Transmitted by Chair of the Development of the Test Procedure (DTP) sub-group of the Worldwide harmonized Light vehicles Test Procedure (WLTP) informal working group

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Introductory notes:

1. Spelling: The *Concise Oxford English Dictionary*, twelfth edition, is the current authority for spelling in the United Nations.

2. Decimal points: Thousands are separated by a comma, decimal places are indicated by a point. Example: 12,345.67 Nm.

3. Square brackets indicate text or numerical values which are currently being developed or have yet to be approved by various working groups including the Vehicle Propulsion Sytem Definitions (VPSD) group. Additional details to the bracketed items can be found in the file "WLTP-2013-020 Consolidated Draft GTR 20.05.2013" available on the CIRCABC site.

B. TEXT OF REGULATION

B.1. PURPOSE

[This regulation aims at providing a world-wide harmonised method to determine the levels of gaseous and particulate emissions, fuel or energy consumption, and electric range from light-duty vehicles under different conditions in a repeatable and reproducible manner designed to be representative of real world vehicle operation. The results will provide the basis for the regulation of these vehicles within regional type approval and certification procedures.]

B. TEXT OF REGULATION

B.2. SCOPE/APPLICATION

[This regulation applies to the measurement of the emission of gaseous and particulate species, fuel and/or energy consumption and electric range from vehicles of categories 1-2 and 2, having a maximum mass not exceeding 3 500 kg and from all vehicles of category 1-1.]

B.3. DEFINITIONS

EQUIPMENT

"Accuracy" means the difference between a measured value and a reference value, traceable to a national standard and describes the correctness of a result; See Figure 2;

"Calibration" means the process of setting a measurement system's response so that its output agrees with a range of reference signals. Contrast with "verification";

"Calibration gas" means a purified gas mixture used to calibrate gas analysers;

"Delay time" means the difference in time between the change of the component to be measured at the reference point and a system response of 10 per cent of the final reading (t_{10}) with the sampling probe being defined as the reference point. For gaseous components, this is the transport time of the measured component from the sampling probe to the detector. See Figure 1;

"Dew point" means a measure of humidity stated as the equilibrium temperature in °C or K at which water condenses under a given pressure from moist air with a given absolute humidity;

"Double dilution method" means the process of separating a part of the diluted exhaust flow and mixing it with an appropriate amount of dilution air prior to the particulate sampling filter;

"Full-flow exhaust dilution system" means the continuous dilution of the total vehicle exhaust with ambient air in a controlled manner using a constant volume sampler;

"Single dilution method" means the process of mixing the total exhaust flow with dilution air prior to separating a fraction of the diluted exhaust stream for analysis;

"Linearisation" means the application of a range of concentrations or materials to establish a mathematical relationship between concentration and system response;

"Non-methane hydrocarbons (NMHC)" means the sum of all hydrocarbon species excluding methane;

"Non-oxygenated hydrocarbons (HC)" means compounds that consist of hydrogen and carbon only;

"Non-methane, non-ethanol organic gases (NMNEOG)" means NMHC minus ethanol plus formaldehyde plus acetaldehyde;

"ppm" means parts per million on a volume basis;

"Precision" means the degree to which repeated measurements under unchanged conditions show the same results (Figure 2). In this GTR, precision requirements always refer to one standard deviation.

“Reference value” means a value traceable to a national standard. See Figure 2;

"Response time" means the difference in time between the change of the component to be measured at the reference point and a system response of 90 per cent of the final reading (t_{90}) with the sampling probe being defined as the reference point, whereby the change of the measured component is at least 60 per cent full scale (FS) and takes place in less than 0.1 second. The system response time consists of the delay time to the system and of the rise time of the system. See Figure 1;

"Rise time" means the difference in time the 10 per cent and 90 per cent response of the final reading ($t_{90} – t_{10}$). See Figure 1;

“Set point” means the target value which a control system aims to reach;

"Span" means to adjust an instrument so that it gives a proper response to a calibration standard that represents between 75 per cent and 100 per cent of the maximum value in the instrument range or expected range of use;

"Span gas" means a purified gas mixture used to span gas analysers;

“Total hydrocarbons (THC)” means all hydrocarbon compounds measurable by a flame ionisation detector (FID);

"Transformation time" means the difference in time between the change of the component to be measured at the reference point and a system response of 50 per cent of the final reading (t_{50}) with the sampling probe being defined as the reference point. See Figure 1;

"Verification" means to evaluate whether or not a measurement system's outputs agrees with a ~~range of~~ applied reference signals to within one or more predetermined thresholds for acceptance;

"Zero gas" means a gas containing no analyte which is used to set a zero response on an analyser;

~~["to zero" means to adjust an instrument so it gives a zero response to a zero calibration standard];~~

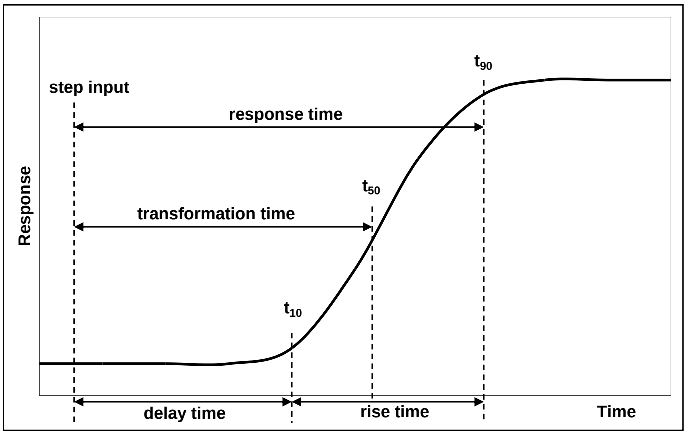


Figure 1: Definitions of system response

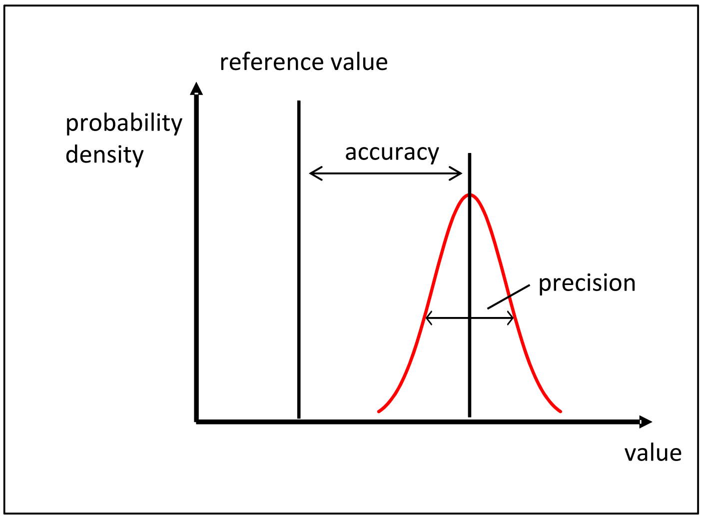


Figure 2: Definition of accuracy, precision and reference value

ROAD AND DYNAMOMETER LOAD

"Aerodynamic drag" means the force that opposes a vehicle's forward motion through air;

"Aerodynamic stagnation point" means the point on the surface of a vehicle where wind velocity is equal to zero;

["Best case test vehicle"];

"Chassis dynamometer load setting" means the load to be set on the power absorption unit of the chassis dynamometer;

"Chassis dynamometer using coefficient control" means a chassis dynamometer whose power absorption characteristics are determined by coefficients of a road-load approximation polynomial of second order;

"Chassis dynamometer using polygonal control" means a chassis dynamometer whose power absorption characteristics are determined by load values at several speed points;

"Dynamometer operation mode" means the mode in which the vehicle must be set for proper and representative testing on a chassis dynamometer;

["Highest aerodynamic drag vehicle"];

"On-board anemometry" means measurement of wind speed and direction with an anemometer installed on the test vehicle;

"Reference atmospheric conditions" with regards to road load measurements means the atmospheric conditions to which these measurement results are corrected:
(a) atmospheric pressure: p_0 = 100 kPa, unless otherwise specified by regulations;
(b) atmospheric temperature: T_0 = 293 K, unless otherwise specified by regulations;

(c) dry air density: ρ_0 = 1,189 kg/m^3, unless otherwise specified by regulations;
(d) wind speed: 0 m/s;

[“Reference speed” means the vehicle speed at which a chassis dynamometer load is verified. Reference speeds may be continuous speed points covering the complete cycle speed range];

"Road load" means the opposition to the movement of a vehicle. It is the total resistance if using the coastdown method or the running resistance if using the torque meter method;

“Rolling resistance” means the forces in the drivetrain and tyres opposing the motion of a vehicle;

“Running resistance” means the torque resisting the forward motion of a vehicle, measured by torque meters installed at the driven wheels of a vehicle;

“Simulated road load” means the road load calculated from measured coastdown data;

“Speed range” means the range of speed between the maximum speed of the WLTC cycle for the class of test vehicle plus 10 km/h and minimum reference speed of 15 km/h over which the coastdown test is conducted;

“Stationary anemometry” means measurement of wind speed and direction with an anemometer at a location and height above road level alongside the test road where the most representative wind conditions will be experienced;

“Target road load” means the road load to be reproduced on the chassis dynamometer;

“Total resistance” means the total force resisting movement of a vehicle, including the frictional forces in the drive-train;

[“Vehicle coastdown mode” means a special mode of operation, for example by decoupling drivetrain components from the wheels mechanically and/or electrically, enabling an accurate and repeatable road load determination and an accurate dynamometer setting];

"Wind correction" means correction of the effect of wind on road load based on input of the stationary or on-board anemometry.

["Worst case test vehicle" means the vehicle chosen for road load determination with the worst-case combination of road load-relevant characteristics such as mass, aerodynamic drag and rolling resistance];

["Best case test vehicle" means the vehicle chosen for road load determination with the best case for at least one of the road load relevant characteristics];

["Reference mass (RM)" means the unladen mass (UM) of a vehicle plus (a) 100 kg and (b) a variable mass];

[“Test mass high (TM_H)” means the highest mass of a test vehicle for road load and emissions determination];

[“Test mass low (TM_L)”];

["Unladen mass"];

["Maximum laden mass (LM)"]

VEHICLES WITH COMPLETE OR PARTIAL ELECTRIC PROPULSION

"All-electric range (AER)" in the case of OVC-HEV means the total distance travelled from the beginning of the charge-depleting test over a number of complete WLTC cycles to the point in time during the test when the combustion engine starts to consume fuel;

"All-electric range (AER)" in the case of PEV means the total distance travelled from the beginning of the charge-depleting test over a number of WLTC cycles until the break-off criteria is reached;

["Charge-depleting actual range (R_{cda})"]

"Charge-depleting cycle range (R_{cdc})" means the distance from the beginning of the charge-depleting test to the end of the last cycle prior to the cycle or cycles satisfying the break-off criteria, including the transient cycle where the vehicle may have operated in both depleting and sustaining modes;

"Charge-depleting (CD) operation condition" means an operating condition in which the energy stored in the REESS may fluctuate but, on average, decreases while the vehicle is driven until transition to charge-sustaining operation;

"Charge-depleting (CD) break-off criteria" is determined based on absolute or relative net energy change;

"Charge-sustaining (CS) operation condition" means an operating condition in which the energy stored in the REESS may fluctuate but, on average, is maintained at a neutral charging balance level while the vehicle is driven;

["Electric machine (EM)" means an energy converter transforming electric energy into mechanical energy or vice versa];

["Rechargeable electric energy storage system (REESS)" means a system storing electric energy];

"Electrified vehicle (EV)" means a vehicle with a powertrain containing at least one electric machine as an energy converter;

["Energy converter" means the part of the powertrain converting one form of energy into a different one];

["Energy storage system" means the part of the powertrain onboard of the vehicle that can store chemical, electrical or mechanical energy and which can be refilled or recharged externally and/or internally];

"Equivalent all-electric range (EAER)" means that portion of the total charge-depleting actual range (R_{CDA}) attributable to the use of electricity from the REESS over the charge-depleting range test;

["First sustaining cycle n+1" means the cycle in a series of whole cycles in charge-depleting operating condition in which the RCB break-off criteria is detected for the first time];

["Fuel cell" means an energy converter transforming chemical energy into electrical energy or viuce versa;]

["Fuel cell electric vehicle (FCEV)" means a vehicle propelled solely by a fuel cell power-train;]

["Fuel cell hybrid electric vehicle (FCHEV)" means a vehicle propelled by a fuel cell power-train and a hybrid electric powertrain;]

["Fuel cell vehicle (FCV)" means a vehicle with a powertrain containing exclusively fuel cell(s) and electric machine(s) as energy converter;]

"Hybrid mode" means an operation mode in which all installed fuel consuming engines and electric motors shall run when required;

"Highest electric energy consuming hybrid mode" means the hybrid mode with the highest electric energy consumption of all driver-selectable hybrid modes;

"Highest fuel consuming mode" means the mode with the highest fuel consumption of all driver-selectable modes;

["Hybrid electric vehicle (HEV)" means a hybrid vehicle (HV) with a powertrain containing at least one electric machine as energy converter];

["Hybrid vehicle (HV)" means a vehicle with a powertrain containing at least two different types of energy converters and two different types of energy storage systems];

"Net energy change" means the ratio of the REESS energy change, Wh, divided by the cycle energy demand of the test vehicle, Wh;

"Not off-vehicle charging (NOVC)" means that the REESS cannot be charged externally, also known as "not externally chargeable";

"NOVC-HEV" means a not off-vehicle chargeable hybrid electric vehicle;

"Off-vehicle charging (OVC)" means that the REESS can be charged externally, also known as "externally chargeable";

"OVC-HEV" means an off-vehicle charging hybrid electric vehicle;

"Pure electric mode" means operation by an electric machine only using electric energy from a REESS without fuel being consumed under any condition;

“Pure electric vehicle (PEV)” means a vehicle with a powertrain where all energy converters are electric machines and all storage systems are rechargeable electric energy storage systems (REESSs);

["Recharged energy (EAC)" means the AC electric energy which is recharged from the grid at the mains socket. In case of DC-charged vehicles, the electrical energy shall be measured between the AC-DC converter and the grid];

"REESS charge balance (RCB)" means the charge balance of the REESS measured in Ah;

"REESS correction criteria" means the RCB value (Ah) which determines if and when correction of the CO_2 and/or fuel consumption value in CS operation condition is necessary;

["Transient cycle n" means the cycle prior to the first sustaining cycle n+1 in a series of whole cycles in charge-depleting operating condition];

["First sustaining cycle n+1" is the cycle in a series of whole cycles in charge-depleting operating condition in which the RCB break-off criteria is detected for the first time];

"Utility factor" means the weighting of the CO_2 emissions and fuel consumption between the charge-depleting condition (CD) and the charge-sustaining condition (CS);

POWERTRAIN

["Bi-fuel gas(eous) vehicle" means a bi-fuel vehicle that can run on petrol and also on either LPG, NG/biomethane or hydrogen];

[“Bi-fuel vehicle” means a vehicle with a powertrain containing two separate fuel storage systems and a fuel delivery system transporting [forwarding] and that can run part-time on two different fuels and is designed to run on only one fuel at a time];
[“Bi-Fuel vehicle” means a vehicle (a) with a powertrain containing two separate fuel storage systems, each having a dedicated delivery system, and (b) which can run part-time on two different fuels but on only one fuel at a time];

["[Internal] Combustion engine ([I]CE)” means an energy converter with intermittent or continuous oxidation of combustible material];

[“Compression ignition engine” means an engine which uses the latent heat built up by compressing air inside a combustion chamber as the means for igniting fuel];
[“Compression ignition engine” means an engine in which combustion is initiated by heat produced from compression of the air in the cylinder or combustion space];

“Drivetrain” means the connected elements of the powertrain, downstream of the final energy converter;

[“Dual-fuel vehicle” means a vehicle containing a fuel delivery system blending two different fuels taken from two separated fuel storage systems, where the consumed amount of one of the fuels relative to the other one may vary depending on operation];

[“Flex-fuel vehicle” means a vehicle with one fuel storage system containing a blended fuel];

[“Fuel storage system” means a refillable chemical energy storage system on board of the vehicle];

["Gaseous fuel system" means a system composed of gaseous fuel storage, fuel delivery, metering and control components fitted to an engine in order to allow the engine to run on LPG, CNG or hydrogen as a mono-fuel, bi-fuel or multi-fuel application];

["Mono-fuel gaseous vehicle" means a mono-fuel vehicle that runs primarily on LPG, NG/biomethane, or hydrogen but may also have a petrol system for emergency purposes or for starting only, where the petrol tank does not contain more than [15] litres of petrol];

[“Mono-fuel vehicle” means a vehicle that is designed to run primarily on one type of fuel];

“Powertrain” means the total combination in a vehicle, of energy storage system(s), energy converter(s) and [drivetrain]/[power-transmission system](s) for the purpose of vehicle propulsion, including peripherals and excluding ancillaries;

[“[Internal] combustion engine ([I]CE) vehicle” means a vehicle equipped with a powertrain containing exclusively of at least one [I]CE as energy converter];

["Semi-automatic transmission" means a transmission which is shifted by hand but requires no manual operation of the clutch];

GENERAL

"Ambient condition test" means the measurement of the vehicle's cold start exhaust emissions and fuel economy at a initial test cell temperature of 296 ± 3 K (296 +/- 5 deg K during the test) and at a humidity of $5.5 \leq H \leq 12.2$ g H_2O / kg dry air.

[“Ancillary devices” are additional equipment which consume energy from the vehicle but are not required for vehicle operation];

"Catalytic converter" or "catalyst" means an emission pollution control device which converts products of combustion in the exhaust of an engine to other substances by way of catalysed chemical reactions;

"Cycle energy demand" means the calculated positive energy required by the vehicle to drive the prescribed cycle;

[“Predominant mode” means a single mode which is always selected when the vehicle is switched on regardless of the operating mode selected when the vehicle was previously shut down. The default mode must not be able to be redefined];

"Exhaust aftertreatment device or system" means any emission-reducing device or system that is installed downstream of the engine;

"Fuel consumption" means the amount of fuel consumed during a test;

["Green house gas (GHG) emissions" means gases emitted from the propulsion that contribute to the greenhouse effect by absorbing infrared radiation produced by solar warming of the Earth's surface];

[“Mode” means a distinct driver-selectable condition which could affect emissions, and fuel and energy consumption];

[“Positive ignition engine” means an engine in which combustion is initiated by a localised high temperature in the cylinder produced by energy supplied from a source external to the cylinder];

“Reference conditions” with regards to calculating the mass of emissions means the conditions upon which gas densities are based, namely 101.325 kPa and 273.15 K;

"Tailpipe emissions" or "exhaust emissions" means the emission of gaseous and solid species at the tailpipe of the vehicle;

"Gaseous emissions species" means all compounds emitted in gaseous form from the vehicle exhaust as required to be measured by this regulation;

"Useful life" means the relevant period of distance and/or time over which compliance with the relevant gaseous and particulate emission limits has to be assured;

PM/PN

“Buoyancy correction” means correction of the PM mass measurement to account for the effect of filter buoyancy in air;

"Particle number (PN)" means the total number of solid particles emitted from the vehicle exhaust and as specified in this regulation;

"Particulate aftertreatment device" means an exhaust aftertreatment system designed to reduce emissions of particulate matter (PM) and particle number (PN);

"Particulate matter (PM)" means any material that is collected on the filter media from diluted vehicle exhaust as specified in this regulation ;

CYCLE

“Class 1 vehicles” means vehicles having a power to unladen mass ratio of ≤ 22 W/kg;

“Class 2 vehicles” means vehicles having a power to unladen mass ratio of > 22 but ≤ 34 W/kg;

“Class 3 vehicles” means vehicles having a power to unladen mass ratio of > 34 W/kg;

"WLTC city cycle" means the combination of the low and medium phases, depending on the class of vehicle;

"Rated engine power (P_{rated})" means engine power in kW as specified in Regulation No. 85;

“Maximum speed (v_{max})” means the maximum speed of a vehicle as declared by the manufacturer according to Regulation No. 68 and not that which may be artificially restricted;

"Rated engine speed" means the range of rotational speed at which an engine develops maximum power;

PROCEDURE

["Continuous regeneration"];

"deNO$_x$ system" means an exhaust aftertreatment system, such as passive and active lean NO$_x$ catalysts, NO$_x$ adsorbers and selective catalytic reduction (SCR) systems, designed to reduce emissions of oxides of nitrogen (NO$_x$) (e.g.);

"Driver-selectable operating mode" mean any mode of operation which can be selected by the driver of the vehicle;

["Multi-mode" means that more than one operating mode can be selected by the driver or automatically set];

["Multiplicative factor"];
g
["Additive factor"];

"Periodic regeneration" means the regeneration of an exhaust aftertreatment device that does not occur during every WLTP test cycle, but requires a regeneration process in less than 4,000 km of normal vehicle operation.

B.4.: SYMBOLS

1.1. General symbols

Symbol	Unit	Term	Subject
v_{max}	km/h	maximum velocity	
P_{mr}	W/kg	power to unladen mass ratio	cycle
P_{rated}	kW	maximum rated engine power as declared by the manufacturer	cycle
s	min^{-1}	rated engine speed at which an engine develops its maximum power	cycle
n_{idle}	min^{-1}	idling speed	cycle
n_{min_drive}	min^{-1}	minimum engine speed for short trips	cycle
ng_{max}		number of forward gears	cycle
ndv_i		ratio determined by dividing n in min^{-1} by v in km/h for each gear i, i = 1 to ng_{max}	cycle
m_t	kg	test mass of the vehicle	cycle
f_0, f_1, f_2		f_0, f_1, f_2, driving resistance coefficients	cycle
$P_{wot}(n_{norm})/P_{rated}$		full load power curve, normalised to rated power and (rated engine speed – idling speed).	cycle
$P_{required,j}$	kW	power required at time j seconds	cycle
f_0		road load coefficient in N	cycle
f_1	N/(km/h)	is the road load parameter dependent on velocity	cycle
f_2	N/(km/h)²	is the road load parameter based on the square of velocity	cycle
v_j	km/h	vehicle velocity at second j	cycle
a_j	m/s²	vehicle acceleration at time j seconds	cycle
m_t	kg	vehicle test mass	cycle
kr		a factor taking the inertial resistances of the drivetrain during acceleration into account and set to 1.1	cycle
n_{min}		minimum gear to be used	cycle; conflict with n for rpm
n_{max}		maximum gear to be used	cycle
$P_{norm\_}$		percentage of rated power available at $n_{norm\_i,\,j}$ at full load condition from the normalised full load power curve	cycle
SM		safety margin accounting for the difference between stationary full load condition power curve and the power available during transient conditions	cycle
ΔP_t	kPa	tyre pressure adjustment	road load
T_{soak}	K	tyre soaking temperature	road load
T_{amb}	K	test ambient temperature	road load
p		statistical accuracy	road load
n		number of pairs of measurements	road load
ΔT_j	s	mean coastdown time at speed v_j	road load
ΔT_{ji}	s	harmonised average coastdown time of the i^{th} pair of measurements at speed v_j	road load
ΔT_{jai} , ΔT_{jbi}	s	coastdown times of the i^{th} measurement at speed V_j in each direction, respectively	road load
σ		standard deviation	road load
t		coefficient	road load
F_{ja}, F_{jb}	N	total vehicle resistance at velocity v_j in directions a and b	road load
m	kg	average of the test vehicle masses at the beginning and end	road load

Symbol	Unit	Term	Subject
		of road load determination	
m_r	kg	equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdown on the road	road load
Δt_{ja}, Δt_{jb}	s	mean coastdown times in directions a and b, respectively, corresponding to velocity v_j	road load
F_a, F_b	N	total vehicle resistances in each direction	road load
f_{0a}, f_{0b}	N	constant terms in each direction	road load
f_{1a}, f_{1b}	N·h/km	first-order term coefficients of vehicle velocity in each direction	road load
f_{2a}, f_{2b}	$N \cdot (h/km)^2$	second-order term coefficients of the vehicle velocity in each direction	road load
v	km/h	vehicle velocity average total resistance F_{avg}	road load
F_{avg}	N	average total resistance	road load
f_0		average of coefficients f_{0a} and f_{0b}	road load normal CD
f_1		average of coefficients f_{1a} and f_{1b}	road load normal CD
f_2		average of coefficients f_{2a} andf_{2b}	road load normal CD
Δt_j	s	harmonised average of alternate coastdown time measurements at velocity v_j	road load
Fj	N	average total resistance	road load
Δt_{ja} , Δt_{jb}	s	coastdown times at speed V_j in each direction, respectively	road load
m	kg	test vehicle mass	road load anemometer
m_r	kg	equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdown on the road	road load anemometer
dv/dt	km/h/s	acceleration	road load anemometer
a_{mech}	N	first order coefficient of mechanical drag	road load anemometer
b_{mech}	N/(km/h)	second order coefficient of mechanical drag, N/(km/h)	road load anemometer
c_{mech}	$N/(km/h)^2$	third order coefficient of mechanical drag	road load anemometer
v_r	km/h	relative wind velocity	road load anemometer
ρ	kg/m^3	air density	road load anemometer
S	m^2	projected frontal area of a vehicle	road load anemometer
a_i (i = 0 to 4)	$degrees^{-n}$	aerodynamic drag coefficient as a function of yaw angle	road load anemometer
a_0		coefficient for aerodynamic drag as a function of yaw angle;	road load anemometer
θ	degrees	yaw-angle apparent wind relative to the direction of vehicle travel	road load anemometer
F	N	total resistance	road load anemometer
v_{jm}	km/h	mean velocity	road load torque meter
C_{jm}	N·m	mean torque	road load torque meter

Symbol	Unit	Term	Subject
v_{ji}	km/h	vehicle velocity of the i^{th} data set	road load torque meter
k		number of data sets	road load torque meter
C_{ji}	Nm	torque of the i^{th} data set	road load torque meter
C_{js}	Nm	compensation term for speed drift	road load torque meter
r_j or r'_j	m	dynamic tyre radius	road load torque meter
N	s^{-1}	rotational frequency of the driven tyre	road load torque meter
α_j	m/s^2	mean acceleration	road load torque meter
t_i	s	time at which the i^{th} data set was sampled	road load torque meter
C_j	Nm	running resistance at velocity vj	road load torque meter
C_{jmi}	Nm	average torque of the i^{th} pair of data sets at velocity v_j	road load torque meter
C_{jmai} , C_{jmbi}	Nm	mean torques of the i^{th} data sets at velocity v_j	road load torque meter
s	Nm	standard deviation	road load torque meter
v_{jmi},	v_{jmi},	average velocity	road load torque meter
v_{jmai} , v_{jmbi}	km/h	mean speeds of the i^{th} pair of data sets at velocity v_j for each direction, a and b respectively	road load torque meter
C_a ,C_b	Nm	running resistances in each direction	road load torque meter
c_{0a} , c_{0b}	Nm	constant terms in each direction	road load torque meter
c_{1a} , c_{1b}	Nm(h/km)	coefficients of the first-order term in each direction	road load torque meter
c_{2a} , c_{2b}	$Nm(h/km)^2$	coefficients of the second-order term in each direction	road load torque meter
C*	Nm	corrected total running resistance	road load torque meter
K_2		correction factor for air resistance	road load
T	K	mean atmospheric temperature	road load
ρ	kPa	mean atmospheric pressure	road load
K_0	K^{-1}	correction factor for rolling resistance	road load
w_1	N	wind correction resistance	road load
v_w	m/s	average wind velocity alongside the test road during the coastdown test	road load
w_2	N	wind correction resistance (torque-meter method)	road load
F*	N	corrected total resistance determined by the conventional coastdown	road load
F_d	N	chassis dynamometer setting load	dyno load setting
v	km/h.	speed of the chassis dynamometer roller	dyno load setting
F_{tj}	N	target road load at reference speed v_j	dyno CD
v_j	km/h	j^{th} reference speed	dyno CD
ε_j	per cent	error of the simulated road load	dyno CD
A_d, B_d , C_d,		arbitrary initial dynamometer coefficients	initial setting torque meter

Symbol	Unit	Term	Subject
a_t, b_t , c_t		target torque coefficients	initial setting torque meter
F_{mj}	N	measured road load for each reference speed vj, in newtons	CD, calculation of simulated road load
m_d	kg	equivalent inertia-mass of the chassis dynamometer	CD, calculation of simulated road load
m'_r	kg	equivalent effective mass of drive wheels and vehicle components rotating with the wheels during coastdown on the dynamometer	CD, calculation of simulated road load
ΔT_j	s	coastdown time corresponding to speed v_j	CD, calculation of simulated road load
v_{ji}	km/h	vehicle speed of the i^{th} data set	Calculation of simulated road load, torque meter
C_{ji}	Nm	torque of the i^{th} data set	Calculation of simulated road load, torque meter
C_{jc}	Nm	compensation term for the speed drift	Calculation of simulated road load, torque meter
$F_{d\,j}$*	N	new chassis dynamometer setting load	Adjustment of chassis dyna-mometer load setting, CD method
F_j	N	adjustment road load	Adjustment of chassis dyna-mometer load setting, CD method
F_{sj}	N	simulated road load at reference speed V_j,	Adjustment of chassis dyna-mometer load setting, CD method
F_{tj}	N	target road load at reference speed V_j,	Adjustment of chassis dyna-mometer load setting, CD method
A_d*, B_d* and C_d*	coeffi-cients.	new chassis dynamometer setting coefficients	Adjustment of chassis dyna-mometer load setting, CD method
F^*_{dj}	N	new chassis dynamometer setting load	Adjustment of chassis dyna-mometer load setting using torque method
f_{ej}	N	adjustment road load	Adjustment of chassis dyna-mometer load

