warm-up procedure. Consecutive coastdown runs shall be started immediately. At the request of the manufacturer and with approval of the responsible authority, the time between the warm-up procedure and coastdowns using the iterative method may be extended to ensure a proper vehicle setting for the coastdown. The manufacturer shall provide the responsible authority with evidence for requiring additional time and evidence that the chassis dynamometer load setting parameters (e.g. coolant and/or oil temperature, force on a dynamometer) are not affected.

8.1.3. Verification

8.1.3.1. The target road load value shall be calculated using the target road load coefficient, , and for each reference speed, :

where:

At, Bt and Ct are the target road load parameters;

is the target road load at reference speed , N;

is the jth reference speed, km/h.

8.1.3.2. The measured road load shall be calculated using the following equation:

where:

Δv is 5 km/h;

Fmj is the measured road load for each reference speed vj, N;

TM is the test mass of the vehicle, kg;

mr is the equivalent effective mass of rotating components according to paragraph 2.5.1. of this annex, kg;

∆tj is the coastdown time corresponding to speed vj, s.

8.1.3.3. The coefficients As, Bs and Cs in the road load equation of the simulated road load on the chassis dynamometer shall be calculated using a least squares regression analysis:

The simulated road load for each reference speed vj shall be determined using the following equation, using the calculated As, Bs and Cs:

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8.1.3.4. For dynamometer load setting, two different methods may be used. If the vehicle is accelerated by the dynamometer, the methods described in paragraph 8.1.3.4.1. of this annex shall be used. If the vehicle is accelerated under its own power, the methods in paragraphs 8.1.3.4.1. or 8.1.3.4.2. of this annex shall be used and the minimum acceleration multiplied by speed shall be 6 m²/sec³. Vehicles which are unable to achieve 6 m2/s3 shall be driven with the acceleration control fully applied.

8.1.3.4.1. Fixed run method

8.1.3.4.1.1. The dynamometer software shall perform a total of four coastdowns. From the first coastdown, the dynamometer setting coefficients for the second run shall be calculated according to paragraph 8.1.4. of this annex. Following the first coastdown, the software shall perform three additional coastdowns with either the fixed dynamometer setting coefficients determined after the first coastdown or the adjusted dynamometer setting coefficients according to paragraph 8.1.4. of this annex.

8.1.3.4.1.2. The final dynamometer setting coefficients A, B and C shall be calculated using the following equations:

where:

At, Bt and Ct are the target road load parameters;

, and are the simulated road load coefficients of the nth run;

, and are the dynamometer setting coefficients of the nth run;

n is the index number of coastdowns including the first stabilisation run.

8.1.3.4.2. Iterative method

The calculated forces in the specified speed ranges shall either be within ±10 N after a least squares regression of the forces for two consecutive coastdowns when compared with the target values, or additional coastdowns shall be performed after adjusting the chassis dynamometer load setting according to paragraph 8.1.4. of this annex until the tolerance is satisfied.

8.1.4. Adjustment

The chassis dynamometer setting load shall be adjusted according to the following equations:

Therefore:

where:

Fdj is the initial chassis dynamometer setting load, N;

is the adjusted chassis dynamometer setting load, N;

Fj is the adjustment road load equal to , N;

Fsj is the simulated road load at reference speed vj, N;

Ftj is the target road load at reference speed vj, N;

, and are the new chassis dynamometer setting coefficients.

8.1.5. At, Bt and Ct shall be used as the final values of f0, f1 and f2, and shall be used for the following purposes:

(a) Determination of downscaling, paragraph 8. of Annex B1;

(b) Determination of gearshift points, Annex B2;

(c) Interpolation of CO2 and fuel consumption, paragraph 3.2.3. of Annex B7;

(d) Calculation of results of electric and hybrid-electric vehicles, paragraph 4. of Annex B8.

8.2. Chassis dynamometer load setting using the torque meter method

This method is applicable when the running resistance is determined using the torque meter method described in paragraph 4.4. of this annex.

In the case of a road load matrix family, this method shall be applied when the running resistance of the representative vehicle is determined using the torque meter method as specified in paragraph 4.4. of this annex. The target running resistance values are the values calculated using the method specified in paragraph 5.1. of this annex.

8.2.1. Initial load setting

For a chassis dynamometer of coefficient control, the chassis dynamometer power absorption unit shall be adjusted with the arbitrary initial coefficients, , and , of the following equation:

where:

is the chassis dynamometer setting load, N;

is the speed of the chassis dynamometer roller, km/h.

The following coefficients are recommended for the initial load setting:

(a)

For single-axis chassis dynamometers, or

For dual-axis chassis dynamometers, where:

, and are the target running resistance coefficients; and

is the dynamic radius of the tyre on the chassis dynamometer obtained at 80 km/h, m, or

(b) Empirical values, such as those used for the setting for a similar type of vehicle.