Symbol	Unit	Term	Subject
			setting using torque method
f_{sj}	N	simulated road load at reference speed v_j	Adjustment of chassis dyna-mometer load setting using torque method
f_{tj}	N	target road load at reference speed v_j	Adjustment of chassis dyna-mometer load setting using torque method
A_d*, B_d* and C_d*	coeffi-cients	new chassis dynamometer setting coefficients	Adjustment of chassis dyna-mometer load setting using torque method
V_0	m^3/rev	PDP CVS pump flow rate at T_p and P_p	PDP CVS
Q_s	m^3/min	PDP CVS air flow at 101.325 kPa and 273.15 K	PDP CVS
T_p	K	PDP CVS pump inlet temperature	PDP CVS
P_p	kPa	PDP CVSabsolute pump inlet pressure	PDP CVS
N	min^{-1}	PDP CVS pump revolutions	inconsistency
x_0		PDP pump speed correlation function	PDP CVS
ΔP_p	kPa	pressure differential from pump inlet to pump outlet	PDP CVS
P_e	kPa	absolute outlet pressure	PDP CVS
D_0, M, A and B		the slope-intercept constants describing the linear least-square fit to generate PDP calibration equations	PDP CVS
Q_s	m^3/min	CFV CVSflow	CFV CVS
T_v	K	temperature at the venturi inlet	CFV CVS
P_v	kPa	absolute pressure at the venturi inlet	CFV CVS
K_v	coefficient	calibration coefficient for each test point	CFV CVS
C_d	coefficient	discharge coefficient of an SSV CVS	SSV CVS
Q_{SSV}	m^3/s	airflow rate at standard conditions (101.3 kPa, 273 K)	SSV CVS
T	K	temperature at the venturi inlet	SSV CVS
dV	m	diameter of the SSV throat	SSV CVS
r_p	ratio	ratio of SSV throat to inlet absolute static pressure	SSV CVS
r_D	ratio	ratio of the SSV throat diameter to the inlet pipe inner diameter	SSV CVS
Re		Reynolds number	SSV CVS
μ	kg/ms	absolute or dynamic viscosity of the gas	SSV CVS
b	kg/ms $K^{0.5}$	an empirical constant	SSV CVS
S	K	an empirical constant	SSV CVS
Q_s	m^3/min	flow-rate in m^3/min at 273.2 K and 101.33 kPa	UFM CVS
$Q_{reference}$	m^3/min	flow rate in m^3/min at 273.2 K and 101.33 kPa of the cali-bration flow meter	UFM CVS
K_v	coefficient	K_v = calibration coefficient	UFM CVS
V_{ep}	-----	volume of diluted exhaust gas flowing through particular filter under standard conditions	double dilution
V_{set}	-----	volume of the double diluted exhaust gas passing through the particulate collection filters	double dilution
V_{ssd}	-----	volume of secondary air	double dilution
m_{uncor}	mg	uncorrected particulate sample mass	buoyancy cor-rection

Symbol	Unit	Term	Subject
ρ_a	kg/m^3	air density	buoyancy correction
ρ_w	kg/m^3	density of balance calibration weight	buoyancy correction
ρ_f	kg/m^3	density of the particulate sampling filter	buoyancy correction
p_b	kPa	total atmospheric pressure	buoyancy correction
T_a	K	air temperature in the balance environment	buoyancy correction
$N_{in}(d_i)$		upstream particle number concentration for particles of diameter d_i	PN
$N_{out}(d_i)$		downstream particle number concentration for particles of diameter d_i	PN
d_i		particle electrical mobility diameter	PN
M'_{sij}	g/km	mass emissions of species (i) over a cycle (or equivalent engine test bench cycle) without regeneration	Single regeneration
M'_{rij}	g/km	mass emissions of species (i) in g/km over one cycle (or equivalent engine test bench cycle) during regeneration	Single regeneration
M_{si}	g/km	mean mass emission of species (i) in without regeneration	Single regeneration
M_{ri}	g/km	mean mass emission of species (i) during regeneration	Single regeneration
M_{pi}	g/km	mean mass emission of species (i)	Single regeneration
d		number of operating cycles required for regeneration	Single regeneration
D		number of operating cycles between two cycles where regenerative phases occur	Single regeneration
M_{si}	g/km	mean mass of all events (j) of species (i) without regeneration	Multiple regeneration
M_{ri}	g/km	mean mass emission of all events (j) of species (i) during regeneration	Multiple regeneration
M_{pi}	g/km	mean mass emission of all events (j) of species (i)	Multiple regeneration
M_{sij}	g/km	mean mass emission of event (j) of species (i) without regeneration	Multiple regeneration
M_{rij}	g/km	mean mass emission of event (j) of species (i) during regeneration	Multiple regeneration
$M'_{sij,k}$	g/km	mass emissions of event (j) of species (i) over one cycle without regeneration; k test points	Multiple regeneration
$M'_{rij,k}$	g/km	mass emissions of event (j) of species (i) over one cycle during regeneration; k test points	Multiple regeneration
n_j		number of test points of event (j) at which emissions measurements are made between two cycles where regenerative phases occur	Multiple regeneration
d_j		number of operating cycles of event (j) required for regeneration	Multiple regeneration
D_j		number of operating cycles of event (j) between two cycles where regenerative phases occur	Multiple regeneration
V	l/test	uncorrected diluted gas volume per test	PDP air, gas volume
P_B	kPa	test room barometric pressure	PDP air, gas volume
P_1	kPa	vacuum at the inlet to the positive displacement pump relative to the ambient barometric pressure	PDP air, gas volume
T_p	K	average temperature of the diluted exhaust gas entering the positive displacement pump during the test	PDP air, gas volume

Symbol	Unit	Term	Subject
M_i	g/km	the mass emission of emissions species (i)	mass emissions
V_{mix}		volume of the diluted exhaust gas corrected to standard conditions (273.15 K and 101.325 kPa)	mass emissions
Q_i	g/l	density of emissions species (i) at standard conditions (273.15 K and 101.325 kPa)	mass emissions
KH		humidity correction factor	mass emissions
C_i		concentration of emissions species (i) corrected by the amount of species (i) in dilution air	mass emissions
d	km	distance travelled over the cycle or phase	mass emissions
C_e	ppm	measured concentration of species (i) in diluted gas	mass emissions
C_d	ppm	concentration of gaseous species (i) in dilution air	mass emissions
DF		dilution factor	mass emissions
C_{CO2}	per cent volume	concentration of CO_2 in diluted exhaust gas	mass emissions
C_{HC}	ppm carbon equivalent	concentration of HC in diluted exhaust gas	mass emissions
C_{CO}	ppm	concentration of CO in diluted exhaust gas	mass emissions
C_e		flow-weighted average concentration	flow-weighted emissions
$q_{vCVS}(i)$		CVS flow rate at time $t = i \times \Delta t$	flow-weighted emissions
$C_{(i)}$		concentration at time $t = i \times \Delta t$	flow-weighted emissions
Δt	s	sampling interval	flow-weighted emissions
V		CVS volume	flow-weighted emissions
H_a	g/H_2O/kg dry air	absolute humidity	KH
R_a	per cent	relative humidity of ambient air	KH
P_d	kPa	saturation vapour pressure at ambient temperature	KH
P_B	kPa	atmospheric pressure in test cell	KH
$M_{CO2,i}$	g/km	CO_2 mass emissions for vehicle i in the vehicle family	CO_2 regression
$M_{CO2,L}$	g/km	CO_2 mass emissions for vehicle i at $TM_{L,actual}$	CO_2 regression
OM_i	kg	mass of optional equipment installed on vehicle i	CO_2 regression
ΔM_{CO2}	g/km	ΔM_{CO2} is the difference in mass CO_2 emissions at $TM_{H, actual}$ and $TM_{L, actual}$	CO_2 regression
ΔTM	kg	mass difference between $TM_{H, actual}$ and $TM_{L, actual}$	CO_2 regression
P_e		particulate mass collected by one or more filters	PM
M_p	g/km	particulate mass emissions	PM
V_{ap}	??	volume of tunnel air flowing through the background particulate filter under standard conditions	PM
P_a		particulate mass collected by background filter	PM
N	particles/km	particle number emission	PN
V	l/test	diluted exhaust gas volume corrected to standard conditions	PN
k	factor	particle number calibration factor	PN
$\overline{C_s}$	[??]	corrected concentration of particles from diluted exhaust gas	PN
C_b	[??]	dilution air or dilution tunnel background particle concen-	PN

Symbol	Unit	Term	Subject
		tration	
$\overline{f_r}$	[??]	mean particle concentration reduction factor	PN
$\overline{f_{rb}}$	[??]	mean particle concentration reduction factor for background air	PN
d	km	cycle distance travelled	PN
C_i	particles/ cm³	discrete particle concentration measurement in diluted exhaust	PN
n		number of discrete particle concentration measurements	PN
f	Hz	data logging frequency of particle counter	PN
$M_{i,CD,j}$	mg/km	mass of the emissions species measured during the j^{th} phase	OVC CD emissions
UF		fractional utility factor	
$M_{i,weighted}$	mg/km	utility factor-weighted exhaust emissions of each measured emission species	OVC CD, CS emissions
$M_{i,CD,j}$	mg/km	mass species emissions measured during the j^{th} charge-depleting phase	OVC CD emissions
$M_{i,CS}$	mg/km	mass species emissions for a charge-sustaining test	OVC CS emissions
$CO_{2,CD}$	g/km	utility factor-adjusted mass of CO_2 emissions during charge-depleting mode	OVC CO_2
$CO_{2,CD,j}$	g/km	CO_2 emissions measured during the j^{th} charge-depleting phase, g/km	
FC_{CD}	l/100 km	utility factor-adjusted fuel consumption charge-depleting mode	OVC fuel cons., CD mode
$FC_{CD,j}$	l/100 km	fuel consumption measured during the j^{th} charge-depletion phase, l/100 km	OVC fuel cons., CD mode
ΔE_{REESS}	MJ	change in the electrical REESS energy content	OVC CS fuel cons.
V_{REESS}	V	nominal REESS voltage	OVC CS fuel cons.
RCB	Ah	REESS charging balance over a whole cycle	OVC CS fuel cons.
E_{Fuel}	MJ	energy content of the consumed fuel	OVC CS fuel cons.
$CO_{2,weighted}$	g/km	utility factor-weighted CO_2 emissions	weighted CD and CS CO2
$CO_{2,CD,j}$	g/km	CO_2 emissions measured during the j^{th} charge-depleting phase	weighted CD and CS CO2
$CO_{2,CS}$	g/km	CO_2 emissions for the charge-sustaining test	weighted CD and CS CO2
$FC_{weighted}$	l/100 km	utility factor-weighted fuel consumption, l/100 km	weighted CD and CS fuel cons.
$FC_{CD,j}$	l/100 km	fuel consumption measured during the j^{th} charge-depleting phase	weighted CD and CS fuel cons.
FC_{CS}	l/100 km	fuel consumption measured during the charge-sustaining test	weighted CD and CS fuel cons.
$C_{weighted}$	Wh/km	utility factor-weighted total energy consumption	OVC elect. energy
$C_{CD,j}$	Wh	calculated fraction of E_{AC} used in the j^{th} phase during the charge-depleting test	OVC elect. energy
RCB_j	Ah	measured charge balance of the j^{th} phase during the	OVC elect.

Symbol	Unit	Term	Subject
		charge-depleting test	energy
D_j	km	distance driven in the j^{th} phase during the charge-depleting test	OVC elect. energy
E_{AC}	Wh	measured recharged electric energy from the grid	OVC elect. energy
C	Wh/km	electric energy consumption	OVC elect. energy
R_{cdc}	km	charge-depleting cycle range	OVC elect.range
$CO_{2,n,cycle}$	g/km	CO_2 emissions over the n^{th} drive cycle in charge-depleting operating condition	OVC CD cycle range
$CO_{2,CD,average,n-1}$	g/km	average CO_2 emissions in charge-depleting operating condition until the $n-1^{th}$ drive cycle	OVC CD cycle range
$D_{j,cycle}$	km	test distance travelled during j^{th} drive cycle	OVC CD cycle range
D_n	km	test distance travelled during the n^{th} drive cycle in charge-depleting operating condition	OVC CD cycle range
ΔSOC_n	per cent	change of state of charge during the n^{th} drive cycle under charge-depleting conditions	OVC CD cycle range
ΔSOC_{n-1}	per cent	change of state of charge during the $n-1^{th}$ drive cycle under charge-depleting conditions	OVC CD cycle range
K_{fuel}	l/100 km/Ah	fuel consumption correction coefficient	RCB charge compensation
FC_i	l/100 km	fuel consumption measured during i^{th} manufacturer's test	RCB charge compensation
Q_i	Ah	electricity balance measured during i^{th} manufacturer's test	RCB charge compensation
FC_0	l/100 km	fuel consumption at $\Delta E_{batt} = 0$	RCB charge compensation
FC	l/100 km	fuel consumption measured during the test, l/100 km	RCB charge compensation
FC'	km/l	fuel consumption	RCB charge compensation
K_{CO2}	g/km/Ah	CO_2 emissions correction coefficient, g/km/Ah	RCB charge compensation
M_i	g/km	CO_2 emissions measured during i^{th} manufacturer's test	RCB charge compensation
M_0	g/km	CO_2 emissions at zero REESS energy balance, g/km	CO_2 emission at zero REESS energy balance (M_0)

1.2. Chemical symbols and abbreviations

C_1	Carbon 1 equivalent hydrocarbon
CH_4	Methane
C_2H_6	Ethane
HCHO	Formaldehyde
CH_3CHO	Acetaldehyde
C_2H_5OH	Ethanol
C_3H_8	Propane
CO	Carbon monoxide
CO_2	Carbon dioxide
DOP	Di-octylphtalate

THC	Total hydrocarbons (All compounds measurable by an FID)
NMNEOG	Non-methane, non-ethanol organic gases
H_2O	Water
NMHC	Non-methane hydrocarbons
NO_x	Oxides of nitrogen
NO	Nitric oxide
NO_2	Nitrogen dioxide
N_2O	Nitrous oxide

1.3. General abbreviations

CFV	Critical flow venturi
CLD, CLA	Chemiluminescent detector/analyser
CVS	Constant Volume Sampling
$deNO_x$	NO_x aftertreatment system
ECD	Electron capture detector
ET	Evaporation tube
Extra $High_2$	WLTC cycle extra high speed phase for class 2 vehicles
Extra $High_3$	WLTC cycle extra high speed phase for class 3 vehicles
FID	Flame ionization detector
FTIR	Fourier tansform infrared analyser
GC	Gas chromatograph
HEPA	High efficiency particulate air (filter)
HFID	Heated flame ionization detector
$High_2$	WLTC cycle high speed phase for class 2 vehicles
$High_{3-1}$	WLTC cycle high speed phase for class 3 vehicles with $v_{max} \leq 120$ km/h
$High_{3-2}$	WLTC cycle high speed phase for class 3 vehicles with $v_{max} > 120$ km/h
LoD	Limit of detection
LoQ	Limit of quantification
Low_1	WLTC cycle low speed phase for class 1 vehicles
Low_2	WLTC cycle low speed phase for class 2 vehicles
Low_3	WLTC cycle low speed phase for class 3 vehicles
$Medium_1$	WLTC cycle medium speed phase for class 1 vehicles
$Medium_2$	WLTC cycle medium speed phase for class 2 vehicles
$Medium_{3-1}$	WLTC cycle medium speed phase for class 3 vehicles with $v_{max} \leq$ 120 km/h
$Medium_{3-2}$	WLTC cycle medium speed phase for class 3 vehicles with $v_{max} >$ 120 km/h
LPG	Liquefied petroleum gas
NDIR	Non-dispersive infrared (analyser)
NMC	Non-methane cutter
PAO	Poly-alpha-olefin
PCF	Particle pre-classifier
PDP	Positive displacement pump
Percent FS	Per cent of full scale
PM	Particulate matter
PN	Partical number
PNC	Particle number counter
PND_1	First particle number dilution device
PND_2	Second particle number dilution device
PTS	Particle transfer system
PTT	Particle transfer tube
QCL-IR	Infra-red quantum cascade laser
R_{cda}	Charge-depleting actual range
SSV	Subsonic venturi
USFM	Ultra-Sonic flow meter
VPR	Volatile particle remover

B.5.: GENERAL REQUIREMENTS

1. General requirements

1.1. The vehicle and its components liable to affect the emissions of gaseous and particulate species shall be so designed, constructed and assembled as to enable the vehicle in normal use and under normal conditions of use such as humidity, rain, snow, heat, cold, sand, dirt, vibrations, wear, etc. to comply with the provisions of this GTR during its useful life.

1.1.1. This will include the security of all hoses, joints and connections used within the emission control systems.

1.2. The test vehicle shall be representative in terms of its emissions-related components and functionality of the intended production series to be covered by the approval. The manufacturer and the responsible authority shall agree which vehicle test model is representative.

1.3. Vehicle testing condition
1.3.1. The type and amount of lubricants and coolant for emissions testing shall be as specified for normal vehicle operation by the manufacturer.
1.3.2. The type of fuel for emissions testing shall be as specified in Annex 3 of this GTR.
1.3.3. All emissions controlling systems shall be in working order.
1.3.4. The use of any defeat device is prohibited.
1.3.5. The engine shall be designed to avoid crankcase emissions.
1.3.6. The tyres used for emissions testing shall be as defined in §1.2.4.6. of Annex 6 of this GTR.

1.4. Petrol tank inlet orifices
1.4.1. Subject to paragraph 1.4.2., the inlet orifice of the petrol or ethanol tank shall be so designed as to prevent the tank from being filled from a fuel pump delivery nozzle which has an external diameter of 23.6 mm or greater.

1.4.2. Paragraph 1.4.1. shall not apply to a vehicle in respect of which both of the following conditions are satisfied:

1.4.2.1. The vehicle is so designed and constructed that no device designed to control the emission of gaseous and particulate species shall be adversely affected by leaded petrol, and;
1.4.2.2. The vehicle is conspicuously, legibly and indelibly marked with the symbol for unleaded petrol, specified in ISO 2575:2010 “Road vehicles -- Symbols for controls, indicators and tell-tales”, in a position immediately visible to a person filling the petrol tank. Additional markings are permitted.

1.5. Provisions for electronic system security

1.5.1. Any vehicle with an emission control computer shall include features to deter modification, except as authorised by the manufacturer. The manufacturer shall authorise modifications if these modifications are necessary for the diagnosis, servicing, inspection, retrofitting or repair of the vehicle. Any reprogrammable computer codes or operating parameters shall be resistant to tampering and afford a level of protection at least as good as the provisions in ISO 15031-7 (March 15, 2001) [~~provided that the security exchange is conducted using the protocols and diagnostic connector as prescribed in paragraph 6.5. of Annex 11, Appendix 1~~]. Any removable calibration memory chips shall be potted, encased in a sealed container or protected by electronic algorithms and shall not be changeable without the use of specialised tools and procedures.

1.5.2. Computer-coded engine operating parameters shall not be changeable without the use of specialised tools and procedures (e. g. soldered or potted computer components or sealed (or soldered) comp enclosures).

1.5.3. Manufacturers may seek approval from the responsible authority for an exemption to one of these requirements for those vehicles which are unlikely to require protection. The criteria that the responsible authority will evaluate in considering an exemption will include, but are not limited to, the current availability of performance chips, the high-performance capability of the vehicle and the projected sales volume of the vehicle.

1.5.4. Manufacturers using programmable computer code systems shall deter unauthorised reprogramming. Manufacturers shall include enhanced tamper protection strategies and write-protect features requiring electronic access to an off-site computer maintained by the manufacturer. Methods giving an adequate level of tamper protection will be approved by the responsible authority.

PERFORMANCE REQUIREMENTS

2. Performance Requirements

2.1 Limit values
When implementing the test procedure contained in this GTR as part of their national legislation, Contracting Parties to the 1998 Agreement are encouraged to use limit values which represent at least the same level of severity as their existing regulations; pending the development of harmonized limit values, by the Executive Committee (AC.3) of the 1998 Agreement, for inclusion in the GTR at a later date.

2.2. Emission of gaseous species and particulate matter

The emissions of gaseous species and particulate matter from light-duty vehicles shall be determined using:
(a) the WLTP-DHC test cycles as described in Annex 1;
(b) the gear selection and shift point determination as described in Annex 2;
(c) the appropriate fuel as prescribed in Annex 3;
(d) the road and dynamometer load determined as described in Annex 4;
(e) the test equipment as described in Annex 5;
(f) the test procedure as described in Annexes 6 and 8;
(g) the method of calculation as described in Annexes 7 and 8.

ANNEX 1: DRIVE CYCLES

1. General requirements

1.1. The cycle to be driven is dependent on the test vehicle's rated power to unladen mass ratio, W/kg, and its maximum velocity, v_{max}.

1.2. Unladen mass is defined in B.3. Definitions.

1.3. v_{max} is the maximum speed of the vehicle in km/h as declared by the manufacturer according to Regulation No. 68 and not that which may be artificially restricted.

2. Vehicle classifications

2.1. Class 1 vehicles have a power to unladen mass ratio (P_{mr}) of ≤ 22 W/kg.

2.2. Class 2 vehicles have a power to unladen mass ratio of > 22 but ≤ 34 W/kg.

2.2. Class 3 vehicles have a power to unladen mass ratio of > 34 W/kg.

3. Test Cycles

3.1. Class 1 vehicles

3.1.1. The cycle for class 1 vehicles consists of a low phase (Low_1) and a medium phase ($Medium_1$).

3.1.2. The Low_1 phase is described in Figure 1 and Table 1.

3.1.3. The $Medium_1$ phase is described in Figure 2 and Table 2.

3.2. Class 2 vehicles

3.2.1. The cycle for class 2 vehicles consists of a low phase (Low_2), a medium phase ($Medium_2$), a high phase ($High_2$) and an extra high phase (Extra $High_2$).

3.2.2. The Low_2 phase is described in Figure 3 and Table 3.

3.2.3. The $Medium_2$ phase is described in Figure 4 and Table 4.

3.2.4. The $High_2$ phase is described in Figure 5 and Table 5.

3.2.5. The Extra $High_2$ phase is described in Figure 6 and Table 6.

3.3. Class 3 vehicles

Class 3 vehicles are divided into 2 subclasses according to their maximum speed v_{max}.

3.3.1. Class 3 vehicles with v_{max} ≤ 120 km/h

3.3.1.1. The cycle for class 3 vehicles with v_{max} ≤ 120 km/h consists of a low phase (Low_3) , a medium phase ($Medium_{3-1}$), a high phase ($High_{3-1}$) and an extra high phase (Extra $High_3$).

3.3.1.2. The Low_3 phase is described in Figure 7 and Table 7.

3.3.1.3. The $Medium_{3-1}$ phase is described in Figure 8 and Table 8.

3.3.1.4. The $High_{3-1}$ phase is described in Figure 10 and Table 10.

3.3.1.5. The Extra $High_3$ phase is described in Figure 12 and Table 12.

3.3.2. Class 3 vehicles with v_{max} > 120 km/h

3.3.2.1. The cycle for class 3 vehicles with v_{max} > 120 km/h consist of a low phase (Low_3) phase, a medium phase ($Medium_{3-2}$), a high phase ($High_{3-2}$) and an extra high phase (Extra $High_3$).

3.3.2.2. The Low_3 phase is described in Figure 7 and Table 7.

3.3.2.3. The $Medium_{3-2}$ phase is described in Figure 9 and Table 9.

3.3.2.4. The $High_{3-2}$ phase is described in Figure 11 and Table 11.

3.3.2.5. The Extra $High_3$ phase is described in Figure 12 and Table 12.

3.4. Duration of all phases
3.4.1. All low speed phases last 589 seconds.
3.4.2. All medium speed phases last 433 seconds.
3.4.3. All high speed phases last 455 seconds.
3.4.4. All extra high speed phases last 323 seconds.

4. WLTC Class 1 vehicles

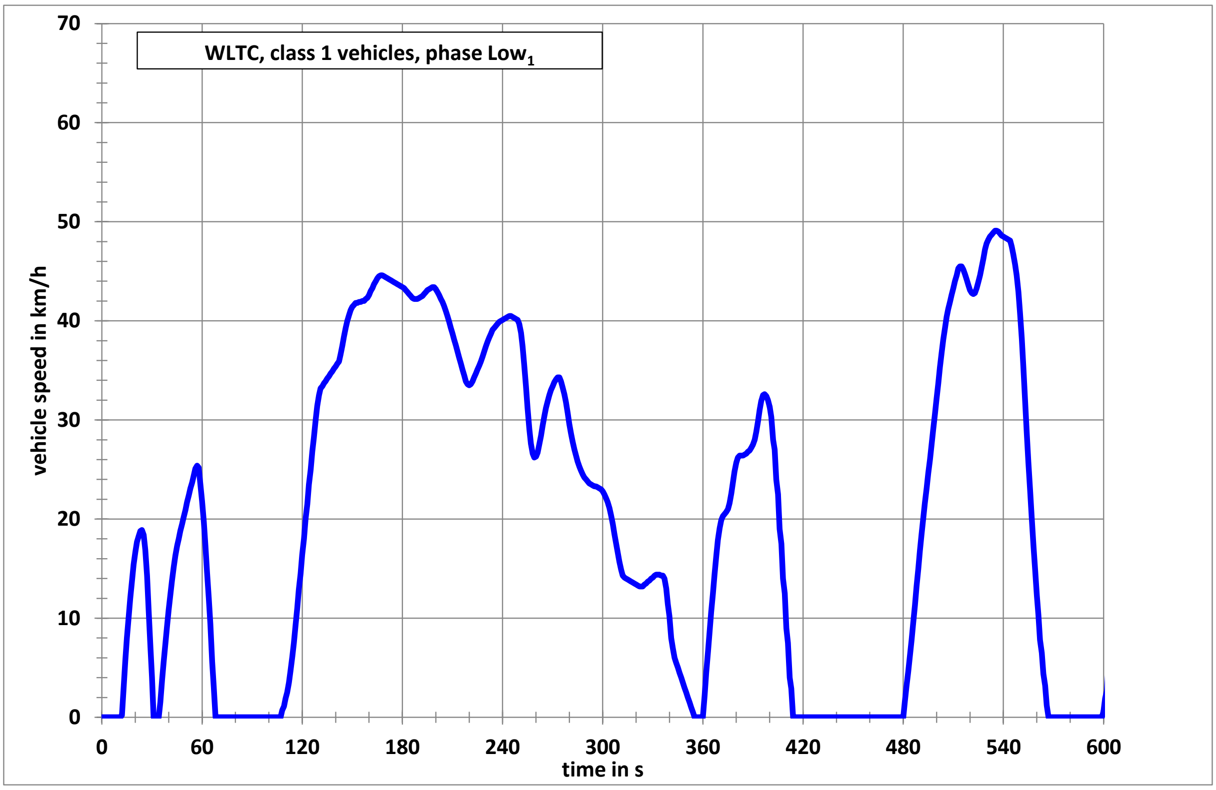


Figure 1: WLTC, Class 1 vehicles, phase L_1

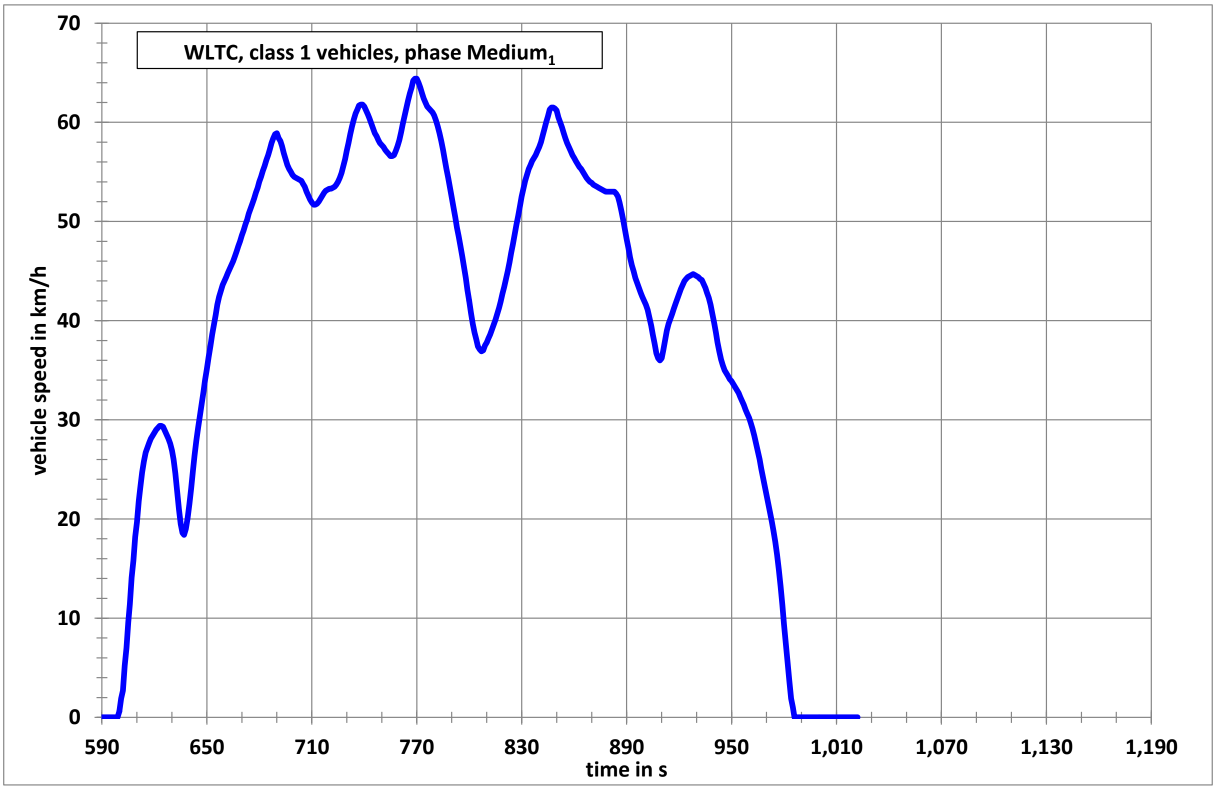


Figure 2: WLTC, Class 1 vehicles, phase $Medium_1$

Table 1: WLTC, Class 1 vehicles, phase Low_1

WLTC class 1 vehicles, phase Low_1					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
0	0.0				
1	0.0	61	19.9	121	18.4
2	0.0	62	17.3	122	20.0
3	0.0	63	14.7	123	21.8
4	0.0	64	12.1	124	23.4
5	0.0	65	9.5	125	25.1
6	0.0	66	6.6	126	26.8
7	0.0	67	4.1	127	28.5
8	0.0	68	0.0	128	30.0
9	0.0	69	0.0	129	31.4
10	0.0	70	0.0	130	32.5
11	0.0	71	0.0	131	33.2
12	0.2	72	0.0	132	33.4
13	3.1	73	0.0	133	33.0
14	5.7	74	0.0	134	32.4
15	8.0	75	0.0	135	32.1
16	10.1	76	0.0	136	31.9
17	12.0	77	0.0	137	31.9
18	13.8	78	0.0	138	32.2
19	15.4	79	0.0	139	32.9
20	16.7	80	0.0	140	33.7
21	17.7	81	0.0	141	34.6
22	18.3	82	0.0	142	35.6
23	18.8	83	0.0	143	36.6
24	18.9	84	0.0	144	37.5
25	18.4	85	0.0	145	38.4
26	16.9	86	0.0	146	39.3
27	14.3	87	0.0	147	40.0
28	10.8	88	0.0	148	40.6
29	7.1	89	0.0	149	41.1
30	4.0	90	0.0	150	41.4
31	0.0	91	0.0	151	41.6
32	0.0	92	0.0	152	41.8
33	0.0	93	0.0	153	41.8
34	0.0	94	0.0	154	41.9
35	1.5	95	0.0	155	41.9
36	4.0	96	0.0	156	42.0
37	5.8	97	0.0	157	42.1
38	7.5	98	0.0	158	42.2
39	9.2	99	0.0	159	42.3
40	10.9	100	0.0	160	42.6
41	12.4	101	0.0	161	43.0
42	13.9	102	0.0	162	43.4
43	15.4	103	0.0	163	43.7
44	16.6	104	0.0	164	44.1
45	17.5	105	0.0	165	44.4
46	18.3	106	0.0	166	44.5
47	18.9	107	0.0	167	44.6
48	19.5	108	0.7	168	44.5
49	20.1	109	1.1	169	44.4
50	20.8	110	1.5	170	44.4
51	21.6	111	2.5	171	44.3
52	22.5	112	3.5	172	44.3
53	23.2	113	4.7	173	44.3
54	23.9	114	6.1	174	44.2
55	24.5	115	7.8	175	44.1
56	25.1	116	9.6	176	44.0
57	25.4	117	11.4	177	43.9
58	25.2	118	13.1	178	43.8
59	24.2	119	15.0	179	43.7
60	22.3	120	16.6	180	43.5