For a chassis dynamometer of polygonal control, adequate load values at each reference speed shall be set for the chassis dynamometer power absorption unit.

8.2.2. Wheel torque measurement

The torque measurement test on the chassis dynamometer shall be performed with the procedure defined in paragraph 4.4.2. of this annex. The torque meter(s) shall be identical to the one(s) used in the preceding road test.

8.2.3. Verification

8.2.3.1. The target running resistance (torque) curve shall be determined using the equation in paragraph 4.5.5.2.1. of this annex and may be written as follows:

8.2.3.2. The simulated running resistance (torque) curve on the chassis dynamometer shall be calculated according to the method described and the measurement precision specified in paragraph 4.4.3.2. of this annex, and the running resistance (torque) curve determination as described in paragraph 4.4.4. of this annex with applicable corrections according to paragraph 4.5. of this annex, all with the exception of measuring in opposite directions, resulting in a simulated running resistance curve:

The simulated running resistance (torque) shall be within a tolerance of ±10 N×r’ from the target running resistance at every speed reference point where r’ is the dynamic radius of the tyre in metres on the chassis dynamometer obtained at 80 km/h.

If the tolerance at any reference speed does not satisfy the criterion of the method described in this paragraph, the procedure specified in paragraph 8.2.3.3. of this annex shall be used to adjust the chassis dynamometer load setting.

8.2.3.3. Adjustment

The chassis dynamometer load setting shall be adjusted using the following equation:

therefore:

where:

is the new chassis dynamometer setting load, N;

Fej is the adjustment road load equal to (Fsj-Ftj), Nm;

is the simulated road load at reference speed vj, Nm;

is the target road load at reference speed vj, Nm;

, and are the new chassis dynamometer setting coefficients;

r’ is the dynamic radius of the tyre on the chassis dynamometer obtained at 80 km/h, m.

Paragraphs 8.2.2. and 8.2.3. of this annex shall be repeated until the tolerance in paragraph 8.2.3.2. of this annex is met.

8.2.3.4. The mass of the driven axle(s), tyre specifications and chassis dynamometer load setting shall be recorded when the requirement of paragraph 8.2.3.2. of this annex is fulfilled.

8.2.4. Transforming running resistance coefficients to road load coefficients f0, f1, f2

8.2.4.1. If the vehicle does not coast down in a repeatable manner and a vehicle coastdown mode according to paragraph 4.2.1.8.5. of this annex is not feasible, the coefficients f0, f1 and f2 in the road load equation shall be calculated using the equations in paragraph 8.2.4.1.1. of this annex. In any other case, the procedure described in paragraphs 8.2.4.2. to 8.2.4.4. inclusive of this annex shall be performed.

8.2.4.1.1.

where:

c0, c1, c2 are the running resistance coefficients determined in paragraph 4.4.4. of this annex, Nm, Nm/(km/h), Nm/(km/h)²;

r is the dynamic tyre radius of the vehicle with which the running resistance was determined, m;

1.02 is an approximate coefficient compensating for drivetrain losses.

8.2.4.1.2. The determined f0, f1, f2 values shall not be used for a chassis dynamometer setting or any emission or range testing. They shall be used only in the following cases:

(a) Determination of downscaling, paragraph 8. of Annex B1;

(b) Determination of gearshift points, Annex B2;

(c) Interpolation of CO2 and fuel consumption, paragraph 3.2.3 of Annex B7;

(d) Calculation of results of electric and hybrid-electric vehicles, paragraph 4. of Annex B8.

8.2.4.2. Once the chassis dynamometer has been set within the specified tolerances, a vehicle coastdown procedure shall be performed on the chassis dynamometer as outlined in paragraph 4.3.1.3. of this annex. The coastdown times shall be recorded.

8.2.4.3. The road load Fj at reference speed vj, N, shall be determined using the following equation:

where:

Fj is the road load at reference speed vj, N;

TM is the test mass of the vehicle, kg;

mr is the equivalent effective mass of rotating components according to paragraph 2.5.1. of this annex, kg;

∆v = 5 km/h

∆tj is the coastdown time corresponding to speed vj, s.

8.2.4.4. The coefficients f0, f1 and f2 in the road load equation shall be calculated with a least squares regression analysis over the reference speed range.

1. \* \* In accordance with the programme of work of the Inland Transport Committee for 2020 as outlined in proposed programme budget for 2020 (A/74/6 (part V sect. 20) para 20.37), the World Forum will develop, harmonize and update UN Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate. [↑](#footnote-ref-2)