WLTC class 1 vehicles, phase Low_1					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
181	43.4	241	40.1	301	22.5
182	43.1	242	40.1	302	22.1
183	42.9	243	40.0	303	21.7
184	42.7	244	39.8	304	21.1
185	42.5	245	39.8	305	20.4
186	42.3	246	39.8	306	19.5
187	42.2	247	39.9	307	18.5
188	42.2	248	40.1	308	17.6
189	42.2	249	40.1	309	16.6
190	42.3	250	39.7	310	15.7
191	42.4	251	38.8	311	14.9
192	42.4	252	37.4	312	14.3
193	42.6	253	35.6	313	13.8
194	42.8	254	33.4	314	13.6
195	43.1	255	31.2	315	13.4
196	43.3	256	29.1	316	13.4
197	43.4	257	27.6	317	13.5
198	43.4	258	26.6	318	13.5
199	43.4	259	26.2	319	13.5
200	43.2	260	26.3	320	13.4
201	42.9	261	26.7	321	13.3
202	42.6	262	27.5	322	13.1
203	42.2	263	28.4	323	12.9
204	41.9	264	29.4	324	12.9
205	41.5	265	30.4	325	12.8
206	41.0	266	31.2	326	13.0
207	40.5	267	31.9	327	13.4
208	39.9	268	32.5	328	13.8
209	39.3	269	33.0	329	14.1
210	38.7	270	33.4	330	14.2
211	38.1	271	33.8	331	14.4
212	37.6	272	34.1	332	14.5
213	37.1	273	34.3	333	14.5
214	36.5	274	34.3	334	14.4
215	35.7	275	33.9	335	14.3
216	35.1	276	33.3	336	14.3
217	34.4	277	32.6	337	14.0
218	33.9	278	31.8	338	13.0
219	33.6	279	30.7	339	11.4
220	33.5	280	29.6	340	9.2
221	33.6	281	28.6	341	6.9
222	33.9	282	27.8	342	4.8
223	34.3	283	27.2	343	3.3
224	34.8	284	26.4	344	2.3
225	35.2	285	25.8	345	1.9
226	35.6	286	25.3	346	1.7
227	36.0	287	24.9	347	1.6
228	36.4	288	24.5	348	1.4
229	36.9	289	24.2	349	1.3
230	37.4	290	24.0	350	1.2
231	37.9	291	23.8	351	1.1
232	38.3	292	23.6	352	1.0
233	38.7	293	23.5	353	0.8
234	39.1	294	23.4	354	0.6
235	39.3	295	23.3	355	0.0
236	39.5	296	23.3	356	0.0
237	39.7	297	23.2	357	0.0
238	39.9	298	23.1	358	0.0
239	40.0	299	23.0	359	0.0
240	40.1	300	22.8	360	0.0

WLTC class 1 vehicles, phase Low_1					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
361	2.2	421	0.0	481	1.6
362	4.5	422	0.0	482	3.1
363	6.6	423	0.0	483	4.5
364	8.6	424	0.0	484	6.1
365	10.6	425	0.0	485	7.6
366	12.5	426	0.0	486	9.4
367	14.4	427	0.0	487	11.3
368	16.3	428	0.0	488	13.3
369	17.9	429	0.0	489	15.0
370	19.1	430	0.0	490	16.9
371	19.9	431	0.0	491	18.5
372	20.3	432	0.0	492	20.1
373	20.5	433	0.0	493	21.7
374	20.7	434	0.0	494	23.2
375	21.0	435	0.0	495	24.6
376	21.6	436	0.0	496	25.8
377	22.6	437	0.0	497	27.5
378	23.7	438	0.0	498	28.9
379	24.8	439	0.0	499	30.5
380	25.7	440	0.0	500	32.1
381	26.2	441	0.0	501	33.8
382	26.4	442	0.0	502	35.3
383	26.4	443	0.0	503	36.8
384	26.4	444	0.0	504	38.3
385	26.5	445	0.0	505	39.6
386	26.6	446	0.0	506	40.6
387	26.8	447	0.0	507	41.3
388	26.9	448	0.0	508	42.0
389	27.2	449	0.0	509	42.5
390	27.5	450	0.0	510	43.2
391	28.0	451	0.0	511	44.1
392	28.8	452	0.0	512	44.8
393	29.9	453	0.0	513	45.3
394	31.0	454	0.0	514	45.5
395	31.9	455	0.0	515	45.5
396	32.5	456	0.0	516	45.2
397	32.6	457	0.0	517	44.7
398	32.4	458	0.0	518	44.2
399	32.0	459	0.0	519	43.6
400	31.3	460	0.0	520	43.1
401	30.3	461	0.0	521	42.8
402	28.5	462	0.0	522	42.7
403	26.2	463	0.0	523	42.8
404	23.6	464	0.0	524	43.3
405	21.1	465	0.0	525	43.9
406	19.0	466	0.0	526	44.6
407	17.5	467	0.0	527	45.4
408	16.0	468	0.0	528	46.3
409	14.0	469	0.0	529	47.2
410	11.4	470	0.0	530	47.8
411	8.4	471	0.0	531	48.2
412	5.3	472	0.0	532	48.5
413	2.9	473	0.0	533	48.7
414	0.0	474	0.0	534	48.9
415	0.0	475	0.0	535	49.1
416	0.0	476	0.0	536	49.1
417	0.0	477	0.0	537	49.0
418	0.0	478	0.0	538	48.8
419	0.0	479	0.0	539	48.6
420	0.0	480	0.0	540	48.5

WLTC class 1 vehicles, phase Low_1					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
541	48.6				
542	48.7				
543	48.6				
544	48.2				
545	47.5				
546	46.7				
547	45.7				
548	44.6				
549	42.9				
550	40.8				
551	38.2				
552	35.3				
553	31.8				
554	28.7				
555	25.8				
556	22.9				
557	20.2				
558	17.8				
559	15.5				
560	13.3				
561	11.3				
562	9.3				
563	7.4				
564	5.5				
565	3.7				
566	2.2				
567	0.0				
568	0.0				
569	0.0				
570	0.0				
571	0.0				
572	0.0				
573	0.0				
574	0.0				
575	0.0				
576	0.0				
577	0.0				
578	0.0				
579	0.0				
580	0.0				
581	0.0				
582	0.0				
583	0.0				
584	0.0				
585	0.0				
586	0.0				
587	0.0				
588	0.0				
589	0.0				

Table 2: WLTC, Class 1 vehicles, phase $Medium_1$

WLTC class 1 vehicles, phase $Medium_1$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
590	0.0	650	35.2	710	51.7
591	0.0	651	36.3	711	51.6
592	0.0	652	37.5	712	51.5
593	0.0	653	38.5	713	51.7
594	0.0	654	39.7	714	52.0
595	0.0	655	40.8	715	52.3
596	0.0	656	41.7	716	52.7
597	0.0	657	42.5	717	52.9
598	0.0	658	43.2	718	53.1
599	0.0	659	43.7	719	53.3
600	0.6	660	44.1	720	53.3
601	1.9	661	44.4	721	53.3
602	2.7	662	44.8	722	53.3
603	5.2	663	45.1	723	53.4
604	7.0	664	45.6	724	53.5
605	9.4	665	46.0	725	53.8
606	11.5	666	46.5	726	54.3
607	13.8	667	47.0	727	54.8
608	15.9	668	47.5	728	55.5
609	18.1	669	48.0	729	56.3
610	19.9	670	48.6	730	57.1
611	21.8	671	49.1	731	57.9
612	23.4	672	49.7	732	58.8
613	24.7	673	50.3	733	59.6
614	25.8	674	50.8	734	60.4
615	26.7	675	51.2	735	61.1
616	27.2	676	51.8	736	61.5
617	27.7	677	52.3	737	61.7
618	28.1	678	52.9	738	61.8
619	28.4	679	53.4	739	61.8
620	28.7	680	54.0	740	61.6
621	29.0	681	54.5	741	61.2
622	29.2	682	55.0	742	60.8
623	29.4	683	55.6	743	60.4
624	29.4	684	56.2	744	59.8
625	29.3	685	56.7	745	59.4
626	28.9	686	57.3	746	58.9
627	28.5	687	57.9	747	58.5
628	28.1	688	58.4	748	58.1
629	27.6	689	58.8	749	57.9
630	26.9	690	58.9	750	57.7
631	26.0	691	58.4	751	57.5
632	24.6	692	58.1	752	57.3
633	22.8	693	57.6	753	57.0
634	21.0	694	56.9	754	56.7
635	19.5	695	56.3	755	56.4
636	18.6	696	55.7	756	56.4
637	18.4	697	55.2	757	56.6
638	19.0	698	54.9	758	56.9
639	20.1	699	54.6	759	57.4
640	21.5	700	54.4	760	58.1
641	23.1	701	54.4	761	58.9
642	24.9	702	54.4	762	59.8
643	26.4	703	54.3	763	60.6
644	27.9	704	54.2	764	61.4
645	29.2	705	53.9	765	62.2
646	30.5	706	53.5	766	63.0
647	31.6	707	53.1	767	63.7
648	32.8	708	52.6	768	64.2
649	33.9	709	52.1	769	64.4

WLTC class 1 vehicles, phase $Medium_1$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
770	64.4	830	52.5	890	48.2
771	64.0	831	53.4	891	47.2
772	63.5	832	54.2	892	46.3
773	62.9	833	54.9	893	45.5
774	62.3	834	55.4	894	44.9
775	61.8	835	55.8	895	44.3
776	61.5	836	56.2	896	43.8
777	61.3	837	56.4	897	43.2
778	61.3	838	56.7	898	42.8
779	61.2	839	57.0	899	42.4
780	60.9	840	57.4	900	42.0
781	60.4	841	57.9	901	41.7
782	59.7	842	58.6	902	41.3
783	59.0	843	59.3	903	40.7
784	58.2	844	60.1	904	39.6
785	57.2	845	60.8	905	38.4
786	56.2	846	61.3	906	37.5
787	55.3	847	61.5	907	36.7
788	54.4	848	61.5	908	36.2
789	53.5	849	61.4	909	36.0
790	52.5	850	61.2	910	36.2
791	51.4	851	60.6	911	37.0
792	50.4	852	60.0	912	38.0
793	49.4	853	59.4	913	39.0
794	48.5	854	58.9	914	39.7
795	47.5	855	58.4	915	40.2
796	46.5	856	57.9	916	40.7
797	45.5	857	57.5	917	41.2
798	44.3	858	57.0	918	41.7
799	43.2	859	56.7	919	42.3
800	42.0	860	56.3	920	42.7
801	40.7	861	56.0	921	43.2
802	39.6	862	55.8	922	43.6
803	38.6	863	55.6	923	44.0
804	37.8	864	55.3	924	44.2
805	37.4	865	55.0	925	44.1
806	37.1	866	54.6	926	44.1
807	36.9	867	54.4	927	44.1
808	37.0	868	54.2	928	44.3
809	37.4	869	54.0	929	44.4
810	37.8	870	53.9	930	44.5
811	38.2	871	53.7	931	44.4
812	38.6	872	53.6	932	44.3
813	39.0	873	53.5	933	44.1
814	39.5	874	53.4	934	43.7
815	40.1	875	53.3	935	43.3
816	40.6	876	53.1	936	42.9
817	41.2	877	53.0	937	42.5
818	41.9	878	53.0	938	41.8
819	42.6	879	53.0	939	40.9
820	43.4	880	53.1	940	39.8
821	44.2	881	53.3	941	38.7
822	45.0	882	53.3	942	37.7
823	45.8	883	53.3	943	36.7
824	46.8	884	53.1	944	35.9
825	47.7	885	52.8	945	35.3
826	48.7	886	52.2	946	34.9
827	49.7	887	51.3	947	34.6
828	50.7	888	50.2	948	34.4
829	51.6	889	49.2	949	34.2

WLTC class 1 vehicles, phase $Medium_1$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
950	33.9	1010	0.0		
951	33.6	1011	0.0		
952	33.3	1012	0.0		
953	33.0	1013	0.0		
954	32.8	1014	0.0		
955	32.4	1015	0.0		
956	31.9	1016	0.0		
957	31.4	1017	0.0		
958	31.0	1018	0.0		
959	30.6	1019	0.0		
960	30.3	1020	0.0		
961	29.8	1021	0.0		
962	29.1	1022	0.0		
963	28.5				
964	27.7				
965	26.8				
966	25.8				
967	24.9				
968	24.2				
969	23.8				
970	23.4				
971	22.9				
972	22.2				
973	21.1				
974	19.6				
975	18.1				
976	16.0				
977	14.0				
978	12.0				
979	10.3				
980	8.5				
981	6.5				
982	4.6				
983	3.1				
984	1.9				
985	1.0				
986	0.0				
987	0.0				
988	0.0				
989	0.0				
990	0.0				
991	0.0				
992	0.0				
993	0.0				
994	0.0				
995	0.0				
996	0.0				
997	0.0				
998	0.0				
999	0.0				
1000	0.0				
1001	0.0				
1002	0.0				
1003	0.0				
1004	0.0				
1005	0.0				
1006	0.0				
1007	0.0				
1008	0.0				
1009	0.0				

5. WLTC for Class 2 vehicles

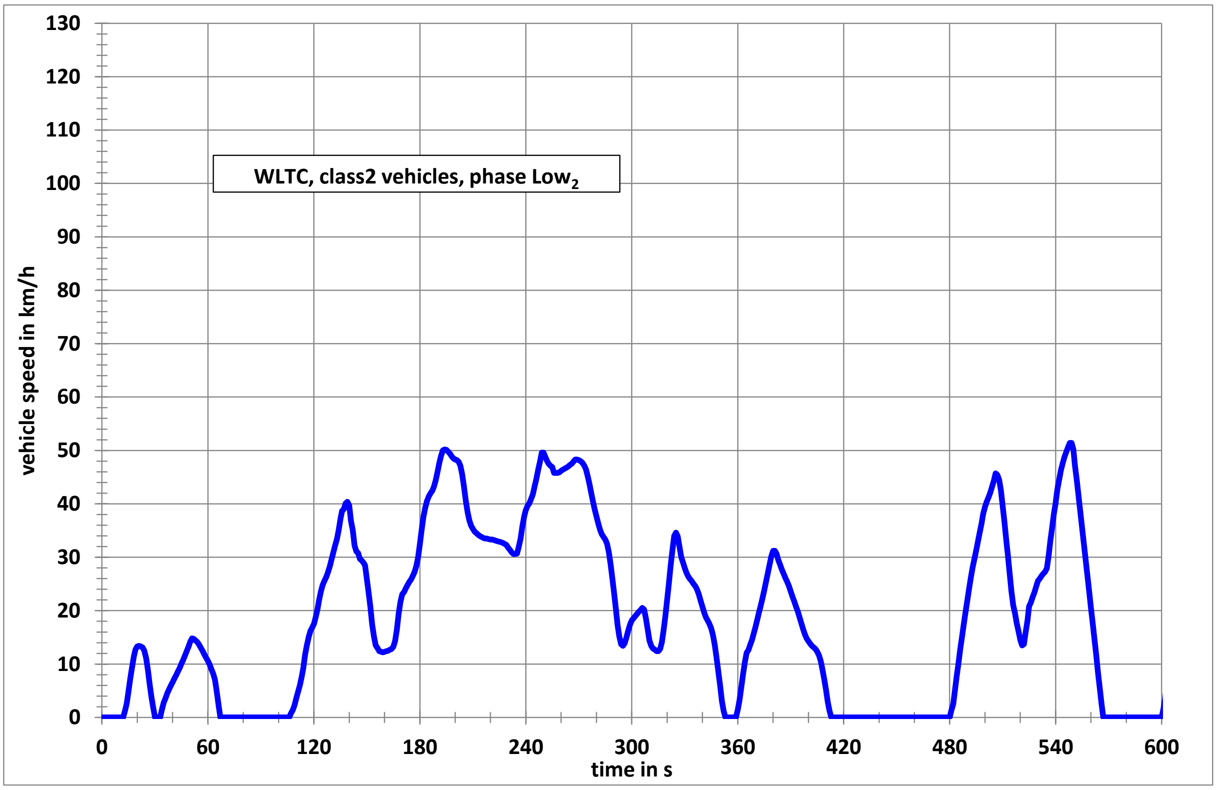


Figure 3: WLTC, Class 2 vehicles, phase Low_2

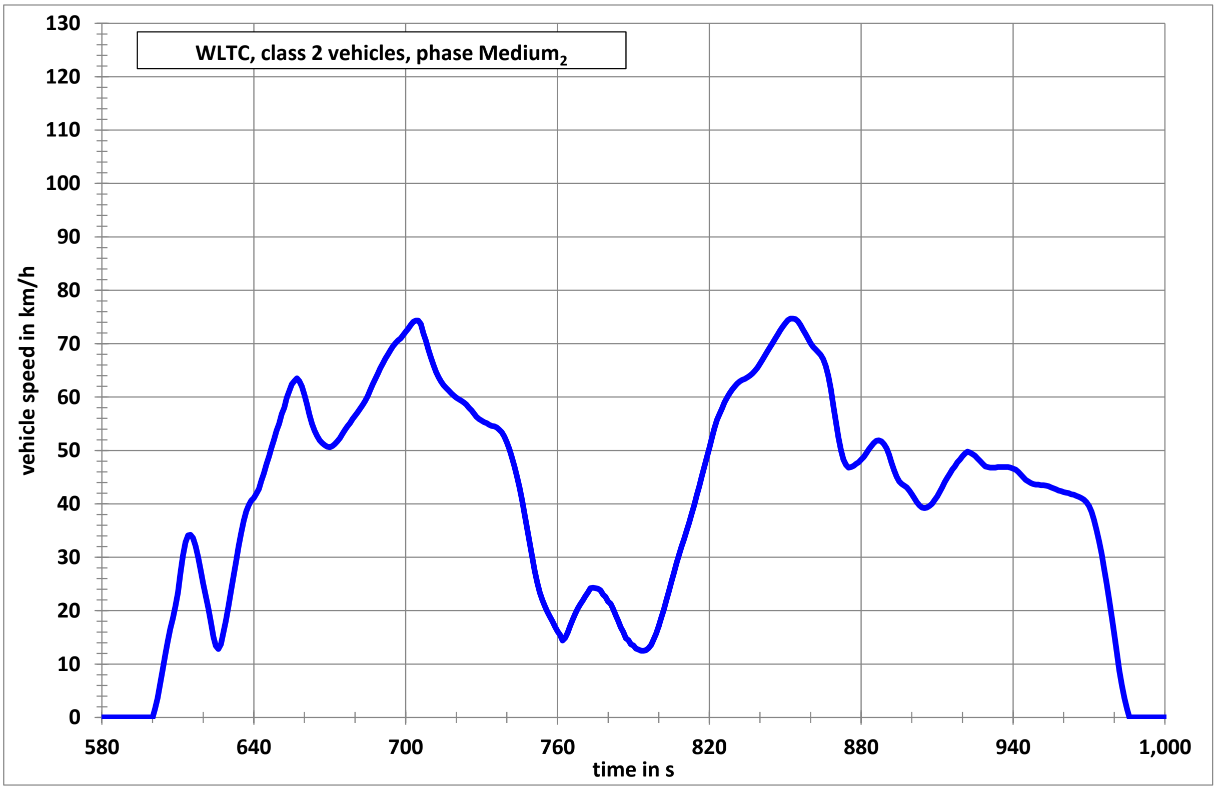


Figure 4: WLTC, Class 2 vehicles, phase $Medium_2$

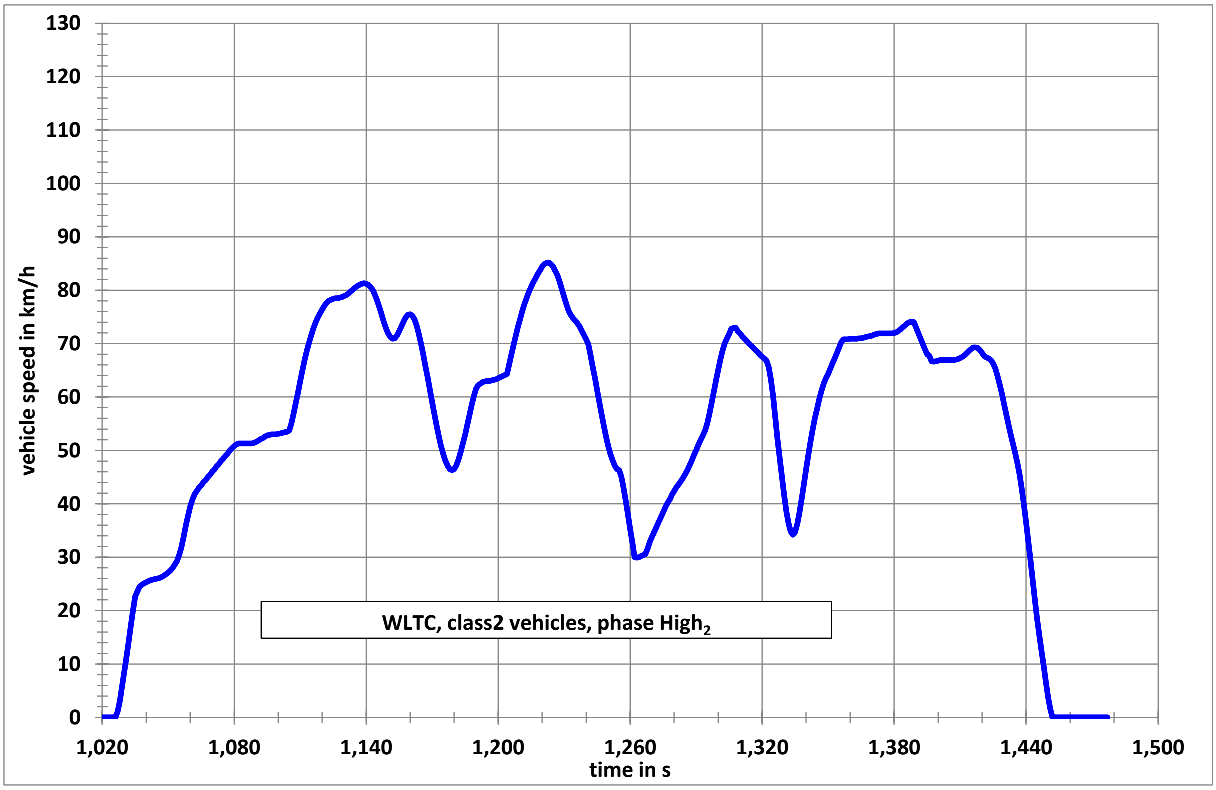


Figure 5: WLTC, Class 2 vehicles, phase $High_2$

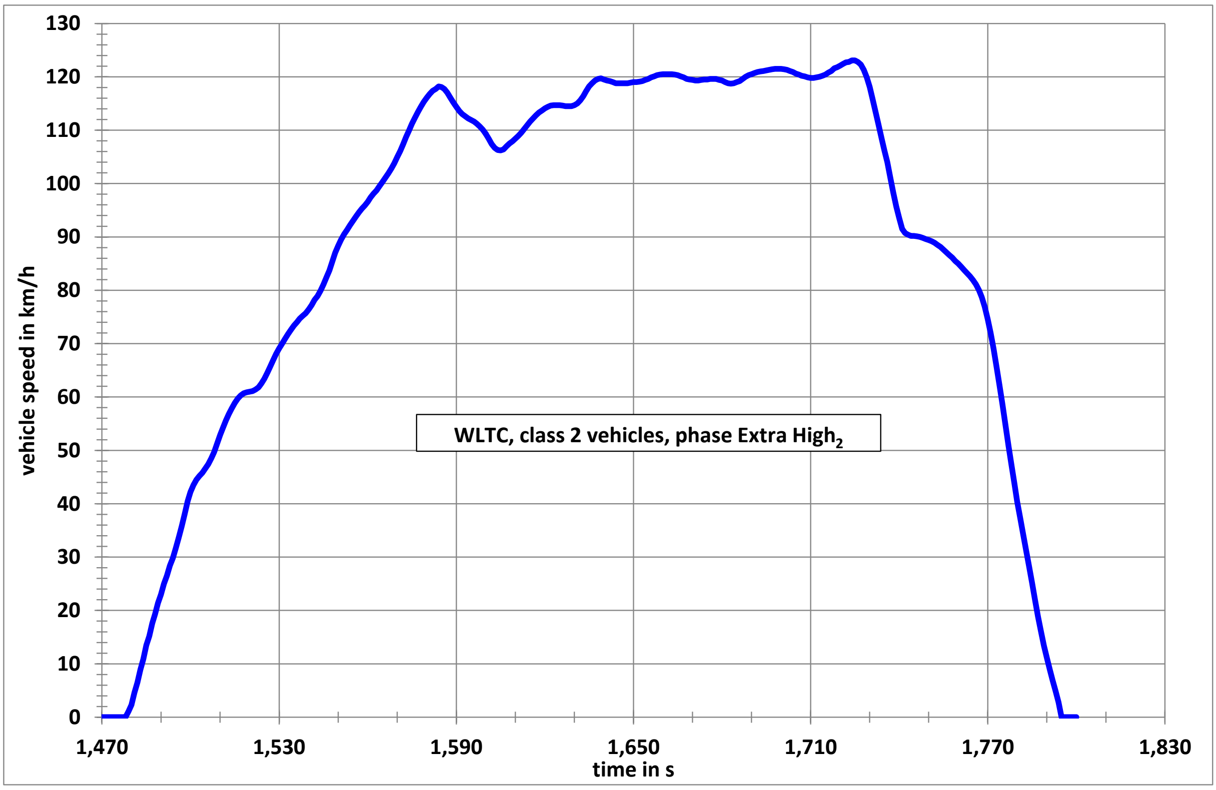


Figure 6: WLTC, Class 2 vehicles, phase Extra $High_2$

Table 3: WLTC, Class 2 vehicles, phase Low_2

WLTC class 2 vehicles, phase Low_2					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
0	0.0				
1	0.0	61	9.9	121	18.8
2	0.0	62	9.0	122	20.3
3	0.0	63	8.2	123	22.0
4	0.0	64	7.0	124	23.6
5	0.0	65	4.8	125	24.8
6	0.0	66	2.3	126	25.6
7	0.0	67	0.0	127	26.3
8	0.0	68	0.0	128	27.2
9	0.0	69	0.0	129	28.3
10	0.0	70	0.0	130	29.6
11	0.0	71	0.0	131	30.9
12	0.0	72	0.0	132	32.2
13	1.2	73	0.0	133	33.4
14	2.6	74	0.0	134	35.1
15	4.9	75	0.0	135	37.2
16	7.3	76	0.0	136	38.7
17	9.4	77	0.0	137	39.0
18	11.4	78	0.0	138	40.1
19	12.7	79	0.0	139	40.4
20	13.3	80	0.0	140	39.7
21	13.4	81	0.0	141	36.8
22	13.3	82	0.0	142	35.1
23	13.1	83	0.0	143	32.2
24	12.5	84	0.0	144	31.1
25	11.1	85	0.0	145	30.8
26	8.9	86	0.0	146	29.7
27	6.2	87	0.0	147	29.4
28	3.8	88	0.0	148	29.0
29	1.8	89	0.0	149	28.5
30	0.0	90	0.0	150	26.0
31	0.0	91	0.0	151	23.4
32	0.0	92	0.0	152	20.7
33	0.0	93	0.0	153	17.4
34	1.5	94	0.0	154	15.2
35	2.8	95	0.0	155	13.5
36	3.6	96	0.0	156	13.0
37	4.5	97	0.0	157	12.4
38	5.3	98	0.0	158	12.3
39	6.0	99	0.0	159	12.2
40	6.6	100	0.0	160	12.3
41	7.3	101	0.0	161	12.4
42	7.9	102	0.0	162	12.5
43	8.6	103	0.0	163	12.7
44	9.3	104	0.0	164	12.8
45	10.0	105	0.0	165	13.2
46	10.8	106	0.0	166	14.3
47	11.6	107	0.8	167	16.5
48	12.4	108	1.4	168	19.4
49	13.2	109	2.3	169	21.7
50	14.2	110	3.5	170	23.1
51	14.8	111	4.7	171	23.5
52	14.7	112	5.9	172	24.2
53	14.4	113	7.4	173	24.8
54	14.1	114	9.2	174	25.4
55	13.6	115	11.7	175	25.8
56	13.0	116	13.5	176	26.5
57	12.4	117	15.0	177	27.2
58	11.8	118	16.2	178	28.3
59	11.2	119	16.8	179	29.9
60	10.6	120	17.5	180	32.4

WLTC class 2 vehicles, phase Low_2					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
181	35.1	241	39.6	301	18.6
182	37.5	242	40.1	302	19.0
183	39.2	243	40.9	303	19.4
184	40.5	244	41.8	304	19.8
185	41.4	245	43.3	305	20.1
186	42.0	246	44.7	306	20.5
187	42.5	247	46.4	307	20.2
188	43.2	248	47.9	308	18.6
189	44.4	249	49.6	309	16.5
190	45.9	250	49.6	310	14.4
191	47.6	251	48.8	311	13.4
192	49.0	252	48.0	312	12.9
193	50.0	253	47.5	313	12.7
194	50.2	254	47.1	314	12.4
195	50.1	255	46.9	315	12.4
196	49.8	256	45.8	316	12.8
197	49.4	257	45.8	317	14.1
198	48.9	258	45.8	318	16.2
199	48.5	259	45.9	319	18.8
200	48.3	260	46.2	320	21.9
201	48.2	261	46.4	321	25.0
202	47.9	262	46.6	322	28.4
203	47.1	263	46.8	323	31.3
204	45.5	264	47.0	324	34.0
205	43.2	265	47.3	325	34.6
206	40.6	266	47.5	326	33.9
207	38.5	267	47.9	327	31.9
208	36.9	268	48.3	328	30.0
209	35.9	269	48.3	329	29.0
210	35.3	270	48.2	330	27.9
211	34.8	271	48.0	331	27.1
212	34.5	272	47.7	332	26.4
213	34.2	273	47.2	333	25.9
214	34.0	274	46.5	334	25.5
215	33.8	275	45.2	335	25.0
216	33.6	276	43.7	336	24.6
217	33.5	277	42.0	337	23.9
218	33.5	278	40.4	338	23.0
219	33.4	279	39.0	339	21.8
220	33.3	280	37.7	340	20.7
221	33.3	281	36.4	341	19.6
222	33.2	282	35.2	342	18.7
223	33.1	283	34.3	343	18.1
224	33.0	284	33.8	344	17.5
225	32.9	285	33.3	345	16.7
226	32.8	286	32.5	346	15.4
227	32.7	287	30.9	347	13.6
228	32.5	288	28.6	348	11.2
229	32.3	289	25.9	349	8.6
230	31.8	290	23.1	350	6.0
231	31.4	291	20.1	351	3.1
232	30.9	292	17.3	352	1.2
233	30.6	293	15.1	353	0.0
234	30.6	294	13.7	354	0.0
235	30.7	295	13.4	355	0.0
236	32.0	296	13.9	356	0.0
237	33.5	297	15.0	357	0.0
238	35.8	298	16.3	358	0.0
239	37.6	299	17.4	359	0.0
240	38.8	300	18.2	360	1.4

WLTC class 2 vehicles, phase Low_2					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
361	3.2	421	0.0	481	1.4
362	5.6	422	0.0	482	2.5
363	8.1	423	0.0	483	5.2
364	10.3	424	0.0	484	7.9
365	12.1	425	0.0	485	10.3
366	12.6	426	0.0	486	12.7
367	13.6	427	0.0	487	15.0
368	14.5	428	0.0	488	17.4
369	15.6	429	0.0	489	19.7
370	16.8	430	0.0	490	21.9
371	18.2	431	0.0	491	24.1
372	19.6	432	0.0	492	26.2
373	20.9	433	0.0	493	28.1
374	22.3	434	0.0	494	29.7
375	23.8	435	0.0	495	31.3
376	25.4	436	0.0	496	33.0
377	27.0	437	0.0	497	34.7
378	28.6	438	0.0	498	36.3
379	30.2	439	0.0	499	38.1
380	31.2	440	0.0	500	39.4
381	31.2	441	0.0	501	40.4
382	30.7	442	0.0	502	41.2
383	29.5	443	0.0	503	42.1
384	28.6	444	0.0	504	43.2
385	27.7	445	0.0	505	44.3
386	26.9	446	0.0	506	45.7
387	26.1	447	0.0	507	45.4
388	25.4	448	0.0	508	44.5
389	24.6	449	0.0	509	42.5
390	23.6	450	0.0	510	39.5
391	22.6	451	0.0	511	36.5
392	21.7	452	0.0	512	33.5
393	20.7	453	0.0	513	30.4
394	19.8	454	0.0	514	27.0
395	18.8	455	0.0	515	23.6
396	17.7	456	0.0	516	21.0
397	16.6	457	0.0	517	19.5
398	15.6	458	0.0	518	17.6
399	14.8	459	0.0	519	16.1
400	14.3	460	0.0	520	14.5
401	13.8	461	0.0	521	13.5
402	13.4	462	0.0	522	13.7
403	13.1	463	0.0	523	16.0
404	12.8	464	0.0	524	18.1
405	12.3	465	0.0	525	20.8
406	11.6	466	0.0	526	21.5
407	10.5	467	0.0	527	22.5
408	9.0	468	0.0	528	23.4
409	7.2	469	0.0	529	24.5
410	5.2	470	0.0	530	25.6
411	2.9	471	0.0	531	26.0
412	1.2	472	0.0	532	26.5
413	0.0	473	0.0	533	26.9
414	0.0	474	0.0	534	27.3
415	0.0	475	0.0	535	27.9
416	0.0	476	0.0	536	30.3
417	0.0	477	0.0	537	33.2
418	0.0	478	0.0	538	35.4
419	0.0	479	0.0	539	38.0
420	0.0	480	0.0	540	40.1

WLTC class 2 vehicles, phase Low_2					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
541	42.7				
542	44.5				
543	46.3				
544	47.6				
545	48.8				
546	49.7				
547	50.6				
548	51.4				
549	51.4				
550	50.2				
551	47.1				
552	44.5				
553	41.5				
554	38.5				
555	35.5				
556	32.5				
557	29.5				
558	26.5				
559	23.5				
560	20.4				
561	17.5				
562	14.5				
563	11.5				
564	8.5				
565	5.6				
566	2.6				
567	0.0				
568	0.0				
569	0.0				
570	0.0				
571	0.0				
572	0.0				
573	0.0				
574	0.0				
575	0.0				
576	0.0				
577	0.0				
578	0.0				
579	0.0				
580	0.0				
581	0.0				
582	0.0				
583	0.0				
584	0.0				
585	0.0				
586	0.0				
587	0.0				
588	0.0				
589	0.0				

Table 4: WLTC, Class 2 vehicles, phase $Medium_2$

WLTC class 2 vehicles, phase $Medium_2$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
590	0.0	650	55.0	710	67.4
591	0.0	651	56.8	711	66.0
592	0.0	652	58.0	712	64.7
593	0.0	653	59.8	713	63.7
594	0.0	654	61.1	714	62.9
595	0.0	655	62.4	715	62.2
596	0.0	656	63.0	716	61.7
597	0.0	657	63.5	717	61.2
598	0.0	658	63.0	718	60.7
599	0.0	659	62.0	719	60.3
600	0.0	660	60.4	720	59.9
601	1.6	661	58.6	721	59.6
602	3.6	662	56.7	722	59.3
603	6.3	663	55.0	723	59.0
604	9.0	664	53.7	724	58.6
605	11.8	665	52.7	725	58.0
606	14.2	666	51.9	726	57.5
607	16.6	667	51.4	727	56.9
608	18.5	668	51.0	728	56.3
609	20.8	669	50.7	729	55.9
610	23.4	670	50.6	730	55.6
611	26.9	671	50.8	731	55.3
612	30.3	672	51.2	732	55.1
613	32.8	673	51.7	733	54.8
614	34.1	674	52.3	734	54.6
615	34.2	675	53.1	735	54.5
616	33.6	676	53.8	736	54.3
617	32.1	677	54.5	737	53.9
618	30.0	678	55.1	738	53.4
619	27.5	679	55.9	739	52.6
620	25.1	680	56.5	740	51.5
621	22.8	681	57.1	741	50.2
622	20.5	682	57.8	742	48.7
623	17.9	683	58.5	743	47.0
624	15.1	684	59.3	744	45.1
625	13.4	685	60.2	745	43.0
626	12.8	686	61.3	746	40.6
627	13.7	687	62.4	747	38.1
628	16.0	688	63.4	748	35.4
629	18.1	689	64.4	749	32.7
630	20.8	690	65.4	750	30.0
631	23.7	691	66.3	751	27.5
632	26.5	692	67.2	752	25.3
633	29.3	693	68.0	753	23.4
634	32.0	694	68.8	754	22.0
635	34.5	695	69.5	755	20.8
636	36.8	696	70.1	756	19.8
637	38.6	697	70.6	757	18.9
638	39.8	698	71.0	758	18.0
639	40.6	699	71.6	759	17.0
640	41.1	700	72.2	760	16.1
641	41.9	701	72.8	761	15.5
642	42.8	702	73.5	762	14.4
643	44.3	703	74.1	763	14.9
644	45.7	704	74.3	764	15.9
645	47.4	705	74.3	765	17.1
646	48.9	706	73.7	766	18.3
647	50.6	707	71.9	767	19.4
648	52.0	708	70.5	768	20.4
649	53.7	709	68.9	769	21.2

WLTC class 2 vehicles, phase $Medium_2$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
770	21.9	830	62.0	890	50.4
771	22.7	831	62.5	891	49.2
772	23.4	832	62.9	892	47.7
773	24.2	833	63.2	893	46.3
774	24.3	834	63.4	894	45.1
775	24.2	835	63.7	895	44.2
776	24.1	836	64.0	896	43.7
777	23.8	837	64.4	897	43.4
778	23.0	838	64.9	898	43.1
779	22.6	839	65.5	899	42.5
780	21.7	840	66.2	900	41.8
781	21.3	841	67.0	901	41.1
782	20.3	842	67.8	902	40.3
783	19.1	843	68.6	903	39.7
784	18.1	844	69.4	904	39.3
785	16.9	845	70.1	905	39.2
786	16.0	846	70.9	906	39.3
787	14.8	847	71.7	907	39.6
788	14.5	848	72.5	908	40.0
789	13.7	849	73.2	909	40.7
790	13.5	850	73.8	910	41.4
791	12.9	851	74.4	911	42.2
792	12.7	852	74.7	912	43.1
793	12.5	853	74.7	913	44.1
794	12.5	854	74.6	914	44.9
795	12.6	855	74.2	915	45.6
796	13.0	856	73.5	916	46.4
797	13.6	857	72.6	917	47.0
798	14.6	858	71.8	918	47.8
799	15.7	859	71.0	919	48.3
800	17.1	860	70.1	920	48.9
801	18.7	861	69.4	921	49.4
802	20.2	862	68.9	922	49.8
803	21.9	863	68.4	923	49.6
804	23.6	864	67.9	924	49.3
805	25.4	865	67.1	925	49.0
806	27.1	866	65.8	926	48.5
807	28.9	867	63.9	927	48.0
808	30.4	868	61.4	928	47.5
809	32.0	869	58.4	929	47.0
810	33.4	870	55.4	930	46.9
811	35.0	871	52.4	931	46.8
812	36.4	872	50.0	932	46.8
813	38.1	873	48.3	933	46.8
814	39.7	874	47.3	934	46.9
815	41.6	875	46.8	935	46.9
816	43.3	876	46.9	936	46.9
817	45.1	877	47.1	937	46.9
818	46.9	878	47.5	938	46.9
819	48.7	879	47.8	939	46.8
820	50.5	880	48.3	940	46.6
821	52.4	881	48.8	941	46.4
822	54.1	882	49.5	942	46.0
823	55.7	883	50.2	943	45.5
824	56.8	884	50.8	944	45.0
825	57.9	885	51.4	945	44.5
826	59.0	886	51.8	946	44.2
827	59.9	887	51.9	947	43.9
828	60.7	888	51.7	948	43.7
829	61.4	889	51.2	949	43.6

WLTC class 2 vehicles, phase $Medium_2$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
950	43.6	1010	0.0		
951	43.5	1011	0.0		
952	43.5	1012	0.0		
953	43.4	1013	0.0		
954	43.3	1014	0.0		
955	43.1	1015	0.0		
956	42.9	1016	0.0		
957	42.7	1017	0.0		
958	42.5	1018	0.0		
959	42.4	1019	0.0		
960	42.2	1020	0.0		
961	42.1	1021	0.0		
962	42.0	1022	0.0		
963	41.8				
964	41.7				
965	41.5				
966	41.3				
967	41.1				
968	40.8				
969	40.3				
970	39.6				
971	38.5				
972	37.0				
973	35.1				
974	33.0				
975	30.6				
976	27.9				
977	25.1				
978	22.0				
979	18.8				
980	15.5				
981	12.3				
982	8.8				
983	6.0				
984	3.6				
985	1.6				
986	0.0				
987	0.0				
988	0.0				
989	0.0				
990	0.0				
991	0.0				
992	0.0				
993	0.0				
994	0.0				
995	0.0				
996	0.0				
997	0.0				
998	0.0				
999	0.0				
1000	0.0				
1001	0.0				
1002	0.0				
1003	0.0				
1004	0.0				
1005	0.0				
1006	0.0				
1007	0.0				
1008	0.0				
1009	0.0				

Table 5: WLTC, Class 2 vehicles, phase $High_2$

WLTC class 2 vehicles, phase $High_2$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1023	0.0	1083	51.3	1143	80.0
1024	0.0	1084	51.3	1144	79.1
1025	0.0	1085	51.3	1145	78.0
1026	0.0	1086	51.3	1146	76.8
1027	1.1	1087	51.3	1147	75.5
1028	3.0	1088	51.3	1148	74.1
1029	5.7	1089	51.4	1149	72.9
1030	8.4	1090	51.6	1150	71.9
1031	11.1	1091	51.8	1151	71.2
1032	14.0	1092	52.1	1152	70.9
1033	17.0	1093	52.3	1153	71.0
1034	20.1	1094	52.6	1154	71.5
1035	22.7	1095	52.8	1155	72.3
1036	23.6	1096	52.9	1156	73.2
1037	24.5	1097	53.0	1157	74.1
1038	24.8	1098	53.0	1158	74.9
1039	25.1	1099	53.0	1159	75.4
1040	25.3	1100	53.1	1160	75.5
1041	25.5	1101	53.2	1161	75.2
1042	25.7	1102	53.3	1162	74.5
1043	25.8	1103	53.4	1163	73.3
1044	25.9	1104	53.5	1164	71.7
1045	26.0	1105	53.7	1165	69.9
1046	26.1	1106	55.0	1166	67.9
1047	26.3	1107	56.8	1167	65.7
1048	26.5	1108	58.8	1168	63.5
1049	26.8	1109	60.9	1169	61.2
1050	27.1	1110	63.0	1170	59.0
1051	27.5	1111	65.0	1171	56.8
1052	28.0	1112	66.9	1172	54.7
1053	28.6	1113	68.6	1173	52.7
1054	29.3	1114	70.1	1174	50.9
1055	30.4	1115	71.5	1175	49.4
1056	31.8	1116	72.8	1176	48.1
1057	33.7	1117	73.9	1177	47.1
1058	35.8	1118	74.9	1178	46.5
1059	37.8	1119	75.7	1179	46.3
1060	39.5	1120	76.4	1180	46.5
1061	40.8	1121	77.1	1181	47.2
1062	41.8	1122	77.6	1182	48.3
1063	42.4	1123	78.0	1183	49.7
1064	43.0	1124	78.2	1184	51.3
1065	43.4	1125	78.4	1185	53.0
1066	44.0	1126	78.5	1186	54.9
1067	44.4	1127	78.5	1187	56.7
1068	45.0	1128	78.6	1188	58.6
1069	45.4	1129	78.7	1189	60.2
1070	46.0	1130	78.9	1190	61.6
1071	46.4	1131	79.1	1191	62.2
1072	47.0	1132	79.4	1192	62.5
1073	47.4	1133	79.8	1193	62.8
1074	48.0	1134	80.1	1194	62.9
1075	48.4	1135	80.5	1195	63.0
1076	49.0	1136	80.8	1196	63.0
1077	49.4	1137	81.0	1197	63.1
1078	50.0	1138	81.2	1198	63.2
1079	50.4	1139	81.3	1199	63.3
1080	50.8	1140	81.2	1200	63.5
1081	51.1	1141	81.0	1201	63.7
1082	51.3	1142	80.6	1202	63.9

WLTC class 2 vehicles, phase $High_2$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1203	64.1	1263	29.9	1323	65.6
1204	64.3	1264	30.0	1324	63.3
1205	66.1	1265	30.2	1325	60.2
1206	67.9	1266	30.4	1326	56.2
1207	69.7	1267	30.6	1327	52.2
1208	71.4	1268	31.6	1328	48.4
1209	73.1	1269	33.0	1329	45.0
1210	74.7	1270	33.9	1330	41.6
1211	76.2	1271	34.8	1331	38.6
1212	77.5	1272	35.7	1332	36.4
1213	78.6	1273	36.6	1333	34.8
1214	79.7	1274	37.5	1334	34.2
1215	80.6	1275	38.4	1335	34.7
1216	81.5	1276	39.3	1336	36.3
1217	82.2	1277	40.2	1337	38.5
1218	83.0	1278	40.8	1338	41.0
1219	83.7	1279	41.7	1339	43.7
1220	84.4	1280	42.4	1340	46.5
1221	84.9	1281	43.1	1341	49.1
1222	85.1	1282	43.6	1342	51.6
1223	85.2	1283	44.2	1343	53.9
1224	84.9	1284	44.8	1344	56.0
1225	84.4	1285	45.5	1345	57.9
1226	83.6	1286	46.3	1346	59.7
1227	82.7	1287	47.2	1347	61.2
1228	81.5	1288	48.1	1348	62.5
1229	80.1	1289	49.1	1349	63.5
1230	78.7	1290	50.0	1350	64.3
1231	77.4	1291	51.0	1351	65.3
1232	76.2	1292	51.9	1352	66.3
1233	75.4	1293	52.7	1353	67.3
1234	74.8	1294	53.7	1354	68.3
1235	74.3	1295	55.0	1355	69.3
1236	73.8	1296	56.8	1356	70.3
1237	73.2	1297	58.8	1357	70.8
1238	72.4	1298	60.9	1358	70.8
1239	71.6	1299	63.0	1359	70.8
1240	70.8	1300	65.0	1360	70.9
1241	69.9	1301	66.9	1361	70.9
1242	67.9	1302	68.6	1362	70.9
1243	65.7	1303	70.1	1363	70.9
1244	63.5	1304	71.0	1364	71.0
1245	61.2	1305	71.8	1365	71.0
1246	59.0	1306	72.8	1366	71.1
1247	56.8	1307	72.9	1367	71.2
1248	54.7	1308	73.0	1368	71.3
1249	52.7	1309	72.3	1369	71.4
1250	50.9	1310	71.9	1370	71.5
1251	49.4	1311	71.3	1371	71.7
1252	48.1	1312	70.9	1372	71.8
1253	47.1	1313	70.5	1373	71.9
1254	46.5	1314	70.0	1374	71.9
1255	46.3	1315	69.6	1375	71.9
1256	45.1	1316	69.2	1376	71.9
1257	43.0	1317	68.8	1377	71.9
1258	40.6	1318	68.4	1378	71.9
1259	38.1	1319	67.9	1379	71.9
1260	35.4	1320	67.5	1380	72.0
1261	32.7	1321	67.2	1381	72.1
1262	30.0	1322	66.8	1382	72.4

WLTC class 2 vehicles, phase $High_2$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1383	72.7	1443	25.8		
1384	73.1	1444	22.1		
1385	73.4	1445	18.6		
1386	73.8	1446	15.3		
1387	74.0	1447	12.4		
1388	74.1	1448	9.6		
1389	74.0	1449	6.6		
1390	73.0	1450	3.8		
1391	72.0	1451	1.6		
1392	71.0	1452	0.0		
1393	70.0	1453	0.0		
1394	69.0	1454	0.0		
1395	68.0	1455	0.0		
1396	67.7	1456	0.0		
1397	66.7	1457	0.0		
1398	66.6	1458	0.0		
1399	66.7	1459	0.0		
1400	66.8	1460	0.0		
1401	66.9	1461	0.0		
1402	66.9	1462	0.0		
1403	66.9	1463	0.0		
1404	66.9	1464	0.0		
1405	66.9	1465	0.0		
1406	66.9	1466	0.0		
1407	66.9	1467	0.0		
1408	67.0	1468	0.0		
1409	67.1	1469	0.0		
1410	67.3	1470	0.0		
1411	67.5	1471	0.0		
1412	67.8	1472	0.0		
1413	68.2	1473	0.0		
1414	68.6	1474	0.0		
1415	69.0	1475	0.0		
1416	69.3	1476	0.0		
1417	69.3	1477	0.0		
1418	69.2				
1419	68.8				
1420	68.2				
1421	67.6				
1422	67.4				
1423	67.2				
1424	66.9				
1425	66.3				
1426	65.4				
1427	64.0				
1428	62.4				
1429	60.6				
1430	58.6				
1431	56.7				
1432	54.8				
1433	53.0				
1434	51.3				
1435	49.6				
1436	47.8				
1437	45.5				
1438	42.8				
1439	39.8				
1440	36.5				
1441	33.0				
1442	29.5				

Table 6: WLTC, Class 2 vehicles, phase Extra High$_2$

WLTC class 2 vehicles, phase Extra High$_2$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1478	0.0	1538	75.2	1598	110.7
1479	1.1	1539	75.7	1599	110.1
1480	2.3	1540	76.4	1600	109.3
1481	4.6	1541	77.2	1601	108.4
1482	6.5	1542	78.2	1602	107.4
1483	8.9	1543	78.9	1603	106.7
1484	10.9	1544	79.9	1604	106.3
1485	13.5	1545	81.1	1605	106.2
1486	15.2	1546	82.4	1606	106.4
1487	17.6	1547	83.7	1607	107.0
1488	19.3	1548	85.4	1608	107.5
1489	21.4	1549	87.0	1609	107.9
1490	23.0	1550	88.3	1610	108.4
1491	25.0	1551	89.5	1611	108.9
1492	26.5	1552	90.5	1612	109.5
1493	28.4	1553	91.3	1613	110.2
1494	29.8	1554	92.2	1614	110.9
1495	31.7	1555	93.0	1615	111.6
1496	33.7	1556	93.8	1616	112.2
1497	35.8	1557	94.6	1617	112.8
1498	38.1	1558	95.3	1618	113.3
1499	40.5	1559	95.9	1619	113.7
1500	42.2	1560	96.6	1620	114.1
1501	43.5	1561	97.4	1621	114.4
1502	44.5	1562	98.1	1622	114.6
1503	45.2	1563	98.7	1623	114.7
1504	45.8	1564	99.5	1624	114.7
1505	46.6	1565	100.3	1625	114.7
1506	47.4	1566	101.1	1626	114.6
1507	48.5	1567	101.9	1627	114.5
1508	49.7	1568	102.8	1628	114.5
1509	51.3	1569	103.8	1629	114.5
1510	52.9	1570	105.0	1630	114.7
1511	54.3	1571	106.1	1631	115.0
1512	55.6	1572	107.4	1632	115.6
1513	56.8	1573	108.7	1633	116.4
1514	57.9	1574	109.9	1634	117.3
1515	58.9	1575	111.2	1635	118.2
1516	59.7	1576	112.3	1636	118.8
1517	60.3	1577	113.4	1637	119.3
1518	60.7	1578	114.4	1638	119.6
1519	60.9	1579	115.3	1639	119.7
1520	61.0	1580	116.1	1640	119.5
1521	61.1	1581	116.8	1641	119.3
1522	61.4	1582	117.4	1642	119.2
1523	61.8	1583	117.7	1643	119.0
1524	62.5	1584	118.2	1644	118.8
1525	63.4	1585	118.1	1645	118.8
1526	64.5	1586	117.7	1646	118.8
1527	65.7	1587	117.0	1647	118.8
1528	66.9	1588	116.1	1648	118.8
1529	68.1	1589	115.2	1649	118.9
1530	69.1	1590	114.4	1650	119.0
1531	70.0	1591	113.6	1651	119.0
1532	70.9	1592	113.0	1652	119.1
1533	71.8	1593	112.6	1653	119.2
1534	72.6	1594	112.2	1654	119.4
1535	73.4	1595	111.9	1655	119.6
1536	74.0	1596	111.6	1656	119.9
1537	74.7	1597	111.2	1657	120.1

WLTC class 2 vehicles, phase Extra High$_2$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1658	120.3	1718	121.6	1778	47.3
1659	120.4	1719	121.8	1779	43.8
1660	120.5	1720	122.1	1780	40.4
1661	120.5	1721	122.4	1781	37.4
1662	120.5	1722	122.7	1782	34.3
1663	120.5	1723	122.8	1783	31.3
1664	120.4	1724	123.1	1784	28.3
1665	120.3	1725	123.1	1785	25.2
1666	120.1	1726	122.8	1786	22.0
1667	119.9	1727	122.3	1787	18.9
1668	119.6	1728	121.3	1788	16.1
1669	119.5	1729	119.9	1789	13.4
1670	119.4	1730	118.1	1790	11.1
1671	119.3	1731	115.9	1791	8.9
1672	119.3	1732	113.5	1792	6.9
1673	119.4	1733	111.1	1793	4.9
1674	119.5	1734	108.6	1794	2.8
1675	119.5	1735	106.2	1795	0.0
1676	119.6	1736	104.0	1796	0.0
1677	119.6	1737	101.1	1797	0.0
1678	119.6	1738	98.3	1798	0.0
1679	119.4	1739	95.7	1799	0.0
1680	119.3	1740	93.5	1800	0.0
1681	119.0	1741	91.5		
1682	118.8	1742	90.7		
1683	118.7	1743	90.4		
1684	118.8	1744	90.2		
1685	119.0	1745	90.2		
1686	119.2	1746	90.1		
1687	119.6	1747	90.0		
1688	120.0	1748	89.8		
1689	120.3	1749	89.6		
1690	120.5	1750	89.4		
1691	120.7	1751	89.2		
1692	120.9	1752	88.9		
1693	121.0	1753	88.5		
1694	121.1	1754	88.1		
1695	121.2	1755	87.6		
1696	121.3	1756	87.1		
1697	121.4	1757	86.6		
1698	121.5	1758	86.1		
1699	121.5	1759	85.5		
1700	121.5	1760	85.0		
1701	121.4	1761	84.4		
1702	121.3	1762	83.8		
1703	121.1	1763	83.2		
1704	120.9	1764	82.6		
1705	120.6	1765	81.9		
1706	120.4	1766	81.1		
1707	120.2	1767	80.0		
1708	120.1	1768	78.7		
1709	119.9	1769	76.9		
1710	119.8	1770	74.6		
1711	119.8	1771	72.0		
1712	119.9	1772	69.0		
1713	120.0	1773	65.6		
1714	120.2	1774	62.1		
1715	120.4	1775	58.5		
1716	120.8	1776	54.7		
1717	121.1	1777	50.9		

6. WLTC for Class 3 vehicles

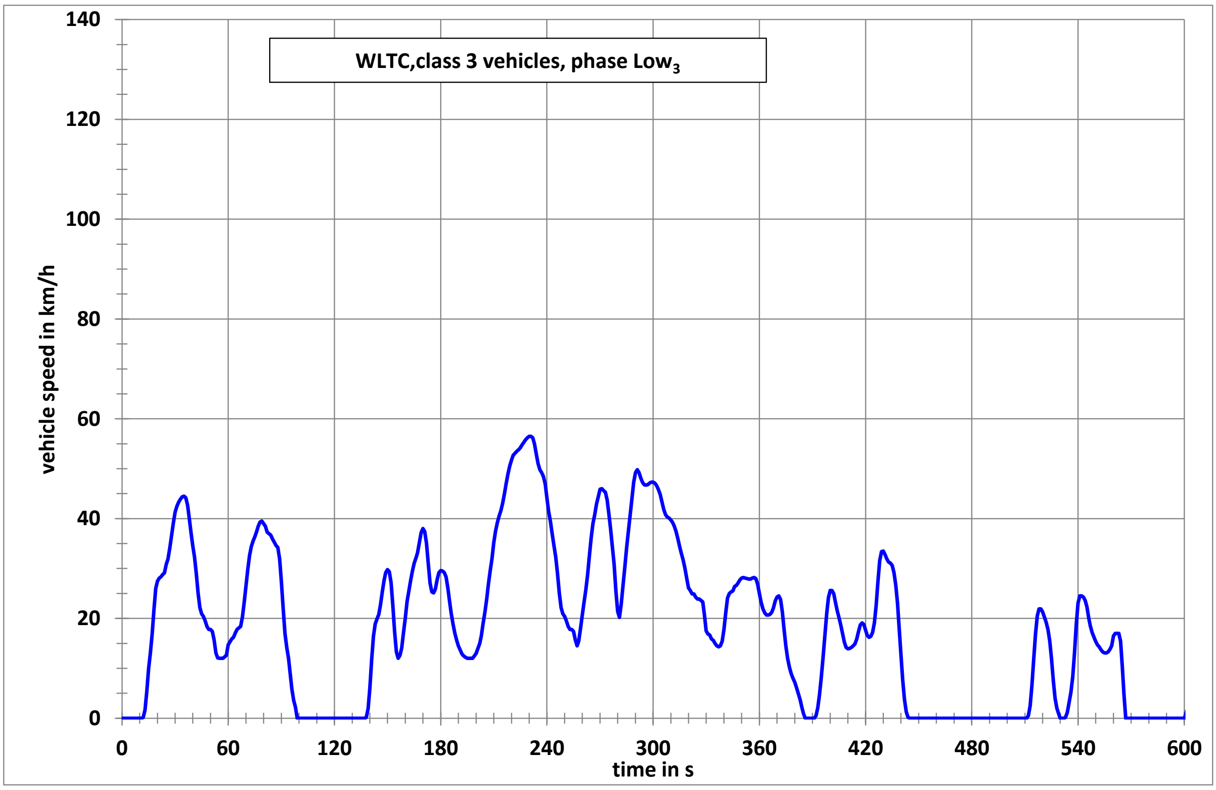


Figure 7: WLTC, Class 3 vehicles, phase Low_3

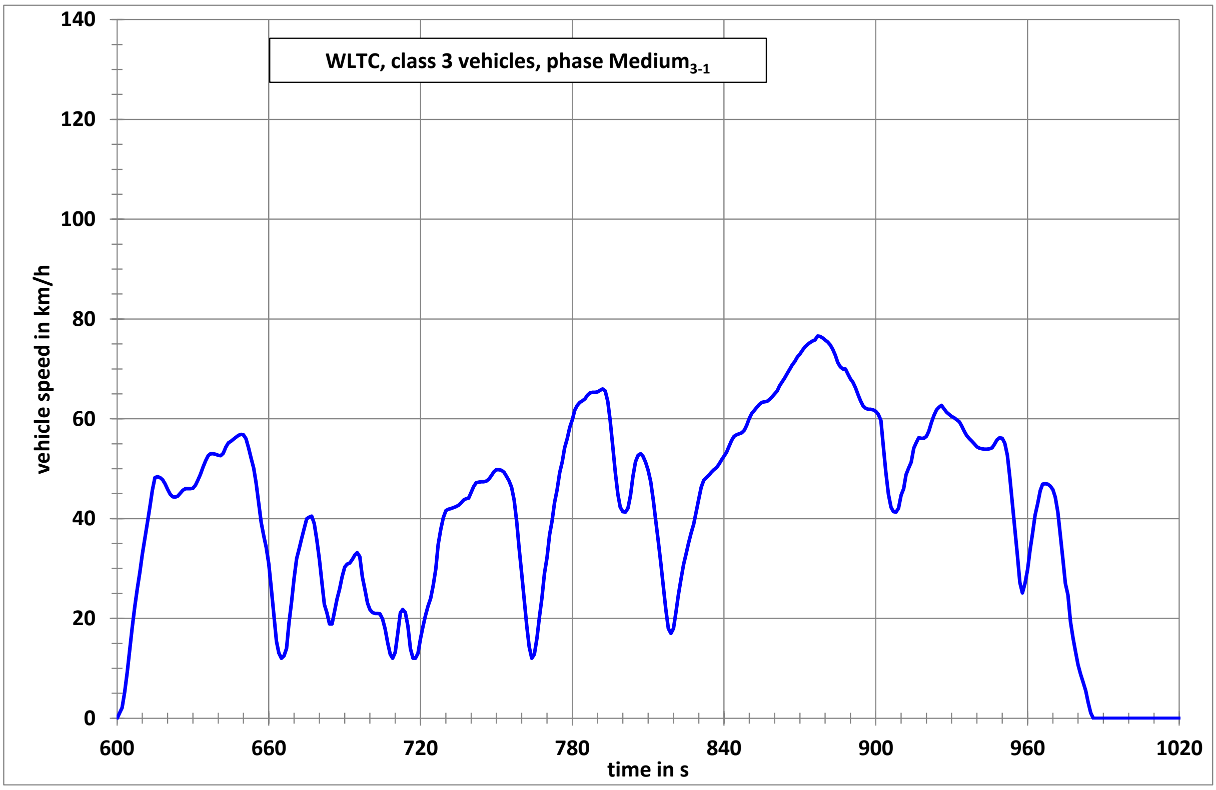


Figure 8: WLTC, Class 3 vehicles, phase $Medium_{3-1}$

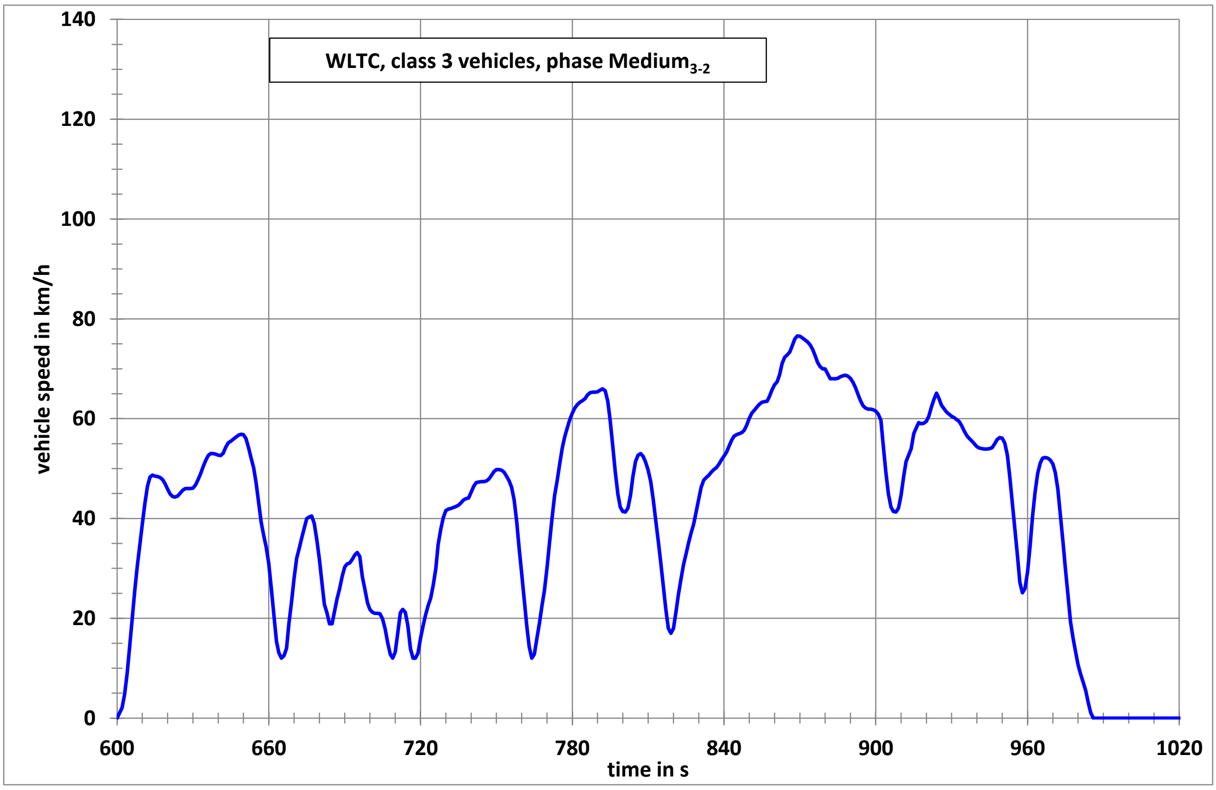


Figure 9: WLTC, Class 3 vehicles, phase $Medium_{3\text{-}2}$

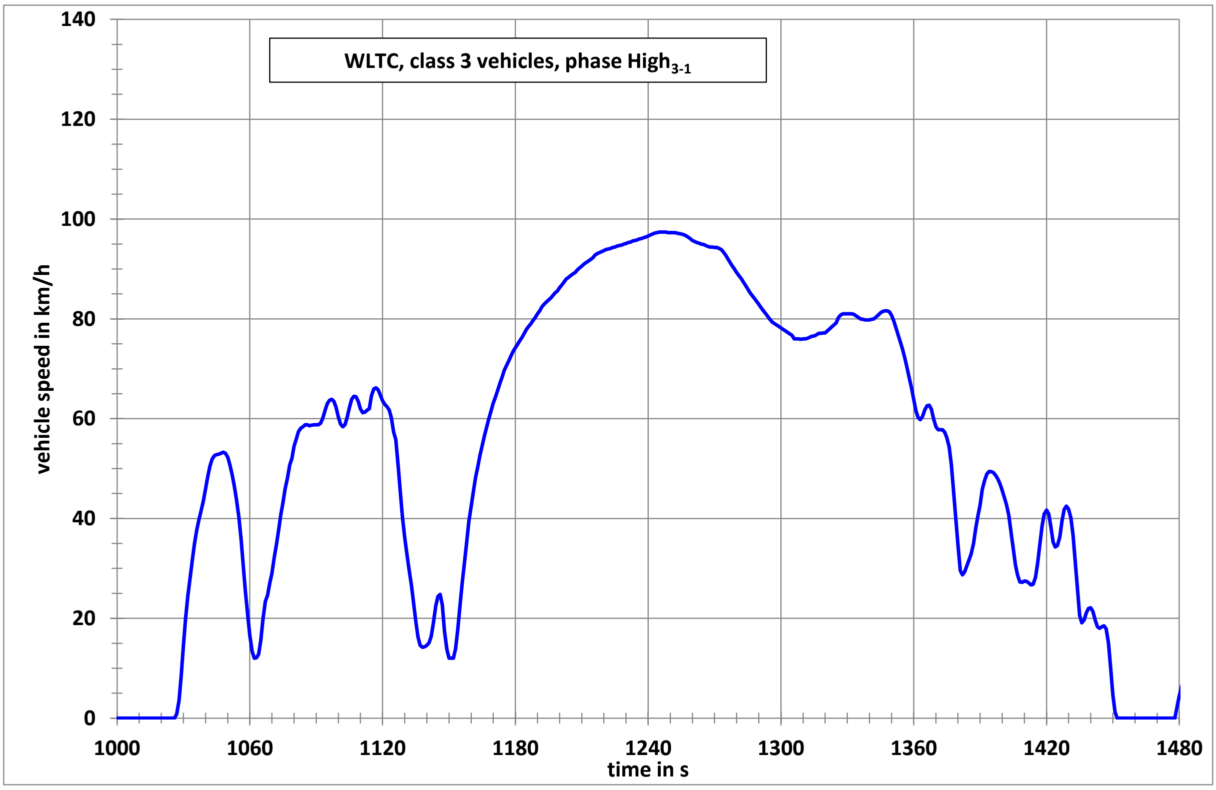


Figure 10: WLTC, Class 3 vehicles, phase $High_{3\text{-}1}$

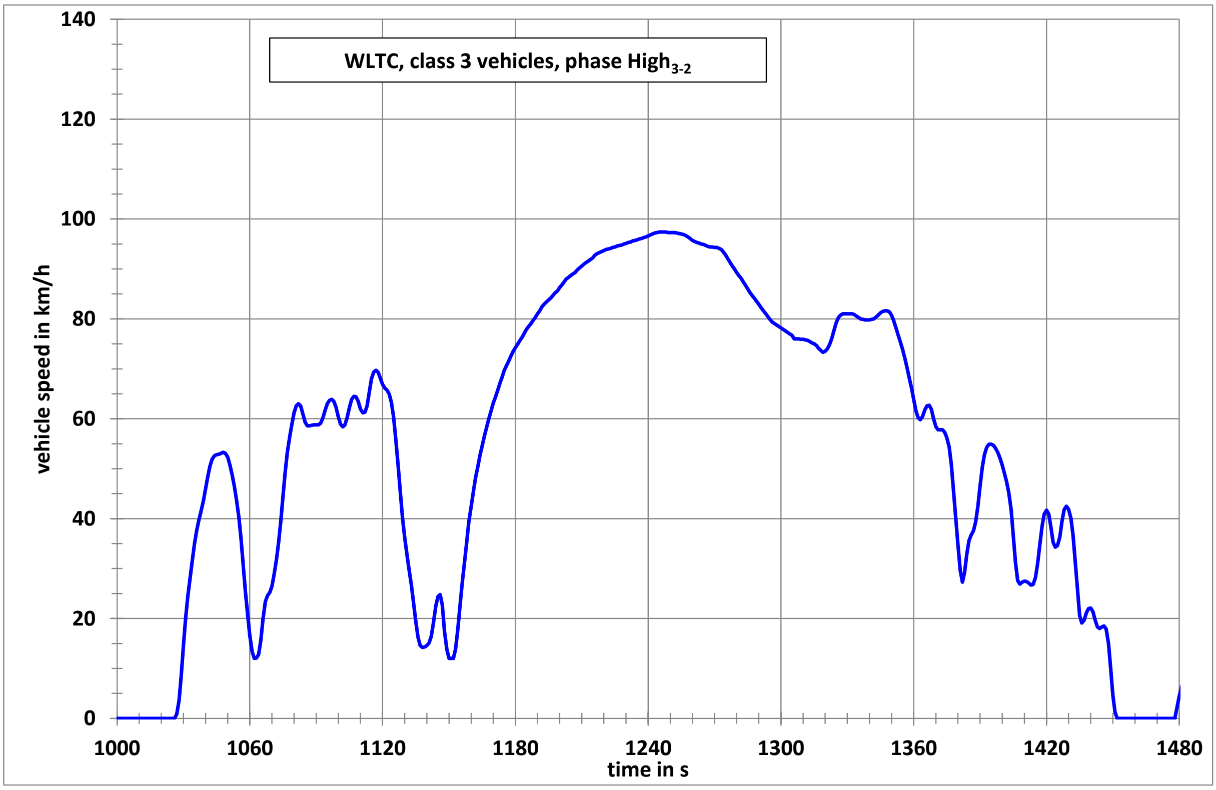


Figure 11: WLTC, Class 3 vehicles, phase $High_{3-2}$

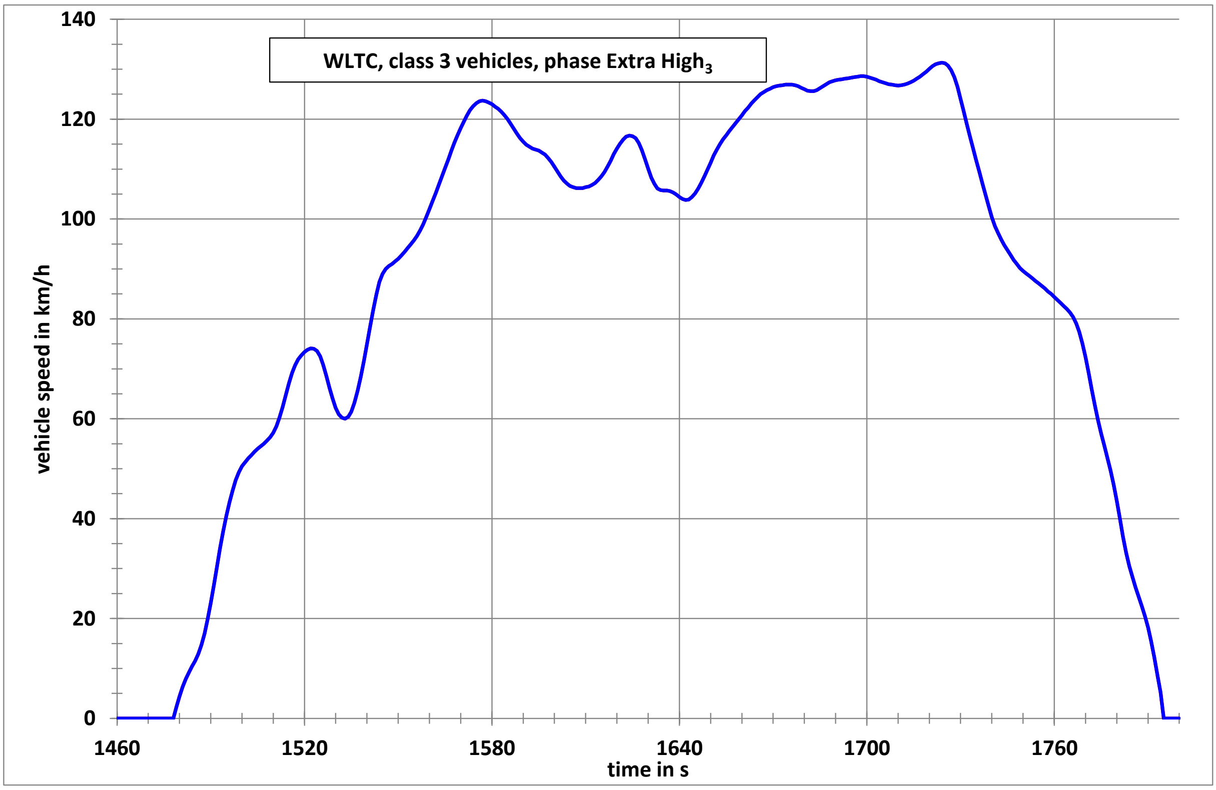


Figure 12: WLTC, Class 3 vehicles, phase Extra $High_3$

Table 7: WLTC, Class 3 vehicles, phase Low_3

WLTC class 3 vehicles, phase Low_3					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
0	0.0				
1	0.0	61	15.3	121	0.0
2	0.0	62	15.9	122	0.0
3	0.0	63	16.2	123	0.0
4	0.0	64	17.1	124	0.0
5	0.0	65	17.8	125	0.0
6	0.0	66	18.1	126	0.0
7	0.0	67	18.4	127	0.0
8	0.0	68	20.3	128	0.0
9	0.0	69	23.2	129	0.0
10	0.0	70	26.5	130	0.0
11	0.0	71	29.8	131	0.0
12	0.2	72	32.6	132	0.0
13	1.7	73	34.4	133	0.0
14	5.4	74	35.5	134	0.0
15	9.9	75	36.4	135	0.0
16	13.1	76	37.4	136	0.0
17	16.9	77	38.5	137	0.0
18	21.7	78	39.3	138	0.2
19	26.0	79	39.5	139	1.9
20	27.5	80	39.0	140	6.1
21	28.1	81	38.5	141	11.7
22	28.3	82	37.3	142	16.4
23	28.8	83	37.0	143	18.9
24	29.1	84	36.7	144	19.9
25	30.8	85	35.9	145	20.8
26	31.9	86	35.3	146	22.8
27	34.1	87	34.6	147	25.4
28	36.6	88	34.2	148	27.7
29	39.1	89	31.9	149	29.2
30	41.3	90	27.3	150	29.8
31	42.5	91	22.0	151	29.4
32	43.3	92	17.0	152	27.2
33	43.9	93	14.2	153	22.6
34	44.4	94	12.0	154	17.3
35	44.5	95	9.1	155	13.3
36	44.2	96	5.8	156	12.0
37	42.7	97	3.6	157	12.6
38	39.9	98	2.2	158	14.1
39	37.0	99	0.0	159	17.2
40	34.6	100	0.0	160	20.1
41	32.3	101	0.0	161	23.4
42	29.0	102	0.0	162	25.5
43	25.1	103	0.0	163	27.6
44	22.2	104	0.0	164	29.5
45	20.9	105	0.0	165	31.1
46	20.4	106	0.0	166	32.1
47	19.5	107	0.0	167	33.2
48	18.4	108	0.0	168	35.2
49	17.8	109	0.0	169	37.2
50	17.8	110	0.0	170	38.0
51	17.4	111	0.0	171	37.4
52	15.7	112	0.0	172	35.1
53	13.1	113	0.0	173	31.0
54	12.1	114	0.0	174	27.1
55	12.0	115	0.0	175	25.3
56	12.0	116	0.0	176	25.1
57	12.0	117	0.0	177	25.9
58	12.3	118	0.0	178	27.8
59	12.6	119	0.0	179	29.2
60	14.7	120	0.0	180	29.6

WLTC class 3 vehicles, phase Low_3					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
181	29.5	241	41.5	301	47.1
182	29.2	242	39.5	302	46.6
183	28.3	243	37.0	303	45.8
184	26.1	244	34.6	304	44.8
185	23.6	245	32.3	305	43.3
186	21.0	246	29.0	306	41.8
187	18.9	247	25.1	307	40.8
188	17.1	248	22.2	308	40.3
189	15.7	249	20.9	309	40.1
190	14.5	250	20.4	310	39.7
191	13.7	251	19.5	311	39.2
192	12.9	252	18.4	312	38.5
193	12.5	253	17.8	313	37.4
194	12.2	254	17.8	314	36.0
195	12.0	255	17.4	315	34.4
196	12.0	256	15.7	316	33.0
197	12.0	257	14.5	317	31.7
198	12.0	258	15.4	318	30.0
199	12.5	259	17.9	319	28.0
200	13.0	260	20.6	320	26.1
201	14.0	261	23.2	321	25.6
202	15.0	262	25.7	322	24.9
203	16.5	263	28.7	323	24.9
204	19.0	264	32.5	324	24.3
205	21.2	265	36.1	325	23.9
206	23.8	266	39.0	326	23.9
207	26.9	267	40.8	327	23.6
208	29.6	268	42.9	328	23.3
209	32.0	269	44.4	329	20.5
210	35.2	270	45.9	330	17.5
211	37.5	271	46.0	331	16.9
212	39.2	272	45.6	332	16.7
213	40.5	273	45.3	333	15.9
214	41.6	274	43.7	334	15.6
215	43.1	275	40.8	335	15.0
216	45.0	276	38.0	336	14.5
217	47.1	277	34.4	337	14.3
218	49.0	278	30.9	338	14.5
219	50.6	279	25.5	339	15.4
220	51.8	280	21.4	340	17.8
221	52.7	281	20.2	341	21.1
222	53.1	282	22.9	342	24.1
223	53.5	283	26.6	343	25.0
224	53.8	284	30.2	344	25.3
225	54.2	285	34.1	345	25.5
226	54.8	286	37.4	346	26.4
227	55.3	287	40.7	347	26.6
228	55.8	288	44.0	348	27.1
229	56.2	289	47.3	349	27.7
230	56.5	290	49.2	350	28.1
231	56.5	291	49.8	351	28.2
232	56.2	292	49.2	352	28.1
233	54.9	293	48.1	353	28.0
234	52.9	294	47.3	354	27.9
235	51.0	295	46.8	355	27.9
236	49.8	296	46.7	356	28.1
237	49.2	297	46.8	357	28.2
238	48.4	298	47.1	358	28.0
239	46.9	299	47.3	359	26.9
240	44.3	300	47.3	360	25.0

WLTC class 3 vehicles, phase Low_3					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
361	23.2	421	16.6	481	0.0
362	21.9	422	16.2	482	0.0
363	21.1	423	16.4	483	0.0
364	20.7	424	17.2	484	0.0
365	20.7	425	19.1	485	0.0
366	20.8	426	22.6	486	0.0
367	21.2	427	27.4	487	0.0
368	22.1	428	31.6	488	0.0
369	23.5	429	33.4	489	0.0
370	24.3	430	33.5	490	0.0
371	24.5	431	32.8	491	0.0
372	23.8	432	31.9	492	0.0
373	21.3	433	31.3	493	0.0
374	17.7	434	31.1	494	0.0
375	14.4	435	30.6	495	0.0
376	11.9	436	29.2	496	0.0
377	10.2	437	26.7	497	0.0
378	8.9	438	23.0	498	0.0
379	8.0	439	18.2	499	0.0
380	7.2	440	12.9	500	0.0
381	6.1	441	7.7	501	0.0
382	4.9	442	3.8	502	0.0
383	3.7	443	1.3	503	0.0
384	2.3	444	0.2	504	0.0
385	0.9	445	0.0	505	0.0
386	0.0	446	0.0	506	0.0
387	0.0	447	0.0	507	0.0
388	0.0	448	0.0	508	0.0
389	0.0	449	0.0	509	0.0
390	0.0	450	0.0	510	0.0
391	0.0	451	0.0	511	0.0
392	0.5	452	0.0	512	0.5
393	2.1	453	0.0	513	2.5
394	4.8	454	0.0	514	6.6
395	8.3	455	0.0	515	11.8
396	12.3	456	0.0	516	16.8
397	16.6	457	0.0	517	20.5
398	20.9	458	0.0	518	21.9
399	24.2	459	0.0	519	21.9
400	25.6	460	0.0	520	21.3
401	25.6	461	0.0	521	20.3
402	24.9	462	0.0	522	19.2
403	23.3	463	0.0	523	17.8
404	21.6	464	0.0	524	15.5
405	20.2	465	0.0	525	11.9
406	18.7	466	0.0	526	7.6
407	17.0	467	0.0	527	4.0
408	15.3	468	0.0	528	2.0
409	14.2	469	0.0	529	1.0
410	13.9	470	0.0	530	0.0
411	14.0	471	0.0	531	0.0
412	14.2	472	0.0	532	0.0
413	14.5	473	0.0	533	0.2
414	14.9	474	0.0	534	1.2
415	15.9	475	0.0	535	3.2
416	17.4	476	0.0	536	5.2
417	18.7	477	0.0	537	8.2
418	19.1	478	0.0	538	13.0
419	18.8	479	0.0	539	18.8
420	17.6	480	0.0	540	23.1

WLTC class 3 vehicles, phase Low_3					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
541	24.5				
542	24.5				
543	24.3				
544	23.6				
545	22.3				
546	20.1				
547	18.5				
548	17.2				
549	16.3				
550	15.4				
551	14.7				
552	14.3				
553	13.7				
554	13.3				
555	13.1				
556	13.1				
557	13.3				
558	13.8				
559	14.5				
560	16.5				
561	17.0				
562	17.0				
563	17.0				
564	15.4				
565	10.1				
566	4.8				
567	0.0				
568	0.0				
569	0.0				
570	0.0				
571	0.0				
572	0.0				
573	0.0				
574	0.0				
575	0.0				
576	0.0				
577	0.0				
578	0.0				
579	0.0				
580	0.0				
581	0.0				
582	0.0				
583	0.0				
584	0.0				
585	0.0				
586	0.0				
587	0.0				
588	0.0				
589	0.0				

Table 8: WLTC, Class 3 vehicles, phase $Medium_{3-1}$

WLTC class 3 vehicles, phase $Medium_{3-1}$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
590	0.0	650	56.8	710	13.2
591	0.0	651	56.0	711	17.1
592	0.0	652	54.2	712	21.1
593	0.0	653	52.1	713	21.8
594	0.0	654	50.1	714	21.2
595	0.0	655	47.2	715	18.5
596	0.0	656	43.2	716	13.9
597	0.0	657	39.2	717	12.0
598	0.0	658	36.5	718	12.0
599	0.0	659	34.3	719	13.0
600	0.0	660	31.0	720	16.0
601	1.0	661	26.0	721	18.5
602	2.1	662	20.7	722	20.6
603	5.2	663	15.4	723	22.5
604	9.2	664	13.1	724	24.0
605	13.5	665	12.0	725	26.6
606	18.1	666	12.5	726	29.9
607	22.3	667	14.0	727	34.8
608	26.0	668	19.0	728	37.8
609	29.3	669	23.2	729	40.2
610	32.8	670	28.0	730	41.6
611	36.0	671	32.0	731	41.9
612	39.2	672	34.0	732	42.0
613	42.5	673	36.0	733	42.2
614	45.7	674	38.0	734	42.4
615	48.2	675	40.0	735	42.7
616	48.4	676	40.3	736	43.1
617	48.2	677	40.5	737	43.7
618	47.8	678	39.0	738	44.0
619	47.0	679	35.7	739	44.1
620	45.9	680	31.8	740	45.3
621	44.9	681	27.1	741	46.4
622	44.4	682	22.8	742	47.2
623	44.3	683	21.1	743	47.3
624	44.5	684	18.9	744	47.4
625	45.1	685	18.9	745	47.4
626	45.7	686	21.3	746	47.5
627	46.0	687	23.9	747	47.9
628	46.0	688	25.9	748	48.6
629	46.0	689	28.4	749	49.4
630	46.1	690	30.3	750	49.8
631	46.7	691	30.9	751	49.8
632	47.7	692	31.1	752	49.7
633	48.9	693	31.8	753	49.3
634	50.3	694	32.7	754	48.5
635	51.6	695	33.2	755	47.6
636	52.6	696	32.4	756	46.3
637	53.0	697	28.3	757	43.7
638	53.0	698	25.8	758	39.3
639	52.9	699	23.1	759	34.1
640	52.7	700	21.8	760	29.0
641	52.6	701	21.2	761	23.7
642	53.1	702	21.0	762	18.4
643	54.3	703	21.0	763	14.3
644	55.2	704	20.9	764	12.0
645	55.5	705	19.9	765	12.8
646	55.9	706	17.9	766	16.0
647	56.3	707	15.1	767	20.4
648	56.7	708	12.8	768	24.0
649	56.9	709	12.0	769	29.0

WLTC class 3 vehicles, phase $Medium_{3-1}$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
770	32.2	830	44.0	890	68.0
771	36.8	831	46.3	891	67.3
772	39.4	832	47.7	892	66.2
773	43.2	833	48.2	893	64.8
774	45.8	834	48.7	894	63.6
775	49.2	835	49.3	895	62.6
776	51.4	836	49.8	896	62.1
777	54.2	837	50.2	897	61.9
778	56.0	838	50.9	898	61.9
779	58.3	839	51.8	899	61.8
780	59.8	840	52.5	900	61.5
781	61.7	841	53.3	901	60.9
782	62.7	842	54.5	902	59.7
783	63.3	843	55.7	903	54.6
784	63.6	844	56.5	904	49.3
785	64.0	845	56.8	905	44.9
786	64.7	846	57.0	906	42.3
787	65.2	847	57.2	907	41.4
788	65.3	848	57.7	908	41.3
789	65.3	849	58.7	909	42.1
790	65.4	850	60.1	910	44.7
791	65.7	851	61.1	911	46.0
792	66.0	852	61.7	912	48.8
793	65.6	853	62.3	913	50.1
794	63.5	854	62.9	914	51.3
795	59.7	855	63.3	915	54.1
796	54.6	856	63.4	916	55.2
797	49.3	857	63.5	917	56.2
798	44.9	858	63.9	918	56.1
799	42.3	859	64.4	919	56.1
800	41.4	860	65.0	920	56.5
801	41.3	861	65.6	921	57.5
802	42.1	862	66.6	922	59.2
803	44.7	863	67.4	923	60.7
804	48.4	864	68.2	924	61.8
805	51.4	865	69.1	925	62.3
806	52.7	866	70.0	926	62.7
807	53.0	867	70.8	927	62.0
808	52.5	868	71.5	928	61.3
809	51.3	869	72.4	929	60.9
810	49.7	870	73.0	930	60.5
811	47.4	871	73.7	931	60.2
812	43.7	872	74.4	932	59.8
813	39.7	873	74.9	933	59.4
814	35.5	874	75.3	934	58.6
815	31.1	875	75.6	935	57.5
816	26.3	876	75.8	936	56.6
817	21.9	877	76.6	937	56.0
818	18.0	878	76.5	938	55.5
819	17.0	879	76.2	939	55.0
820	18.0	880	75.8	940	54.4
821	21.4	881	75.4	941	54.1
822	24.8	882	74.8	942	54.0
823	27.9	883	73.9	943	53.9
824	30.8	884	72.7	944	53.9
825	33.0	885	71.3	945	54.0
826	35.1	886	70.4	946	54.2
827	37.1	887	70.0	947	55.0
828	38.9	888	70.0	948	55.8
829	41.4	889	69.0	949	56.2

WLTC class 3 vehicles, phase $Medium_{3-1}$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
950	56.1	1010	0.0		
951	55.1	1011	0.0		
952	52.7	1012	0.0		
953	48.4	1013	0.0		
954	43.1	1014	0.0		
955	37.8	1015	0.0		
956	32.5	1016	0.0		
957	27.2	1017	0.0		
958	25.1	1018	0.0		
959	27.0	1019	0.0		
960	29.8	1020	0.0		
961	33.8	1021	0.0		
962	37.0	1022	0.0		
963	40.7				
964	43.0				
965	45.6				
966	46.9				
967	47.0				
968	46.9				
969	46.5				
970	45.8				
971	44.3				
972	41.3				
973	36.5				
974	31.7				
975	27.0				
976	24.7				
977	19.3				
978	16.0				
979	13.2				
980	10.7				
981	8.8				
982	7.2				
983	5.5				
984	3.2				
985	1.1				
986	0.0				
987	0.0				
988	0.0				
989	0.0				
990	0.0				
991	0.0				
992	0.0				
993	0.0				
994	0.0				
995	0.0				
996	0.0				
997	0.0				
998	0.0				
999	0.0				
1000	0.0				
1001	0.0				
1002	0.0				
1003	0.0				
1004	0.0				
1005	0.0				
1006	0.0				
1007	0.0				
1008	0.0				
1009	0.0				

Table 9: WLTC, Class 3 vehicles, phase $Medium_{3-2}$

WLTC class 3 vehicles, phase $Medium_{3-2}$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
590	0.0	650	56.8	710	13.2
591	0.0	651	56.0	711	17.1
592	0.0	652	54.2	712	21.1
593	0.0	653	52.1	713	21.8
594	0.0	654	50.1	714	21.2
595	0.0	655	47.2	715	18.5
596	0.0	656	43.2	716	13.9
597	0.0	657	39.2	717	12.0
598	0.0	658	36.5	718	12.0
599	0.0	659	34.3	719	13.0
600	0.0	660	31.0	720	16.0
601	1.0	661	26.0	721	18.5
602	2.1	662	20.7	722	20.6
603	4.8	663	15.4	723	22.5
604	9.1	664	13.1	724	24.0
605	14.2	665	12.0	725	26.6
606	19.8	666	12.5	726	29.9
607	25.5	667	14.0	727	34.8
608	30.5	668	19.0	728	37.8
609	34.8	669	23.2	729	40.2
610	38.8	670	28.0	730	41.6
611	42.9	671	32.0	731	41.9
612	46.4	672	34.0	732	42.0
613	48.3	673	36.0	733	42.2
614	48.7	674	38.0	734	42.4
615	48.5	675	40.0	735	42.7
616	48.4	676	40.3	736	43.1
617	48.2	677	40.5	737	43.7
618	47.8	678	39.0	738	44.0
619	47.0	679	35.7	739	44.1
620	45.9	680	31.8	740	45.3
621	44.9	681	27.1	741	46.4
622	44.4	682	22.8	742	47.2
623	44.3	683	21.1	743	47.3
624	44.5	684	18.9	744	47.4
625	45.1	685	18.9	745	47.4
626	45.7	686	21.3	746	47.5
627	46.0	687	23.9	747	47.9
628	46.0	688	25.9	748	48.6
629	46.0	689	28.4	749	49.4
630	46.1	690	30.3	750	49.8
631	46.7	691	30.9	751	49.8
632	47.7	692	31.1	752	49.7
633	48.9	693	31.8	753	49.3
634	50.3	694	32.7	754	48.5
635	51.6	695	33.2	755	47.6
636	52.6	696	32.4	756	46.3
637	53.0	697	28.3	757	43.7
638	53.0	698	25.8	758	39.3
639	52.9	699	23.1	759	34.1
640	52.7	700	21.8	760	29.0
641	52.6	701	21.2	761	23.7
642	53.1	702	21.0	762	18.4
643	54.3	703	21.0	763	14.3
644	55.2	704	20.9	764	12.0
645	55.5	705	19.9	765	12.8
646	55.9	706	17.9	766	16.0
647	56.3	707	15.1	767	19.1
648	56.7	708	12.8	768	22.4
649	56.9	709	12.0	769	25.6

WLTC class 3 vehicles, phase Medium$_{3-2}$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
770	30.1	830	44.0	890	68.1
771	35.3	831	46.3	891	67.3
772	39.9	832	47.7	892	66.2
773	44.5	833	48.2	893	64.8
774	47.5	834	48.7	894	63.6
775	50.9	835	49.3	895	62.6
776	54.1	836	49.8	896	62.1
777	56.3	837	50.2	897	61.9
778	58.1	838	50.9	898	61.9
779	59.8	839	51.8	899	61.8
780	61.1	840	52.5	900	61.5
781	62.1	841	53.3	901	60.9
782	62.8	842	54.5	902	59.7
783	63.3	843	55.7	903	54.6
784	63.6	844	56.5	904	49.3
785	64.0	845	56.8	905	44.9
786	64.7	846	57.0	906	42.3
787	65.2	847	57.2	907	41.4
788	65.3	848	57.7	908	41.3
789	65.3	849	58.7	909	42.1
790	65.4	850	60.1	910	44.7
791	65.7	851	61.1	911	48.4
792	66.0	852	61.7	912	51.4
793	65.6	853	62.3	913	52.7
794	63.5	854	62.9	914	54.0
795	59.7	855	63.3	915	57.0
796	54.6	856	63.4	916	58.1
797	49.3	857	63.5	917	59.2
798	44.9	858	64.5	918	59.0
799	42.3	859	65.8	919	59.1
800	41.4	860	66.8	920	59.5
801	41.3	861	67.4	921	60.5
802	42.1	862	68.8	922	62.3
803	44.7	863	71.1	923	63.9
804	48.4	864	72.3	924	65.1
805	51.4	865	72.8	925	64.1
806	52.7	866	73.4	926	62.7
807	53.0	867	74.6	927	62.0
808	52.5	868	76.0	928	61.3
809	51.3	869	76.6	929	60.9
810	49.7	870	76.5	930	60.5
811	47.4	871	76.2	931	60.2
812	43.7	872	75.8	932	59.8
813	39.7	873	75.4	933	59.4
814	35.5	874	74.8	934	58.6
815	31.1	875	73.9	935	57.5
816	26.3	876	72.7	936	56.6
817	21.9	877	71.3	937	56.0
818	18.0	878	70.4	938	55.5
819	17.0	879	70.0	939	55.0
820	18.0	880	70.0	940	54.4
821	21.4	881	69.0	941	54.1
822	24.8	882	68.0	942	54.0
823	27.9	883	68.0	943	53.9
824	30.8	884	68.0	944	53.9
825	33.0	885	68.1	945	54.0
826	35.1	886	68.4	946	54.2
827	37.1	887	68.6	947	55.0
828	38.9	888	68.7	948	55.8
829	41.4	889	68.5	949	56.2

Table 10: WLTC, Class 3 vehicles, phase $High_{3-1}$

WLTC class 3 vehicles, phase $High_{3-1}$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1023	0.0	1083	58.1	1143	19.1
1024	0.0	1084	58.4	1144	22.5
1025	0.0	1085	58.8	1145	24.4
1026	0.0	1086	58.8	1146	24.8
1027	0.8	1087	58.6	1147	22.7
1028	3.6	1088	58.7	1148	17.4
1029	8.6	1089	58.8	1149	13.8
1030	14.6	1090	58.8	1150	12.0
1031	20.0	1091	58.8	1151	12.0
1032	24.4	1092	59.1	1152	12.0
1033	28.2	1093	60.1	1153	13.9
1034	31.7	1094	61.7	1154	17.7
1035	35.0	1095	63.0	1155	22.8
1036	37.6	1096	63.7	1156	27.3
1037	39.7	1097	63.9	1157	31.2
1038	41.5	1098	63.5	1158	35.2
1039	43.6	1099	62.3	1159	39.4
1040	46.0	1100	60.3	1160	42.5
1041	48.4	1101	58.9	1161	45.4
1042	50.5	1102	58.4	1162	48.2
1043	51.9	1103	58.8	1163	50.3
1044	52.6	1104	60.2	1164	52.6
1045	52.8	1105	62.3	1165	54.5
1046	52.9	1106	63.9	1166	56.6
1047	53.1	1107	64.5	1167	58.3
1048	53.3	1108	64.4	1168	60.0
1049	53.1	1109	63.5	1169	61.5
1050	52.3	1110	62.0	1170	63.1
1051	50.7	1111	61.2	1171	64.3
1052	48.8	1112	61.3	1172	65.7
1053	46.5	1113	61.7	1173	67.1
1054	43.8	1114	62.0	1174	68.3
1055	40.3	1115	64.6	1175	69.7
1056	36.0	1116	66.0	1176	70.6
1057	30.7	1117	66.2	1177	71.6
1058	25.4	1118	65.8	1178	72.6
1059	21.0	1119	64.7	1179	73.5
1060	16.7	1120	63.6	1180	74.2
1061	13.4	1121	62.9	1181	74.9
1062	12.0	1122	62.4	1182	75.6
1063	12.1	1123	61.7	1183	76.3
1064	12.8	1124	60.1	1184	77.1
1065	15.6	1125	57.3	1185	77.9
1066	19.9	1126	55.8	1186	78.5
1067	23.4	1127	50.5	1187	79.0
1068	24.6	1128	45.2	1188	79.7
1069	27.0	1129	40.1	1189	80.3
1070	29.0	1130	36.2	1190	81.0
1071	32.0	1131	32.9	1191	81.6
1072	34.8	1132	29.8	1192	82.4
1073	37.7	1133	26.6	1193	82.9
1074	40.8	1134	23.0	1194	83.4
1075	43.2	1135	19.4	1195	83.8
1076	46.0	1136	16.3	1196	84.2
1077	48.0	1137	14.6	1197	84.7
1078	50.7	1138	14.2	1198	85.2
1079	52.0	1139	14.3	1199	85.6
1080	54.5	1140	14.6	1200	86.3
1081	55.9	1141	15.1	1201	86.8
1082	57.4	1142	16.4	1202	87.4

WLTC class 3 vehicles, phase $High_{3-1}$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1203	88.0	1263	95.2	1323	78.4
1204	88.3	1264	95.0	1324	78.8
1205	88.7	1265	94.9	1325	79.2
1206	89.0	1266	94.7	1326	80.3
1207	89.3	1267	94.5	1327	80.8
1208	89.8	1268	94.4	1328	81.0
1209	90.2	1269	94.4	1329	81.0
1210	90.6	1270	94.3	1330	81.0
1211	91.0	1271	94.3	1331	81.0
1212	91.3	1272	94.1	1332	81.0
1213	91.6	1273	93.9	1333	80.9
1214	91.9	1274	93.4	1334	80.6
1215	92.2	1275	92.8	1335	80.3
1216	92.8	1276	92.0	1336	80.0
1217	93.1	1277	91.3	1337	79.9
1218	93.3	1278	90.6	1338	79.8
1219	93.5	1279	90.0	1339	79.8
1220	93.7	1280	89.3	1340	79.8
1221	93.9	1281	88.7	1341	79.9
1222	94.0	1282	88.1	1342	80.0
1223	94.1	1283	87.4	1343	80.4
1224	94.3	1284	86.7	1344	80.8
1225	94.4	1285	86.0	1345	81.2
1226	94.6	1286	85.3	1346	81.5
1227	94.7	1287	84.7	1347	81.6
1228	94.8	1288	84.1	1348	81.6
1229	95.0	1289	83.5	1349	81.4
1230	95.1	1290	82.9	1350	80.7
1231	95.3	1291	82.3	1351	79.6
1232	95.4	1292	81.7	1352	78.2
1233	95.6	1293	81.1	1353	76.8
1234	95.7	1294	80.5	1354	75.3
1235	95.8	1295	79.9	1355	73.8
1236	96.0	1296	79.4	1356	72.1
1237	96.1	1297	79.1	1357	70.2
1238	96.3	1298	78.8	1358	68.2
1239	96.4	1299	78.5	1359	66.1
1240	96.6	1300	78.2	1360	63.8
1241	96.8	1301	77.9	1361	61.6
1242	97.0	1302	77.6	1362	60.2
1243	97.2	1303	77.3	1363	59.8
1244	97.3	1304	77.0	1364	60.4
1245	97.4	1305	76.7	1365	61.8
1246	97.4	1306	76.0	1366	62.6
1247	97.4	1307	76.0	1367	62.7
1248	97.4	1308	76.0	1368	61.9
1249	97.3	1309	75.9	1369	60.0
1250	97.3	1310	76.0	1370	58.4
1251	97.3	1311	76.0	1371	57.8
1252	97.3	1312	76.1	1372	57.8
1253	97.2	1313	76.3	1373	57.8
1254	97.1	1314	76.5	1374	57.3
1255	97.0	1315	76.6	1375	56.2
1256	96.9	1316	76.8	1376	54.3
1257	96.7	1317	77.1	1377	50.8
1258	96.4	1318	77.1	1378	45.5
1259	96.1	1319	77.2	1379	40.2
1260	95.7	1320	77.2	1380	34.9
1261	95.5	1321	77.6	1381	29.6
1262	95.3	1322	78.0	1382	28.7

WLTC class 3 vehicles, phase $High_{3-1}$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1383	29.3	1443	18.3		
1384	30.5	1444	18.0		
1385	31.7	1445	18.3		
1386	32.9	1446	18.5		
1387	35.0	1447	17.9		
1388	38.0	1448	15.0		
1389	40.5	1449	9.9		
1390	42.7	1450	4.6		
1391	45.8	1451	1.2		
1392	47.5	1452	0.0		
1393	48.9	1453	0.0		
1394	49.4	1454	0.0		
1395	49.4	1455	0.0		
1396	49.2	1456	0.0		
1397	48.7	1457	0.0		
1398	47.9	1458	0.0		
1399	46.9	1459	0.0		
1400	45.6	1460	0.0		
1401	44.2	1461	0.0		
1402	42.7	1462	0.0		
1403	40.7	1463	0.0		
1404	37.1	1464	0.0		
1405	33.9	1465	0.0		
1406	30.6	1466	0.0		
1407	28.6	1467	0.0		
1408	27.3	1468	0.0		
1409	27.2	1469	0.0		
1410	27.5	1470	0.0		
1411	27.4	1471	0.0		
1412	27.1	1472	0.0		
1413	26.7	1473	0.0		
1414	26.8	1474	0.0		
1415	28.2	1475	0.0		
1416	31.1	1476	0.0		
1417	34.8	1477	0.0		
1418	38.4				
1419	40.9				
1420	41.7				
1421	40.9				
1422	38.3				
1423	35.3				
1424	34.3				
1425	34.6				
1426	36.3				
1427	39.5				
1428	41.8				
1429	42.5				
1430	41.9				
1431	40.1				
1432	36.6				
1433	31.3				
1434	26.0				
1435	20.6				
1436	19.1				
1437	19.7				
1438	21.1				
1439	22.0				
1440	22.1				
1441	21.4				
1442	19.6				

Table 11: WLTC, Class 3 vehicles, phase $High_{3-2}$

WLTC class 3 vehicles, phase $High_{3-2}$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1023	0.0	1083	62.5	1143	19.1
1024	0.0	1084	60.9	1144	22.5
1025	0.0	1085	59.3	1145	24.4
1026	0.0	1086	58.6	1146	24.8
1027	0.8	1087	58.6	1147	22.7
1028	3.6	1088	58.7	1148	17.4
1029	8.6	1089	58.8	1149	13.8
1030	14.6	1090	58.8	1150	12.0
1031	20.0	1091	58.8	1151	12.0
1032	24.4	1092	59.1	1152	12.0
1033	28.2	1093	60.1	1153	13.9
1034	31.7	1094	61.7	1154	17.7
1035	35.0	1095	63.0	1155	22.8
1036	37.6	1096	63.7	1156	27.3
1037	39.7	1097	63.9	1157	31.2
1038	41.5	1098	63.5	1158	35.2
1039	43.6	1099	62.3	1159	39.4
1040	46.0	1100	60.3	1160	42.5
1041	48.4	1101	58.9	1161	45.4
1042	50.5	1102	58.4	1162	48.2
1043	51.9	1103	58.8	1163	50.3
1044	52.6	1104	60.2	1164	52.6
1045	52.8	1105	62.3	1165	54.5
1046	52.9	1106	63.9	1166	56.6
1047	53.1	1107	64.5	1167	58.3
1048	53.3	1108	64.4	1168	60.0
1049	53.1	1109	63.5	1169	61.5
1050	52.3	1110	62.0	1170	63.1
1051	50.7	1111	61.2	1171	64.3
1052	48.8	1112	61.3	1172	65.7
1053	46.5	1113	62.6	1173	67.1
1054	43.8	1114	65.3	1174	68.3
1055	40.3	1115	68.0	1175	69.7
1056	36.0	1116	69.4	1176	70.6
1057	30.7	1117	69.7	1177	71.6
1058	25.4	1118	69.3	1178	72.6
1059	21.0	1119	68.1	1179	73.5
1060	16.7	1120	66.9	1180	74.2
1061	13.4	1121	66.2	1181	74.9
1062	12.0	1122	65.7	1182	75.6
1063	12.1	1123	64.9	1183	76.3
1064	12.8	1124	63.2	1184	77.1
1065	15.6	1125	60.3	1185	77.9
1066	19.9	1126	55.8	1186	78.5
1067	23.4	1127	50.5	1187	79.0
1068	24.6	1128	45.2	1188	79.7
1069	25.2	1129	40.1	1189	80.3
1070	26.4	1130	36.2	1190	81.0
1071	28.8	1131	32.9	1191	81.6
1072	31.8	1132	29.8	1192	82.4
1073	35.3	1133	26.6	1193	82.9
1074	39.5	1134	23.0	1194	83.4
1075	44.5	1135	19.4	1195	83.8
1076	49.3	1136	16.3	1196	84.2
1077	53.3	1137	14.6	1197	84.7
1078	56.4	1138	14.2	1198	85.2
1079	58.9	1139	14.3	1199	85.6
1080	61.2	1140	14.6	1200	86.3
1081	62.6	1141	15.1	1201	86.8
1082	63.0	1142	16.4	1202	87.4

WLTC class 3 vehicles, phase $High_{3-2}$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1203	88.0	1263	95.2	1323	76.1
1204	88.3	1264	95.0	1324	77.7
1205	88.7	1265	94.9	1325	79.2
1206	89.0	1266	94.7	1326	80.3
1207	89.3	1267	94.5	1327	80.8
1208	89.8	1268	94.4	1328	81.0
1209	90.2	1269	94.4	1329	81.0
1210	90.6	1270	94.3	1330	81.0
1211	91.0	1271	94.3	1331	81.0
1212	91.3	1272	94.1	1332	81.0
1213	91.6	1273	93.9	1333	80.9
1214	91.9	1274	93.4	1334	80.6
1215	92.2	1275	92.8	1335	80.3
1216	92.8	1276	92.0	1336	80.0
1217	93.1	1277	91.3	1337	79.9
1218	93.3	1278	90.6	1338	79.8
1219	93.5	1279	90.0	1339	79.8
1220	93.7	1280	89.3	1340	79.8
1221	93.9	1281	88.7	1341	79.9
1222	94.0	1282	88.1	1342	80.0
1223	94.1	1283	87.4	1343	80.4
1224	94.3	1284	86.7	1344	80.8
1225	94.4	1285	86.0	1345	81.2
1226	94.6	1286	85.3	1346	81.5
1227	94.7	1287	84.7	1347	81.6
1228	94.8	1288	84.1	1348	81.6
1229	95.0	1289	83.5	1349	81.4
1230	95.1	1290	82.9	1350	80.7
1231	95.3	1291	82.3	1351	79.6
1232	95.4	1292	81.7	1352	78.2
1233	95.6	1293	81.1	1353	76.8
1234	95.7	1294	80.5	1354	75.3
1235	95.8	1295	79.9	1355	73.8
1236	96.0	1296	79.4	1356	72.1
1237	96.1	1297	79.1	1357	70.2
1238	96.3	1298	78.8	1358	68.2
1239	96.4	1299	78.5	1359	66.1
1240	96.6	1300	78.2	1360	63.8
1241	96.8	1301	77.9	1361	61.6
1242	97.0	1302	77.6	1362	60.2
1243	97.2	1303	77.3	1363	59.8
1244	97.3	1304	77.0	1364	60.4
1245	97.4	1305	76.7	1365	61.8
1246	97.4	1306	76.0	1366	62.6
1247	97.4	1307	76.0	1367	62.7
1248	97.4	1308	76.0	1368	61.9
1249	97.3	1309	75.9	1369	60.0
1250	97.3	1310	75.9	1370	58.4
1251	97.3	1311	75.8	1371	57.8
1252	97.3	1312	75.7	1372	57.8
1253	97.2	1313	75.5	1373	57.8
1254	97.1	1314	75.2	1374	57.3
1255	97.0	1315	75.0	1375	56.2
1256	96.9	1316	74.7	1376	54.3
1257	96.7	1317	74.1	1377	50.8
1258	96.4	1318	73.7	1378	45.5
1259	96.1	1319	73.3	1379	40.2
1260	95.7	1320	73.5	1380	34.9
1261	95.5	1321	74.0	1381	29.6
1262	95.3	1322	74.9	1382	27.3

WLTC class 3 vehicles, phase $High_{3-2}$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1383	29.3	1443	18.3		
1384	32.9	1444	18.0		
1385	35.6	1445	18.3		
1386	36.7	1446	18.5		
1387	37.6	1447	17.9		
1388	39.4	1448	15.0		
1389	42.5	1449	9.9		
1390	46.5	1450	4.6		
1391	50.2	1451	1.2		
1392	52.8	1452	0.0		
1393	54.3	1453	0.0		
1394	54.9	1454	0.0		
1395	54.9	1455	0.0		
1396	54.7	1456	0.0		
1397	54.1	1457	0.0		
1398	53.2	1458	0.0		
1399	52.1	1459	0.0		
1400	50.7	1460	0.0		
1401	49.1	1461	0.0		
1402	47.4	1462	0.0		
1403	45.2	1463	0.0		
1404	41.8	1464	0.0		
1405	36.5	1465	0.0		
1406	31.2	1466	0.0		
1407	27.6	1467	0.0		
1408	26.9	1468	0.0		
1409	27.3	1469	0.0		
1410	27.5	1470	0.0		
1411	27.4	1471	0.0		
1412	27.1	1472	0.0		
1413	26.7	1473	0.0		
1414	26.8	1474	0.0		
1415	28.2	1475	0.0		
1416	31.1	1476	0.0		
1417	34.8	1477	0.0		
1418	38.4				
1419	40.9				
1420	41.7				
1421	40.9				
1422	38.3				
1423	35.3				
1424	34.3				
1425	34.6				
1426	36.3				
1427	39.5				
1428	41.8				
1429	42.5				
1430	41.9				
1431	40.1				
1432	36.6				
1433	31.3				
1434	26.0				
1435	20.6				
1436	19.1				
1437	19.7				
1438	21.1				
1439	22.0				
1440	22.1				
1441	21.4				
1442	19.6				

Figure 12: WLTC, Class 3 vehicles, phase Extra High$_3$

WLTC class 3 vehicles, phase Extra High$_3$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1478	0.0	1538	68.4	1598	112.2
1479	2.2	1539	71.6	1599	111.4
1480	4.4	1540	74.9	1600	110.5
1481	6.3	1541	78.4	1601	109.5
1482	7.9	1542	81.8	1602	108.5
1483	9.2	1543	84.9	1603	107.7
1484	10.4	1544	87.4	1604	107.1
1485	11.5	1545	89.0	1605	106.6
1486	12.9	1546	90.0	1606	106.4
1487	14.7	1547	90.6	1607	106.2
1488	17.0	1548	91.0	1608	106.2
1489	19.8	1549	91.5	1609	106.2
1490	23.1	1550	92.0	1610	106.4
1491	26.7	1551	92.7	1611	106.5
1492	30.5	1552	93.4	1612	106.8
1493	34.1	1553	94.2	1613	107.2
1494	37.5	1554	94.9	1614	107.8
1495	40.6	1555	95.7	1615	108.5
1496	43.3	1556	96.6	1616	109.4
1497	45.7	1557	97.7	1617	110.5
1498	47.7	1558	98.9	1618	111.7
1499	49.3	1559	100.4	1619	113.0
1500	50.5	1560	102.0	1620	114.1
1501	51.3	1561	103.6	1621	115.1
1502	52.1	1562	105.2	1622	115.9
1503	52.7	1563	106.8	1623	116.5
1504	53.4	1564	108.5	1624	116.7
1505	54.0	1565	110.2	1625	116.6
1506	54.5	1566	111.9	1626	116.2
1507	55.0	1567	113.7	1627	115.2
1508	55.6	1568	115.3	1628	113.8
1509	56.3	1569	116.8	1629	112.0
1510	57.2	1570	118.2	1630	110.1
1511	58.5	1571	119.5	1631	108.3
1512	60.2	1572	120.7	1632	107.0
1513	62.3	1573	121.8	1633	106.1
1514	64.7	1574	122.6	1634	105.8
1515	67.1	1575	123.2	1635	105.7
1516	69.2	1576	123.6	1636	105.7
1517	70.7	1577	123.7	1637	105.6
1518	71.9	1578	123.6	1638	105.3
1519	72.7	1579	123.3	1639	104.9
1520	73.4	1580	123.0	1640	104.4
1521	73.8	1581	122.5	1641	104.0
1522	74.1	1582	122.1	1642	103.8
1523	74.0	1583	121.5	1643	103.9
1524	73.6	1584	120.8	1644	104.4
1525	72.5	1585	120.0	1645	105.1
1526	70.8	1586	119.1	1646	106.1
1527	68.6	1587	118.1	1647	107.2
1528	66.2	1588	117.1	1648	108.5
1529	64.0	1589	116.2	1649	109.9
1530	62.2	1590	115.5	1650	111.3
1531	60.9	1591	114.9	1651	112.7
1532	60.2	1592	114.5	1652	113.9
1533	60.0	1593	114.1	1653	115.0
1534	60.4	1594	113.9	1654	116.0
1535	61.4	1595	113.7	1655	116.8
1536	63.2	1596	113.3	1656	117.6
1537	65.6	1597	112.9	1657	118.4

WLTC class 3 vehicles, phase Extra High$_3$					
Time in s	speed in km/h	Time in s	speed in km/h	Time in s	speed in km/h
1658	119.2	1718	129.0	1778	49.7
1659	120.0	1719	129.5	1779	46.8
1660	120.8	1720	130.1	1780	43.5
1661	121.6	1721	130.6	1781	39.9
1662	122.3	1722	131.0	1782	36.4
1663	123.1	1723	131.2	1783	33.2
1664	123.8	1724	131.3	1784	30.5
1665	124.4	1725	131.2	1785	28.3
1666	125.0	1726	130.7	1786	26.3
1667	125.4	1727	129.8	1787	24.4
1668	125.8	1728	128.4	1788	22.5
1669	126.1	1729	126.5	1789	20.5
1670	126.4	1730	124.1	1790	18.2
1671	126.6	1731	121.6	1791	15.5
1672	126.7	1732	119.0	1792	12.3
1673	126.8	1733	116.5	1793	8.7
1674	126.9	1734	114.1	1794	5.2
1675	126.9	1735	111.8	1795	0.0
1676	126.9	1736	109.5	1796	0.0
1677	126.8	1737	107.1	1797	0.0
1678	126.6	1738	104.8	1798	0.0
1679	126.3	1739	102.5	1799	0.0
1680	126.0	1740	100.4	1800	0.0
1681	125.7	1741	98.6		
1682	125.6	1742	97.2		
1683	125.6	1743	95.9		
1684	125.8	1744	94.8		
1685	126.2	1745	93.8		
1686	126.6	1746	92.8		
1687	127.0	1747	91.8		
1688	127.4	1748	91.0		
1689	127.6	1749	90.2		
1690	127.8	1750	89.6		
1691	127.9	1751	89.1		
1692	128.0	1752	88.6		
1693	128.1	1753	88.1		
1694	128.2	1754	87.6		
1695	128.3	1755	87.1		
1696	128.4	1756	86.6		
1697	128.5	1757	86.1		
1698	128.6	1758	85.5		
1699	128.6	1759	85.0		
1700	128.5	1760	84.4		
1701	128.3	1761	83.8		
1702	128.1	1762	83.2		
1703	127.9	1763	82.6		
1704	127.6	1764	82.0		
1705	127.4	1765	81.3		
1706	127.2	1766	80.4		
1707	127.0	1767	79.1		
1708	126.9	1768	77.4		
1709	126.8	1769	75.1		
1710	126.7	1770	72.3		
1711	126.8	1771	69.1		
1712	126.9	1772	65.9		
1713	127.1	1773	62.7		
1714	127.4	1774	59.7		
1715	127.7	1775	57.0		
1716	128.1	1776	54.6		
1717	128.5	1777	52.2		

7. Provisions for vehicles that cannot follow the speed trace

7.1 General remarks

During the validation phase of the cycle development some vehicles with Pmr values close to the borderlines of the vehicle classes (see paragraph 2 of this Annex) had problems to follow the cycle speed trace within the tolerances (+/- 2 km/h, +/- 1 s). For such vehicles the cycle trace needs to be downscaled for those sections where driveability problems will occur.

The downscaling approach was developed based on an analysis of results of extensive modelling work. The downscaling factor is based on the ratio between the maximum required power of the cycle phases where the downscaling has to be applied and the rated power of the vehicle. The maximum required power within the cycle occurs at times with a combination of high vehicle speed and high acceleration values. That means that the road load coefficients as well as the test mass are considered.

7.2 Downscaling procedure

7.2.1 Downscaling procedure for class 1 vehicles

Since the driveability problems are exclusively related to the medium speed phase of the class 1 cycle, the downscaling is related to those sections of the medium speed phase, where the driveability problems occur (see Figure 3).

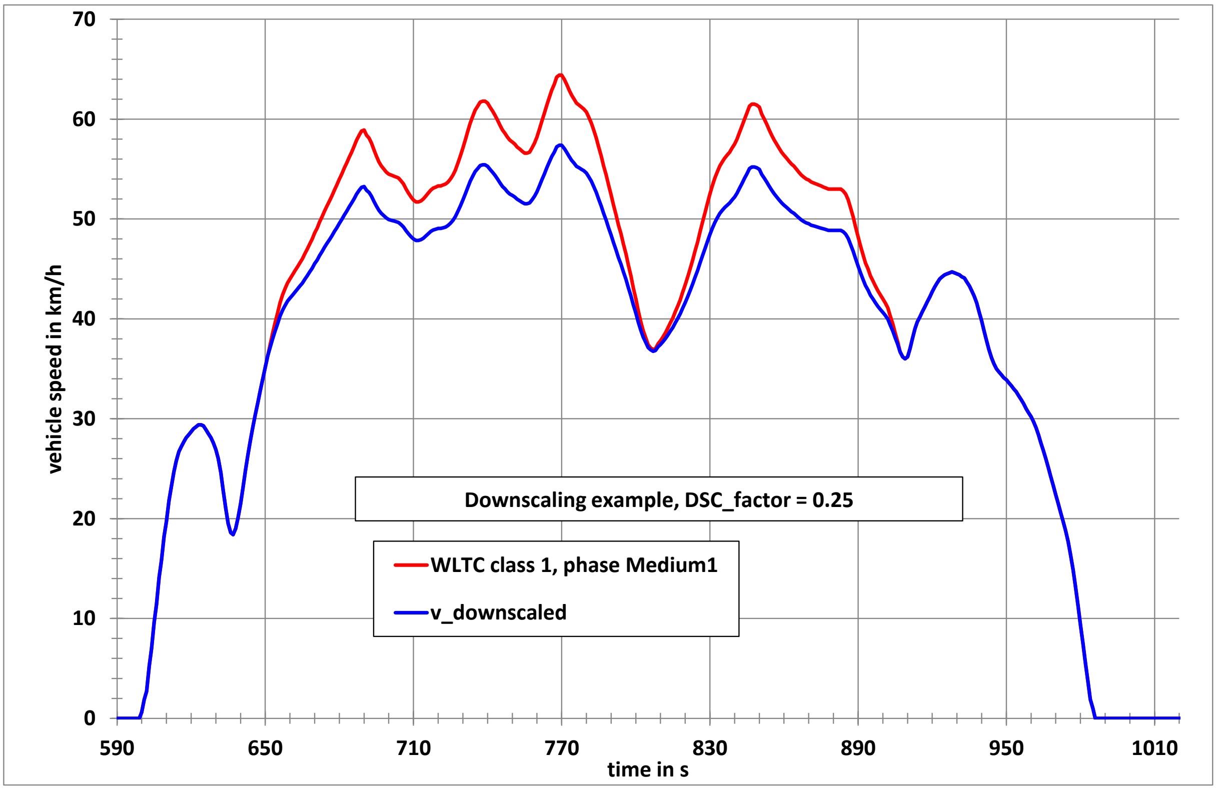


Figure 13: Downscaled medium speed phase of the class 1 WLTC

For the class 1 cycle the downscaling period is the time period between second 651 and second 906. Within this time period the acceleration for the original cycle is calculated using the following equation:

$$a\_orig\_i = (v\_i+1 - v\_i)/3.6 \qquad \text{Equation 1}$$

where:

v_i is the vehicle speed, km/h;
i is the time between 651 and 906 s.

The downscaling is first applied in the time period between second 651 and 848. Second 848 is the time where the maximum speed of the extra high speed phase is reached. The downscaled speed trace is then calculated using the following equation:

$$v\_dsc\_i+1 = v\_dsc\_i + a\_orig\_i * (1 - dsc\_factor) * 3.6 \quad \text{Equation 2}$$

with i = 651 to 848. v_dsc_i = v_orig_i for i = 651.

In order to meet the original vehicle speed at second 907 a correction factor for the deceleration is calculated using the following equation:

$$f\_corr\_dec = (v\_dsc\_848 - 36{,}7) / (v\_orig\_848 - 36{,}7) \quad \text{Equation 3}$$

where 36,7 km/h is the original vehicle speed at second 907.

The downscaled vehicle speed between 849 and 906 s is then calculated using the following equation:

$$v\_dsc\_i = v\_dsc\_i\text{-}1 + a\_orig\_i\text{-}1 * f\_corr\_dec * 3.6 \quad \text{Equation 4}$$

with i = 849 to 906.

7.2.2 Downscaling procedure for class 2 vehicles

Since the driveability problems are exclusively related to the extra high speed phases of the class 2 and class 3 cycles, the downscaling is related to those sections of the extra high speed phases, where the driveability problems occur (see Figure 14).

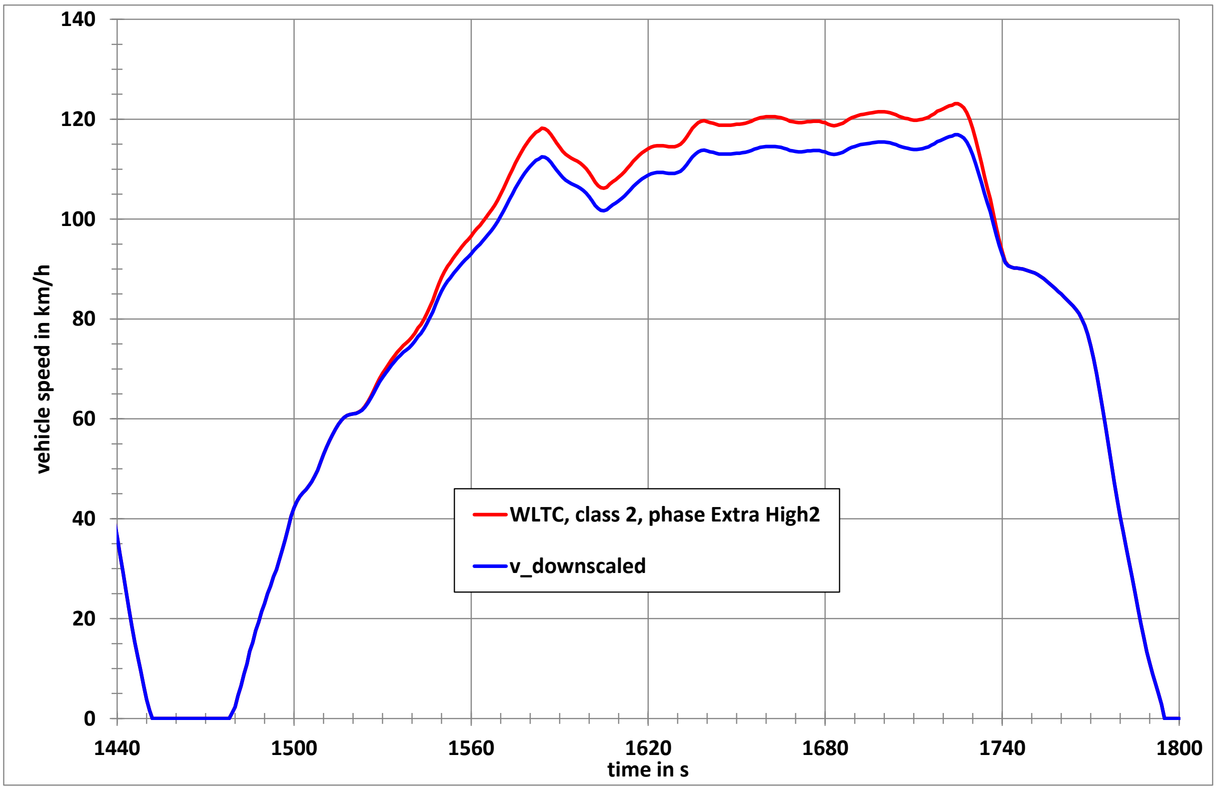


Figure 14: Downscaled extra high speed phase of the class 2 WLTC

For the class 2 cycle the downscaling period is the time period between second 1520 and second 1742. Within this time period the acceleration for the original cycle is calculated using the following equation:

$$a\_orig\_i = (v\_i+1 – v\_i)/3.6 \qquad \text{Equation 5}$$

where:

v_i is the vehicle speed, km/h;

i is the time between 1520 and 1742 s.

The downscaling is first applied in the time period between second 1520 and 1724. Second 1724 is the time where the maximum speed of the extra high speed phase is reached. The downscaled speed trace is then calculated using the following equation:

$$v\_dsc\_i+1 = v\_dsc\_i + a\_orig\_i * (1 – dsc\_factor) * 3.6 \qquad \text{Equation 6}$$

with i = 1520 to 1724. v_dsc_i = v_orig_i for i = 1520.

In order to meet the original vehicle speed at second 1743 a correction factor for the deceleration is calculated using the following equation:

$$f\_corr\_dec = (v\_dsc\_1725 – 90,4) / (v\_orig\_1725 – 90,4) \qquad \text{Equation 7}$$

90,4 km/h is the original vehicle speed at second 1743.
The downscaled vehicle speed between 1726 and 1742 s is then calculated using the following equation:

$$v\_dsc\_i = v\_dsc\_i-1 + a\_orig\_i-1 * f\_corr\_dec * 3.6 \qquad \text{Equation 8}$$

with i = 1726 to 1742.

7.2.3 Downscaling procedure for class 3 vehicles

Figure 15 shows an example for a downscaled extra high speed phase of the class 3 WLTC.

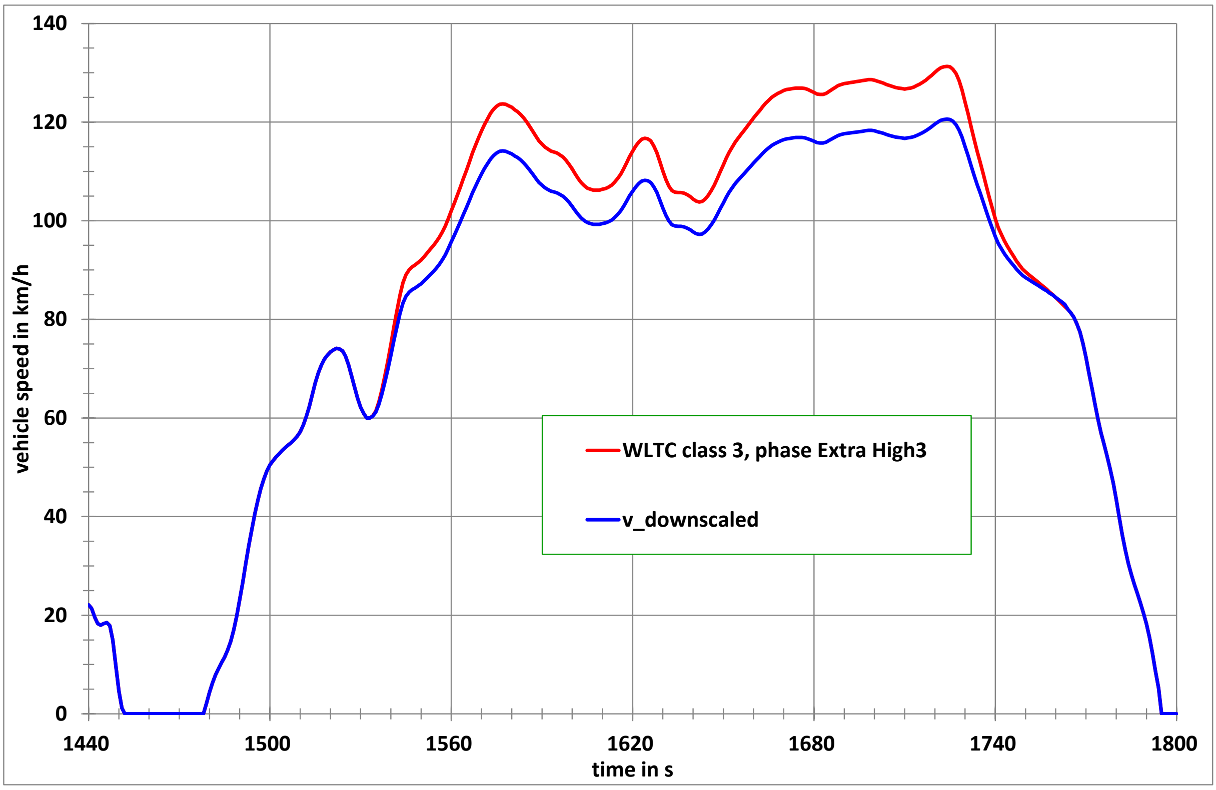


Figure 15: Downscaled extra high speed phase of the class 3 WLTC

For the class 3 cycle this is the period between second 1533 and second 1763. Within this time period the acceleration for the original cycle is calculated using the following equation:

a_orig_i = (v_i+1 – v_i)/3.6 Equation 9

where:
v_i is the vehicle speed, km/h;
i is the time between 1533 and 1762 s.

The downscaling is first applied in the time period between second 1533 and 1724. Second 1724 is the time where the maximum speed of the extra high speed phase is reached. The downscaled speed trace is then calculated using the following equation:

v_dsc_i+1 = v_dsc_i + a_orig_i * (1 – dsc_factor) * 3.6 Equation 10

with i = 1533 to 1723. v_dsc_i = v_orig_i for i = 1533.

In order to meet the original vehicle speed at second 1763 a correction factor for the deceleration is calculated using the following equation:

f_corr_dec = (v_dsc_1724 – 82.6) / (v_orig_1724 – 82.6) Equation 11

82.6 km/h is the original vehicle speed at second 1763.

The downscaled vehicle speed between 1725 and 1762 s is then calculated using the following equation:

v_dsc_i = v_dsc_i-1 + a_orig_i-1 * f_corr_dec * 3.6 Equation 12

with i = 1725 to 1762.
/

7.3 Determination of the downscaling factor

The downscaling factor f_{dsc} is a function of the ratio between the maximum required power of the cycle phases where the downscaling has to be applied and the rated power of the vehicle (P_{rated}).
This ratio is named r_{max}, the maximum required power is named $P_{req, max}$. It is related to a specific time i in the cycle trace.
$P_{req, max, i}$ in kW is calculated from the driving resistance coefficients f_0, f_1, f_2 and the test mass m_{test} as follows:

$$P_{req, max, i} = (f_0 * v_i + f_1 * v_i^{2} + f_2 * v_i^{3} + 1.1 * m_{test} * v_i * a_i)/3600 \qquad \text{Equation 13}$$

with f_0 in N, f_1 in N/(km/h) and f_2 in N/(km/h)^2, m_{test} in kg
The cycle time i where the maximum power is required is

- 764 s for class 1,
- 1574 s for class 2 and
- 1566 s for class 3

The corresponding vehicle speed values v_i and acceleration values a_i are as follows:

- v_i = 61.4 km/h, a_i = 0.22 m/s² for class 1,
- v_i = 109.9 km/h, a_i = 0.36 m/s² for class 2,
- v_i = 111.9 km/h, a_i = 0.50 m/s² for class 3,

The driving resistance coefficients f_0, f_1 and f_2 have to be determined by coastdown measurements or an equivalent method.
r_{max} is calculated using the following equation:

$$r_{max} = P_{req, max, i} / P_{rated} \qquad \text{Equation 14}$$

The downscaling factor f_{dsc} is calculated using the following equation:

$$f_{dsc} = 0, \text{ if } r_{max} < r_0$$

$$a_1 * r_{max} + b_1, \text{ if } r_{max} >= r_0 \qquad \text{Equation 15}$$

The calculation parameter/coefficients r_0, a_1 and b_1 are as follows:.

- r_0 = 1.053, a_1 = 0.5403, b_1 = -0.5385 for class 1
- r_0 = 1.022, a_1 = 0.532, b_1 = -0.5133 for class 2
- r_0 = 1.024, a_1 = 0.63, b_1 = -0.615 for class 3.

The r_0 values are chosen so that the downscaling starts with f_{dsc} = 3%.

Vehicles with extremely low v_max values resulting from speed limiters rather than from engine power limitation do not require downscaling. These limiters could consist of very short gearing of the transmission in combination with an engine speed limiter or other electronic devices that limit v_max at a speed lower than the max. speed that would be determined by the power curve. The following equation determines the thresholds in terms of v_{max} for such vehicles.
If

$$v_{max} < a_2 * r_{max} + b_2 \qquad \text{Equation 16}$$

no downscaling shall be applied for class 2 and class 3 vehicles. v_{max} is the maximum speed of the vehicle in km/h.

The values for the coefficients a_2 and b_2 are as follows:

- a_2 = -42.24, b_2 = 153.93 for class 2,
- a_2 = -62.5, b_2 = 181.75 for class 3.

For class 1 vehicles, no threshold could be determined.

If a vehicle is tested under different configurations in terms of test mass and driving resistance coefficients, the worst case (highest $P_{req, max, i}$ value) has to be used for the determination of the downscaling factor and the resulting downscaled cycle shall be used for all measurements. If the maximum speed of the vehicle is lower than the maximum speed of the downscaled cycle, the vehicle shall be driven with its maximum speed in those cycle periods where the cycle speed is higher than the maximum speed of the vehicle.

If the unlikely situation occurs that the vehicle cannot follow the speed trace of the downscaled cycle within the tolerance for specific periods, it shall be driven with the accelerator pedal fully engaged during these periods.

ANNEX 2: GEAR SELECTION AND SHIFT POINT DETERMINATION FOR VEHICLES EQUIPPED WITH MANUAL TRANSMISSIONS

1. General Approach

1.1. The shifting procedures described in this Annex shall apply to vehicles equipped with manual transmissions.

1.2. The prescribed gears and shifting points are based on the balance between the power required for overcoming driving resistance and acceleration, and the power provided by the engine in all possible gears at a specific cycle phase.

1.3. The calculation to determine the gears to use shall be based on normalised engine speeds (normalised to the span between idling speed and rated engine speed) and normalised full load power curves (normalised to rated power) versus normalised engine speed.

2. Required Data

The following data is required to calculate the gears to be used when driving the cycle on a chassis dynamometer:

(a) $P_{rated,}$ the maximum rated engine power as declared by the manufacturer.

(b) s, the rated engine speed at which an engine develops its maximum power. If the maximum power is developed over an engine speed range, s is determined by the mean of this range.

(c) n_{idle}, idling speed as defined in Annex 1 of Regulation No. 83

(d) ng_{max}, the number of forward gears

(e) n_{min_drive}, minimum engine speed for gears I > 2 when the vehicle is in motipon. The minimum value is determined by the following equation:

$$n_{min\_drive} = n_{idle} + (0.125) \times (s - n_{idle}) \quad (1)$$

Higher values may be used if requested by the manufacturer.

(f) ndv_i, the ratio obtained by dividing n in min^{-1} by v in km/h for each gear i, i = 1 to ng_{max}.

(g) m_t, test mass of the vehicle in kg.

(h) f_0, f_1, f_2, driving resistance coefficients as defined in Annex 4 in N, N/(km/h), and $N/(km/h)^2$ respectively.

(i) $P_{wot}(n_{norm})/P_{rated}$ is the full load power curve, normalised to rated power and (rated engine speed – idling speed), $n_{norm} = (n - n_{idle})/(s - n_{idle})$.

3. Calculations of required power, engine speeds, available power, and possible gear to be used

3.1. Calculation of required power

For every second j of the cycle trace, the power required to overcome driving resistance and to accelerate shall be calculated using the following equation:

$$P_{required,j} = (f_0 \times v_j + f_1 \times (v_j)^2 + f_2 \times (v_j)^3)/3600 + ((kr \times a_j) \times v_j \times m_t))/3600 \quad (2)$$

where:

f_0	is the road load coefficient, N;
f_1	is the road load parameter dependent on velocity, N/(km/h);
f_2	is the road load parameter based on the square of velocity, N/(km/h)²;
$P_{required,j}$	is the required power in kW at second j;
v_j	is the vehicle speed at second j, km/h;
a_j	is the vehicle acceleration at second j, m/s², $a_j = (v_{j+1} - v_j)/3.6$;
m_t	is the vehicle test mass, kg;
kr	is a factor taking the inertial resistances of the drivetrain during acceleration into account and is set to 1.1.

3.2. Determination of engine speeds

For each $v_j \leq 1$ km/h, the engine speed is set to n_{idle} and the gear lever is placed in neutral with the clutch engaged.

For each $v_j \geq 1$ km/h of the cycle trace and each gear i, i = 1 to ng_{max}, the engine speed $n_{i,j}$ is calculated using the following equation:

$$n_{i,j} = ndv_i \times v_j \quad (3)$$

All gears i for which $n_{min} \leq n_{i,j} \leq n_{max}$ are possible gears to be used for driving the cycle trace at v_j.

$n_{max} = 1.2 \times (s - n_{idle}) + n_{idle}$.

If i > 2, $n_{min} = n_{min\_drive}$,

If i = 2 and $ndv_2 \times v_j \geq 0.9 \times n_{idle}$,

$n_{min} = \max(1.15 \times n_{idle}; 0.03*(s - nidle) + nidle)$,

If $ndv_2 \times v_j < \max(1.15 \times n_{idle}; 0.03*(s - nidle) + nidle)$, the clutch shall be disengaged.

If i = 1 $n_{min} = = n_{idle}$

If $ndv_1 \times v_j < n_{idle}$, the clutch shall be disengaged.

3.3. Calculation of available power

The available power for each possible gear i and each vehicle speed value of the cycle trace v_j shall be calculated using the following equation:

$$P_{available,i,j} = P_{norm\_wot}(n\_norm_{i,j}) \times P_n \times SM \quad (4)$$

where:

$n_{norm\_i,\,j} = (ndv_i \times v_j - n_{idle})/(s - n_{idle})$,

P_{rated}	is the rated power, kW;
P_{norm_wot}	is the percentage of rated power available at $n_{norm\_i,\,j}$ at full load condition from the normalised full load power curve;
SM	is a safety margin accounting for the difference between stationary full load condition power curve and the power available during transient conditions. SM is set to 0.9;
n_{idle}	is the idling speed, min^{-1};
s	is the rated engine speed

3.4. Determination of possible gears to be used

The possible gears to be used are determined by the following conditions:

(1) $n_{min} \leq n_{i,j} \leq n_{max}$

(2) $P_{available,i,j} \geq P_{required,j}$

The initial gear to be used for each second j of the cycle trace is the maximum final possible gear i_max. When starting from standstill, only the 1st gear shall be used.

4. Additional requirements for corrections and/or modifications of gear use

The initial gear selection shall be checked and modified in order to avoid too frequent gear-shifts and to ensure driveability and practicality.

Corrections and/or modifications shall be made according to the following requirements:

(a) First gear shall be selected 1 second before beginning an acceleration phase from standstill with the clutch disengaged. Vehicle speeds below 1 km/h imply that the vehicle is standing still.

(b) Gears shall not be skipped during acceleration phases. Gears used during accelerations and decelerations must be used for a period of at least 3 seconds.
E.g. a gear sequence 1, 1, 2, 2, 3, 3, 3, 3, 3 shall be replaced by 1, 1, 1, 2, 2, 2, 3, 3, 3

(c) Gears may be skipped during deceleration phases. For the last phases of a deceleration to a stop, the clutch may be either disengaged or the gear lever placed in neutral and the clutch left engaged.

(d) There shall be no gearshift during transition from an acceleration phase to a deceleration phase. E.g., if $v_j < v_{j+1} > v_{j+2}$ and the gear for the time sequence j and j+1 is i, gear i is also kept for the time j+2, even if the initial gear for j+2 would be i+1.

(e) If a gear i is used for a time sequence of 1 to 5 s and the gear before this sequence is the same as the gear after this sequence, e.g. i-1, the gear use for this sequence shall be corrected to i-1.
Example:

(1) a gear sequence i-1, i, i-1 is replaced by i-1, i-1, i-1

(2) a gear sequence i-1, i, i, i-1 is replaced by i-1, i-1, i-1, i-1

(3) a gear sequence i-1, i, i, i, i-1 is replaced by i-1, i-1, i-1, i-1, i-1

(4) a gear sequence i-1, i, i, i, i, i-1 is replaced by i-1, i-1, i-1 ,i-1, i-1, i-1,

(5) a gear sequence i-1, i, i, i, i, i, i-1 is replaced by i-1, i-1, i-1, i-1, i-1, i-1, i-1.

For all cases (1) to (5), $g_{min} \leq i$ must be fulfilled.

(f) a gear sequence i, i-1, i, shall be replaced by i, i, i, if the following conditions are fulfilled:

(1) engine speed does not drop below n_{min} and

(2) the sequence does not occur more often than 4 times each for the low, medium and high speed cycle phases and not more than 3 times for the extra high speed phase.

Requirement (2) is necessary as the available power will drop below the required power when the gear i-1 is replaced by i. This should not occur too frequently.

(g) If during an acceleration phase a lower gear is required at a higher vehicle speed, the higher gears before shall be corrected to the lower gear, if the lower gear is required for at least 2 s.

Example: $v_j < v_{j+1} < v_{j+2} < v_{j+3} < v_{j+4} < v_{j+5} < v_{j+6}$. The originally calculated gear use is 2, 3, 3, 3, 2, 2, 3. In this case the gear use will be corrected to 2, 2, 2, 2, 2, 2, 3.

Since the above modifications may create new gear use sequences which are in conflict with these requirements, the gear sequences shall be checked twice.

ANNEX 3: REFERENCE FUELS

The reference fuel specifications will be established in Phase III of the WLTP process. The rest of this Annex will remain intentionally blank until this process has been completed.

ANNEX 4: ROAD AND DYNAMOMETER LOAD

1. Scope
This Annex describes the determination of the road load of a test vehicle and the transfer of that road load to a chassis dynamometer. Road load can be determined using coastdown or torque meter methods.

2. Terms and definitions
For the purpose of this document, the terms and definitions given in ISO 3833 and in B.3. of this GTR apply.

3. Required overall measurement accuracy
The required overall measurement accuracy shall be as follows:

a) vehicle speed: ± 0.5 km/h or ± 1 per cent, whichever is greater;
b) time accuracy: min. ± 1ms; time resolution: min. ± 0.01 s
c) wheel torque: ± 3 Nm or ± 0.5 per cent, whichever is greater;
d) wind speed: ± 0.3 m/s
e) wind direction: ± 3°;
f) atmospheric temperature: ± 1 K;
g) atmospheric pressure: ± 0.3 kPa;
h) vehicle mass: ± 10 kg; (± 20 kg for vehicles > 4000 kg)
i) tyre pressure: ± 5 kPa;
j) product of the aerodynamic drag coefficient and frontal projected area ($S * C_d$): ± 2 per cent;
k) chassis dynamometer roller speed: ± 0.5 km/h or ± 1 per cent, whichever is greater;
l) chassis dynamometer force: ± 10 N or ± 0.1 per cent of full scale, whichever is greater.

4. Road load measurement on road

4.1. Requirements for road test

4.1.1. Atmospheric conditions for road test

4.1.1.1. Wind
The average wind speed over the test road shall not exceed 10 m/s. Wind gusts shall not exceed 14 m/s. The wind correction shall be conducted according to the applicable type of anemometry specified in Table 1. In order to decide the applicability of each anemometry type, the average wind speed shall be determined by continuous wind speed measurement, using a recognised meteorological instrument, at a location and height above the road level alongside the test road where the most representative wind conditions will be experienced. Wind correction may be waived when the average wind speed is 3 m/s or less.

Type of anemometry	Average wind speed, m/s		
	Absolute wind speed $v \leq 5$		Absolute wind speed $5 < v \leq 10$
	Crosswind component (v_c) $v_c \leq 3$	Crosswind component (v_c) $3 < v_c \leq 5$	
Stationary anemometry	Applicable	Not applicable	Not applicable
Onboard anemometry	Applicable	Applicable	Applicable
NOTE : Stationary anemometry is recommended when the absolute wind speed is less than 1 m/s.			

Table 1 — Applicable anemometry depending on average wind speed and cross-wind component

4.1.1.2. Atmospheric temperature
The atmospheric temperature should be within the range of 278 up to and including 308 K.
At its option, a manufacturer may choose to perform coastdowns between [274] and [278] K.

4.1.2. Test road
The road surface shall be flat, clean, dry and free of obstacles or wind barriers that might impede the measurement of the running resistance, and its texture and composition shall be representative of current urban and highway road surfaces. The test-road longitudinal slope shall not exceed ± 1 per cent. The local slope between any points 3 m apart shall not deviate more than ± 0.5 per cent from this longitudinal slope. If tests in opposite directions cannot be performed at the same part of the test track (e.g. on an oval test track with an obligatory driving direction), the sum of the longitudinal slopes of the parallel test track segments shall be between 0 and an upward slope of 0.1 per cent. The maximum cross-sectional camber of the test road shall be 1.5 per cent.

4.2. Preparation for road test
4.2.1. Test vehicle
[The test vehicle shall conform in all its components with the production series, or, if the vehicle is different from the production series, a full description shall be given in the test report.]

<u>NOTE: The following section (§4.2.1.1.) is under development</u>

[4.2.1.1. Test vehicle selection]

4.2.1.1.1. The vehicle selected for road load determination for which approval is sought shall be fitted with the worst case combination of permanently installed factory options leading to the highest vehicle air resistance. Permanently installed factory options are those which would be expected to be used under normal driving conditions.
4.2.1.1.1. The vehicle selected for road load determination shall be fitted with the worst case combination of ~~permanently installed~~ factory options, i.e. having the highest air resistance of the vehicle family Options that are intended to increase the carrying capacity and/or use the towing capacity of the vehicle must not be fitted if they are not permanently installed during

normal driving conditions. The options excluded from the road load determination shall be listed in the test report.

4.2.1.1.3. Moveable aerodynamic body parts shall be fixed in the most unfavourable position for the duration of the road load test unless it is obvious that the favourable position is representative for normal driving conditions.
4.2.1.1.3. Moveable aerodynamic body parts shall be operated as representative under normal driving conditions.
4.2.1.1.3. Moveable aerodynamic body parts shall operate as intended under normal driving conditions.
("normal driving conditions" means: a vehicle with *TMH* driven through a *WLTC* cycle at temperatures between [*274 and 308*] *K*

4.2.1.1.4. For the selected tyre, the wheel with the highest expected air drag shall be used.

4.2.1.1.5. Before and after the road load determination procedure, the selected vehicle shall be weighed, including the test driver and equipment, to determine the average weight m (see §4.3.1.4.4). The minimum weight of the vehicle shall be equal to or higher than the target test mass (TMH or TML, calculated according to §4.2.1.1.5.1 and §4.2.1.1.7.5.1) at the beginning of the road load determination procedure. For all further calculations, the average weight m shall be used.

4.2.1.1.5. Before and after the road load determination procedure, the selected vehicle shall be weighed, including the test driver and equipment, to determine the average mass m (see §4.3.1.4.4). The minimum mass of the vehicle shall be equal to or higher than the target test mass (TM_H or TM_L, calculated according to §4.2.1.1.5.1 and §4.2.1.1.7.5.1) at the start of the road load determination procedure.
For the calculation of the CO_2 emissions at additional test masses ~~regression~~ in Annex 7, the actual test masses $TM_{H, actual}$ and $TM_{L, actual}$ will be applied, i.e. the average mass m for the respective test masses.

4.2.1.1.5.1. TM_H shall be calculated by adding (a) the unladen mass of the vehicle family UM, (b) the mass of all optional equipment available for the vehicle family OM_H, (c) 100 kilograms and (d) a variable mass. The mass in (d) shall be [15] per cent of the difference between the maximum laden mass LM and the sum of (a), (b) and (c) for category 1-1 and 1-2 vehicles. The mass in (d) shall be [28] per cent of the difference between the maximum laden mass LM and the sum of (a), (b) and (c) for category 2 vehicles.

4.2.1.1.6. The test vehicle configuration shall be recorded in the approval test report and shall be used for any subsequent testing.

4.2.1.1.7. At the request of the manufacturer, the vehicle may be tested again at a test mass TM_L [and at different road load settings (RL_{HH}, RL_{HL} and RL_{LH})] to determine the CO_2 emission value for individual vehicles in the vehicle family according to the CO_2 regression method in §3.2.3. Annex 7. These additional tests are allowed if OM_H for the vehicle family is 100 kg or higher. If OMH is lower than 100 kg, additional testing is allowed if OM_H is set to 100 kg. The vehicle shall fulfil the following criteria:

4.2.1.1.7.1. The vehicle shall have none of the available factory options for production vehicles installed which negatively influence air resistance.

4.2.1.1.7.2. Options that are designed to positively influence air resistance shall be installed.

4.2.1.1.7.3. Moveable aerodynamic body parts shall be fixed in their most favourable position for the duration of the road load test unless it is obvious that the favourable position is representative for normal driving conditions.
4.2.1.1.7.3. Moveable aerodynamic body parts shall be operated as representative under normal driving conditions.
4.2.1.1.7.3. Moveable aerodynamic body parts shall operate as intended under normal driving conditions.

4.2.1.1.7.4. For the selected tyre, the wheel with the expected lowest air drag shall be used.

4.2.1.1.7.5. The minimum weight of the selected vehicle including the test driver and equipment shall be equal to or higher than the TM_L as calculated according to §4.2.1.1.7.5.1. at the start of the road load determination procedure.

4.2.1.1.7.5.1. TM_L shall be calculated by adding (a) the unladen mass of an empty vehicle including its standard equipment, (b) 100 kilograms representing the mass of the driver, some luggage and non-OEM optional equipment and (c) a variable mass based on the heaviest vehicle.
4.2.1.1.7.5.1. TM_L shall be calculated by subtracting the mass of all optional equipment available for the vehicle family OM_H from TM_H.

4.2.1.1.7.6. The test vehicle configuration shall be recorded in the approval test report and shall be used for any subsequent testing.

NOTE: The following section (§4.2.1.2.) is under development

[4.2.1.2. Test vehicle condition]

4.2.1.2.1. The test vehicle shall be suitably run-in for the purpose of the subsequent test for at least 10,000 but no more than 80,000 km.
4.2.1.2.1.1. At the request of the manufacturer, a vehicle with a minimum of 3,000 km may be used.

4.2.1.2.2. The vehicle shall conform to the manufacturer's intended production vehicle specifications regarding tyre pressures (§4.2.2.3.), wheel alignment, vehicle height, drivetrain and wheel bearing lubricants, and brake adjustment to avoid unrepresentative parasitic drag.

4.2.1.2.3. If an alignment parameter is adjustable (tracking, camber, caster), it shall be set to the nominal value for the manufacturer's intended production vehicle. In absence of a nominal value, it shall be set to the mean of the values recommended by the manufacturer.
Such adjustable parameter(s) and set value shall be recorded in the test report.

4.2.1.2.4. During the road test, the engine bonnet, manually-operated moveable panels and all windows shall be closed.

4.2.1.2.5. If the determination of dynamometer settings cannot meet the criteria described in paragraphs 7.1.3. or 7.2.3. due to non-reproducible forces, the vehicle shall be equipped with a vehicle coastdown mode. The coastdown mode shall be approved and recorded by the responsible authority.

4.2.1.2.6. If a vehicle is equipped with a vehicle coastdown mode, it shall be engaged both during road load determination and on the chassis dynamometer.

[4.2.2. Tyres]

NOTE: Section §4.2.2. is under development

4.2.2.1. Tyre selection

The selection of tyres shall be based on their rolling resistances as measured using the appropriate technical procedure of the contracting party and categorised according to the rolling resistance classes in the table below. From the range of tyres that will be offered on the production vehicle, a tyre shall be selected from the highest rolling resistance class. If multiple tyre types are offered in the highest rolling resistance class, the widest tyre shall be selected. The same tyre type will be used for road load determination at test masses TM_L and TM_H.

Class	Rolling Resistance (RR) - kg/tonne
1	RR ≤ 6.5
2	6.5 < RR ≤ 7.7
3	7.7 < RR ≤ 9.0
4	9.0 < RR ≤ 10.5
5	10.5 < RR ≤ 12.0
6	RR > 12.0

4.2.2.2. Tyre condition

The tyres used for the test shall:

(a) not be older than 2 years after production date,

(b) not be specially conditioned or treated (e.g. heated or artificially aged), with the exception of grinding in the original shape of the tread,

(c) shall be run-in on a road for at least 200 kilometers before road load determination,

(d) shall have a constant tread depth before the test between 100 and 80 per cent of the original tread depth over the full tread width of the tyre,

(e) after measurement of the tread depth, driving distance shall be limited to 500 kilometers. If 500 kilometers are exceeded, the tread depth shall be remeasured.

4.2.2.3. Tyre pressure

The front and rear tyres shall be inflated to the lower limit of the tyre pressure range for the selected tyre, as specified by the vehicle manufacturer.

4.2.2.3.1. Tyre-pressure adjustment

If the difference between ambient and soak temperature is more than 5 K, the tyre pressure shall be adjusted as follows:

(a) the tyres shall be soaked for more than 4 h at 10 per cent above the target pressure.

(b) prior to testing, the tyre pressure shall be reduced to the inflation pressure as specified in 4.2.2.3., adjusted for difference between the soaking environment temperature and the ambient test temperature at a rate of 0.8 kPa per 1 K using the following equation:

$$\Delta P_t = 0.8 \text{ x } (T_{soak} - T_{amb})$$

where:

ΔP_t is the tyre pressure adjustment, kPa,

0.8 is the pressure adjustment factor, kPa/K,

T_{soak} is the tyre soaking temperature, K,

T_{amb} is the test ambient temperature, K.

(c) between the pressure adjustment and the vehicle warm-up the tires will be kept at ambient temperature and shielded from external heat sources including sun radiation.

4.2.3. Instrumentation

Any instruments, especially for those installed outside the vehicle, shall be installed on the vehicle in such a manner as to minimise effects on the aerodynamic characteristics of the vehicle.

4.2.4. Vehicle warm-up

[4.2.4.1. On the road

4.2.4.1.1. Cold vehicle

The vehicle shall be driven at a steady speed (if possible) of 120 km/h until stable condition are reached. Vehicles that are speed limited to below 120 km/h shall be driven at [90 %] of their respective v_{max}. It is recommended to warm up the vehicle for at least 20 min.

4.2.4.1.2. Warmed-up vehicle

The vehicle shall be driven at 90 % of its v_{max} until stable conditions are reached.
If the manufacturer develops a different warm-up cycle/procedure and equivalency can be shown, the responsible authority shall be notified.]

4.2.4.1.3. Criteria for stable condition

These measurements shall be carried out in both directions until a minimum of three consecutive pairs of figures have been obtained which satisfy the statistical accuracy p, in per cent, using the equation in §4.3.1.4.2. of this Annex.

4.2.5. Before warm-up, the vehicle shall be decelerated with the clutch disengaged by moderate braking from 80 to 20 km/h within 5 to 10 seconds. After this braking, there shall be no further manual adjustment of the braking system.

4.3. Measurement and calculation of total resistance by the coastdown method

The total resistance shall be determined by using the multi-segment (§4.3.1.) or on-board anemometer (§4.3.2.) method.

4.3.1. Multi-segment method

4.3.1.1. Selection of speed points for road load curve determination

In order to obtain a road load curve as a function of vehicle speed, a minimum of six speed points, v_j (j = 1, 2, etc.) shall be selected. The highest speed point shall not be lower than the highest reference speed, and the lowest speed point shall not be higher than the lowest reference speed. The interval between each speed point shall not be greater than 20 km/h.

4.3.1.2. Data collection

During the test, elapsed time and vehicle speed shall be measured and recorded at a maximum of 0.2 s intervals, and wind speed and wind direction shall be measured by stationary anemometry at a maximum of 1.0 s intervals.

4.3.1.3. Vehicle coastdown procedure

[4.3.1.3.1 Following warming up, and immediately prior to each test measurement, the vehicle shall be driven at the highest reference speed for no more than 1 min, if necessary. The vehicle shall be accelerated to at least 5 km/h above the speed at which the coastdown time measurement begins ($V_j + \Delta V$) and the coastdown shall begin immediately.
4.3.1.3.1 Following the vehicle warm-up procedure (4.2.4.), and immediately prior to each test measurement, the vehicle maybe driven at the highest reference speed up to a maximum of 1 minute. The vehicle shall be accelerated to at least 5 km/h above the speed at which the coastdown time measurement begins (vj + Δv) and the coastdown shall begin immediately.]

4.3.1.3.2. During coastdown, the transmission shall be in neutral, and the engine shall run at idle. For vehicles with manual transmissions, the clutch shall be engaged. Steering wheel movement shall be avoided as much as possible, and the vehicle brakes shall not be operated until the end of the coastdown.

4.3.1.3.3. The test shall be repeated. Coastdowns shall be performed at the same speeds and under the same conditions.

4.3.1.3.4. Although it is recommended that each coastdown run be performed without interruption, split runs are permitted if data cannot be collected in a continuous way for the entire speed range. For split runs, care shall be taken so that vehicle conditions remain as stable as possible at each split point.

4.3.1.4. Determination of total resistance by coastdown time measurement

4.3.1.4.1. The coastdown time corresponding to the velocity v_j as the elapsed time from the vehicle velocity ($v_j + \Delta v$) to ($v_j - \Delta v$) shall be measured. It is recommended that [Δv= 5 km/h] with the option of Δv= 10 km/h when the vehicle velocity is more than 60 km/h, and 5 km/h when the vehicle velocity is 60 km/h or less.

4.3.1.4.2. These measurements shall be carried out in both directions until a minimum of three consecutive pairs of figures have been obtained which satisfy the statistical accuracy p, in per cent, defined below.

$$p = \frac{t * s}{\sqrt{n}} * \frac{100}{\Delta T_j} \leq 3 \text{ per cent}$$

where:

p is the statistical accuracy;

n is the number of pairs of measurements;

ΔT_j is the mean coastdown time at velocity v_j, in seconds, given by the equation:

$$\Delta T_j = \frac{1}{n}\sum_{i=1}^{n} \Delta T_{ji}$$

ΔT_{ji} is the harmonised average coastdown time of the i[th] pair of measurements at velocity v_j, in seconds, given by the equation:

$$\Delta T_{ji} = \frac{2}{\left(\frac{1}{\Delta T_{jai}}\right) + \left(\frac{1}{\Delta T_{jbi}}\right)}$$

ΔT_{jai} and ΔT_{jbi} are the coastdown times of the i[th] measurement at speed V_j in each direction, respectively, s;

σ is standard deviation, s, defined by:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(\Delta T_{ji} - \Delta T_j)^2}$$

t is a coefficient given in Table 2 below.

t	n	$t/\sqrt{n}$	t	n	$t/\sqrt{n}$
4.3	3	2.48	2.2	10	0.73
3.2	4	1.60	2.2	11	0.66
2.8	5	1.25	2.2	12	0.64
2.6	6	1.06	2.2	13	0.61
2.5	7	0.94	2.2	14	0.59
2.4	8	0.85	2.2	15	0.57
2.3	9	0.77			

Table 2

[4.3.1.4.3. If during a measurement in one direction any (a) external factor or (b) driver action occurs which influences the road load test, that measurement and the paired measurement in the opposite direction shall be rejected.]

4.3.1.4.4. The total resistances, F_{ja} and F_{jb} at velocity v_j in directions a and b, in newtons, are determined by the equations:

$$F_{ja} = -\frac{1}{3.6} \times (m + m_r) \times \frac{2 \times \Delta v}{\Delta t_{ja}}$$

$$F_{jb} = -\frac{1}{3.6} \times (m + m_r) \times \frac{2 \times \Delta v}{\Delta t_{jb}}$$

where:

Fja is the total resistance at velocity (j) in direction a, N;

Fjb is the total resistance at velocity (j) in direction b, N;

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

[m_r is the equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdown on theroad, in kilograms (kg); m_r shall be measured or calculated using an appropriate technique. Alternatively, m_r may be estimated to be 3 per cent of the unladen vehicle mass (UM) for the vehicle family];

Δt_{ja} and Δt_{jb} are the mean coastdown times in directions a and b, respectively, corresponding to velocity v_j, in seconds (s), given by the equations:

$$\Delta t_{ja} = \frac{1}{n}\sum_{i=1}^{n} \Delta t_{jai}$$

$$\Delta t_{jb} = \frac{1}{n}\sum_{i=1}^{n} \Delta t_{jbi}$$

4.3.1.4.5. The total resistance curve shall be determined as follows.
The following regression curve shall be fit to the data sets (v_j, F_{ja}) and (v_j, F_{jb}) corresponding to all the speed points v_j (j = 1, 2, etc.) and direction (a, b) to determine f_0, f_1 and f_2:

$$F_a = f_{0a} + f_{1a}v + f_{2a}v^2$$

$$F_b = f_{0b} + f_{1b}v + f_{2b}v^2$$

where:

F_a and F_b are the total resistances in each direction, N;

f_{0a} and f_{0b} are constant terms in each direction, N;

f_{1a} and f_{1b} are the first-order term coefficients of the vehicle speed in each direction, N·h/km;

f_{2a} and f_{2b} are the second-order term coefficients of the vehicle speed in each direction, $N \cdot (h/km)^2$;

v is vehicle velocity, km/h.

The average total resistance F_{avg} shall be calculated by:

$$F_{avg} = f_0 + f_1 v + f_2 v^2$$

where the coefficients f_0, f_1 and f_2 shall be calculated using the following equations:

$$f_0 = \frac{f_{0a} + f_{0b}}{2}$$

$$f_1 = \frac{f_{1a} + f_{1b}}{2}$$

$$f_2 = \frac{f_{2a} + f_{2b}}{2}$$

where:

f_0, f_1 and f_2 are the average coefficients.

4.3.1.4.5.1. As an alternative to the above calculation, the following equation may be applied to compute the average total resistance, where the harmonised average of the alternate coastdown time shall be used instead of the average of alternate total resistance.

$$F_j = -\frac{1}{3.6} \times (m + m_r) \times \frac{2 \times \Delta v}{\Delta T_j}$$

where:

Δt_j is the harmonised average of alternate coastdown time measurements at velocity v_j, in seconds (s), given by the equation:

$$\Delta t_j = \frac{2}{\frac{1}{\Delta t_{ja}} + \frac{1}{\Delta t_{jb}}}$$

where:

Δt_{ja} and Δt_{jb} are the coastdown times at velocity v_j in each direction, respectively, in seconds (s).

The coefficients f_0, f_1 and f_2 in the total resistance equation shall be calculated with regression analysis.

4.3.2. On-board anemometer-based coastdown method

This method is applicable to a wind speed range up to 10 m/s on a test road as given in Table 1 of this Annex.

4.3.2.1. Selection of speed range for road load curve determination

The test speed range as specified in 4.3.1.1. shall be selected.

4.3.2.2. Data collection

The following data shall be measured and recorded at a maximum of 0.2 s intervals during the test.

a) elapsed time;
b) vehicle speed (measured by on-board anemometry);
c) wind speed and direction (measured by on-board anemometry).

4.4.3. Vehicle coastdown procedure

Vehicle coastdown shall be conducted as specified in 4.3.1.3.1. to 4.3.1.3.4. with an onboard anemometer installed on the vehicle. The anemometer shall be installed in a position such that the effect on the operating characteristics of the vehicle is minimised. It is recommended to install the anemometer at the vehicle's forward aerodynamic stagnation point and approximately 2 m in front of it. Before the coastdown, the anemometer shall be installed on the vehicle and calibrated as specified by the manufacturer.

4.3.2.4. Determination of coefficients a_{mech}, b_{mech} and c_{mech}

Each coefficient shall be calculated by the following equation with multi-regression analysis, using coastdown time and wind data.

$$-\frac{1}{3.6} \times (m + m_r) \times \frac{dv}{dt} =$$

$$a_{mech} + b_{mech} v + c_{mech} v^2 + \frac{1}{2} \times \rho s v_r^2 \times (a_0 + a_1 \theta + a_2 \theta^2 + a_3 \theta^3 + a_4 \theta^4)$$

where:

m is the test vehicle mass, kg;
m_r is the equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdown on the road,kg; m_r should be measured or calculated using an appropriate technique; as an alternative, m_r may be estimated to be 3per cent of the unladen vehicle mass;
dv/dt is acceleration, (km/h)/s;
a_{mech} is a first order coefficient of mechanical drag, N;
b_{mech} is a second order coefficient of mechanical drag, N/(km/h);
c_{mech} is a third order coefficient of mechanical drag, $N/(km/h)^2$;
v is vehicle velocity, km/h;
v_r is relative wind velocity, km/h;
ρ is air density, kg/m^3;
S is the projected frontal area of the vehicle, m^2;
$a_{i\ (i = 0\ to\ 4)}$ are the aerodynamic drag coefficients as a function of yaw angle, $degrees^{-n}$;
θ is the yaw-angle apparent wind relative to the direction of vehicle travel, degrees.

If the wind velocity is close to 0 km/h, the equation theoretically cannot separate c_{mech} and (1/2) x a_0 ρ S appropriately. Therefore, a constrained analysis, where a_0 is fixed if it is previously determined, for example in a wind tunnel, or c_{mech} is assumed to be zero, may be employed.

4.3.2.5. Determination of total resistance using coastdown measurements

The total resistance, F, shall be calculated where all the wind effects are eliminated, by the following equation with the coefficients obtained in 4.4.4.

$$F = a_{mech} + b_{mech} v + \left(c_{mech} + \frac{1}{2} \times a_\theta \rho S\right) \times v^2$$

4.4. Measurement of running resistance by the torque meter method

As an alternative to the coastdown methods, the torque meter method may also be used.

4.4.1. Installation of torque meter

A wheel torque meter shall be installed on each driven wheel.

4.4.2. Procedure and data sampling

4.4.2.1. Start of data collection

Data collection may be started following warm-up and stabilisation of the vehicle at the velocity v_j, where the running resistance is to be measured.

4.4.2.2. Data collection

At least 10 data sets of velocity, torque and time over a period of at least 5 s shall be recorded.

4.4.2.3. Velocity deviation

The deviation from the mean velocity shall be within the values in Table 3.

Table 3

Time period, seconds	Velocity deviation, km/h
5	± 0.2
10	± 0.4
15	± 0.6
20	± 0.8
25	± 1.0
30	± 1.2

4.4.3. Calculation of mean velocity and mean torque

4.4.3.1. Calculation process

Mean velocity v_{jm},(km/h) and mean torque C_{jm}, (N·m) over a time period, shall be calculated as follows:

$$v_{jm} = \frac{1}{k}\sum_{i=1}^{k} v_{ji}$$

and

$$C_{jm} = \frac{1}{k}\sum_{i=1}^{k} C_{ji} - C_{js}$$

where:

v_{ji} is vehicle velocity of the i^{th} data set, km/h;

k is the number of data sets;

C_{ji} is torque of the i^{th} data set, Nm;

C_{js} is the compensation term for velocity drift, Nm, given by the following equation:

$$C_{js} = (m + m_r) * \alpha_j r_j$$

(C_{js} shall be no greater than 5 per cent of the mean torque before compensation, and may be neglected if α_j is no greater than ± 0.005 m/s^2)

where:

m and m_r are the test vehicle mass and the equivalent effective mass, respectively, kg, defined in 4.3.1.4.4;

r_j is the dynamic radius of the tyre, m, given by equation:

$$r_j = \frac{1}{3.6} \times \frac{v_{jm}}{2 \times \pi N}$$

where:

N is the rotational frequency of the driven tyre, s^{-1}

α_j is the mean acceleration, m/s^2 which shall be calculated by the equation:

$$\propto_j = \frac{1}{3.6} \times \frac{k\sum_{i=1}^{k} t_i v_{ji} - \sum_{i=1}^{k} t_i \sum_{i=1}^{k} v_{ji}}{k\sum_{i=1}^{k} t_i^2 - \left(\sum_{i=1}^{k} t_i\right)^2}$$

t_i is the time at which the i^{th} data set was sampled, s.

4.4.3.2. Accuracy of measurement

These measurements shall be carried out in both directions until a minimum of four consecutive figures have been obtained which satisfy accuracy p, in per cent, below. The validity of the data shall be decided in accordance with 4.3.1.4.2.

$$\rho = \frac{ts}{\sqrt{k}} \times \frac{100}{\overline{C_j}} \leq 3 \text{ per cent}$$

where:

k is the number of data sets;

C_j is the running resistance at the velocity v_j, Nm, given by the equation:

$$\overline{C_J} = \frac{1}{k}\sum_{i=1}^{k} C_{jmi}$$

where:

C_{jmi} is the average torque of the i^{th} pair of data sets at velocity v_j, Nm, given by the equation:

$$C_{jmi} = \frac{1}{2} \times \left(C_{jmai} + C_{jmbi}\right)$$

where

C_{jmai} and C_{jmbi} are the mean torques of the i^{th} data sets at velocity v_j determined in 4.5.3.1 for each direction, a and b respectively, Nm

s is the standard deviation, Nm, defined by the equation:

$$s = \sqrt{\frac{1}{k-1}\sum_{i=1}^{k}\left(C_{jmi} - \overline{C_j}\right)^2}$$

t is the coefficient given by replacing n in Table 2 with k.

4.4.3.3. Validity of the measured average velocity

The average velocity v_{jmi}, shall not deviate by more than ± 2 km/h from its mean, $\overline{\mathbf{v_j}}$.

v_{jmi} and $\overline{v_j}$. shall be calculated as follows:

$$\overline{v_j} = \frac{1}{k}\sum_{i=1}^{k} v_{jmi}$$

$$v_{jmi} = \frac{1}{2} \times \left(v_{jmai} + v_{jmbi}\right)$$

where

v_{jmai} and v_{jmbi} are the mean speeds of the i^{th} pair of data sets at velocity v_j determined in 4.4.3.1 for each direction, a and b respectively, km/h.

4.4.4. Running resistance curve determination

The following regression curve shall be fitted to all the data pairs (v_{jm}, C_{jma}) and (v_{jm}, C_{jmb}) for both directions a and b at all speed points v_j (j = 1, 2, etc.) described in 4.3.1.1. to determine c_{0a}, c_{0b}, c_{1a}, c_{1b}, c_{2a} and c_{2b}:

$$C_a = c_{0a} + c_{1a}v + c_{2a}v^2$$
$$C_b = c_{0b} + c_{1b}v + c_{2b}v^2$$

where:

C_a and C_b	are the running resistances in each direction, Nm;
c_{0a} and c_{0b}	are constant terms in each direction, Nm;
c_{1a} are c_{1b}	are the coefficients of the first-order term in each direction, Nm(h/km); c_1 may be assumed to be zero, if the value of c_1V is no greater than 3 per cent of C at the reference speed(s); in this case, the coefficients c_0 and c_2 shall be recalculated;
c_{2a} and c_{2b}	are the coefficients of the second-order term in each direction, $Nm(h/km)^2$;
v	is vehicle velocity, km/h.

The average total torque equation is calculated by the following equation:

$$C_{avg} = c_0 + c_1v + c_2v^2$$

where the average coefficients c_0, c_1 and c_2 shall be calculated using the following equations:

$$c_0 = \frac{c_{0a}+c_{0b}}{2} \qquad c_1 = \frac{c_{1a}+c_{1b}}{2} \qquad c_2 = \frac{c_{2a}+c_{2b}}{2}$$

4.5. Correction to reference conditions

4.5.1. Determination of correction factor for air resistance

The correction factor for air resistance K_2 shall be determined as follows:

$$K_2 = \frac{T}{293} \times \frac{100}{\rho}$$

where:

T is the mean atmospheric temperature, K;

ρ is the mean atmospheric pressure, kPa.

4.5.2. Determination of correction factor for rolling resistance

The correction factor, K_0, for rolling resistance, in reciprocal Kelvins, may be determined based on empirical data for the particular vehicle and tyre test, or may be assumed as follows:

$$K_0 = 8.6 \times 10^{-3} \times K^{-1}$$

4.5.3. Wind correction

4.5.3.1. Wind correction, for absolute wind speed alongside the test road, shall be made by subtracting the difference that cannot be cancelled by alternate runs from the constant term f_0 given in 4.3.1.4.5, or from c_0 given in 4.4.4.

4.5.3.2. The wind correction shall not apply in the on-board-anemometer-based coastdown method (§4.3.2.) as the wind correction is made during the series of data sampling and subsequent analysis. The wind correction resistance w_1 for the coastdown method or w_2 for the torque meter method shall be calculated by the equations:

$$w_1 = 3.6^2 \text{ x } f_2 v^2_w \qquad \text{or} \qquad w_2 = 3.6^2 \text{ x } c_2 v^2_w$$

where:

w_1 is the wind correction resistance, N;
f_2 is the coefficient of the aerodynamic term determined in § 4.3.1.4.5;
v_w is the average wind speed alongside the test road during the test, m/s;
w_2 is the wind correction resistance, N;
c is the coefficient of the aerodynamic term determined in §4.4.4.

4.5.4. Road load curve correction

4.5.4.1. The curve determined in 4.3.1.4.5. shall be corrected to reference conditions as follows:

$$F^* = \left((f_0 - w_1) + f_1 v\right) \times \left(1 + K_0(T - 293)\right) + K_2 f_2 v^2$$

where:

F* is the corrected total resistance, N;
f_0 is the constant term, N;
f_1 is the coefficient of the first-order term, N·(h/km);
f_2 is the coefficient of the second-order term, N·(h/km)^2;
K_0 is the correction factor for rolling resistance as defined in §4.5.2.;
K_2 is the correction factor for air resistance as defined in §4.5.1.;
v is vehicle velocity, km/h;
w_1 is the wind correction resistance as defined in §4.5.3.

4.5.4.2. The curve determined in 4.3.2.5. shall be corrected to reference conditions as follows:

$$F^* = (a_{mech} + b_{mech} v + c_{mech} v^2) \times \left(1 + K_0(T - 293)\right) + \frac{1}{2} \times K_2 a_0 \rho S v^2$$

where:

F* is the corrected total resistance, N;
a_{mech} is the coefficient of mechanical drag, N;
b_{mech} is the coefficient of mechanical drag, N/(km/h);
c_{mech} is the coefficient of mechanical drag, N/(km/h)^2;
ρ is air density, kg/m^3;
S is the projected frontal area of the vehicle, m^2;
a_0 is the coefficient for aerodynamic drag, as a function of yaw angle;
K_0 is the correction factor for rolling resistance as defined in §4.5.2.;
K_2 is the correction factor for air resistance as defined in §4.6.1.1.;
v is vehicle velocity, km/h.

4.5.4.3. The curve determined in 4.4.4. shall be corrected to reference conditions as follows:

$$C^* = \left((c_0 - w_1) + c_1 v\right) \times \left(1 + K_0(T - 293)\right) + K_2 c_2 \rho v^2$$

where:

C^*	is the corrected total running resistance, Nm;
c_0	is the constant term, Nm;
c_1	is the coefficient of the first-order term, Nm (h/km);
c_2	is the coefficient of the second-order term, Nm·(h/km)^2;
K_0	is the correction factor for rolling resistance as defined in §4.5.2.;
K_2	is the correction factor for air resistance as defined in §4.5.1.;
v	is vehicle velocity, km/h;
w_2	is the wind correction resistance as defined in §4.5.3..

5. [Road load measurement using a combination of a wind tunnel and chassis dynamometer]

6. Transferring road load to a chassis dynamometer

6.1. Preparation for chassis dynamometer test

6.1.1. Laboratory condition

6.1.1.1. Roller
The chassis dynamometer roller(s) shall be clean, dry and free from foreign material which might cause tyre slippage. For chassis dynamometers with multiple rollers, the dynamometer shall be run in the same coupled or uncoupled state as the subsequent Type I test. Chassis dynamometer speed shall be measured from the roller coupled to the power-absorption unit.

6.1.1.2. Room temperature
The laboratory atmospheric temperature shall be at a set point of 296 ± 5 K as the standard condition, unless otherwise required by the subsequent test.

6.2. Preparation of chassis dynamometer

6.2.1. Inertia mass setting
The equivalent inertia mass of the chassis dynamometer shall be set in accordance with the vehicle mass or vehicle mass category.

6.2.1. Inertia mass setting
The inertia mass of the chassis dynamometer shall be set to the actual test mass used at the corresponding road load determination, increased by 50% of m_r in case the non-driven wheels are not driven by the chassis dynamometer. If the chassis dynamometer is not capable to meet this setting, the next higher inertia setting shall be applied.

6.2.2. Warming up the chassis dynamometer
The chassis dynamometer shall be warmed up in accordance with the dynamometer manufacturer's recommendations, or as appropriate, so that friction losses of the dynamometer can be stabilised.

6.3. Vehicle preparation

6.3.1. Tyre pressure adjustment

The tyre pressure shall be set to no more than 50 per cent (see §4.2.2.3.) above the lower limit of the tyre pressure range for the selected tyre, as specified by the vehicle manufacturer, and shall be recorded in the test report.

6.3.2. If the determination of dynamometer settings cannot meet the criteria described in paragraphs 7.1.3. due to non-reproducible forces, the vehicle shall be equipped with a vehicle coastdown mode. The coasting mode shall be approved and recorded by the responsible authority.

6.3.2.1. If a vehicle is equipped with a vehicle coastdown mode, it shall be engaged both [during road load determination] and on the chassis dynamometer.

6.3.3. Vehicle setting

The tested vehicle shall be installed on the chassis dynamometer roller in a straight position and restrained in a safe manner. In case of a single roller, the tyre contact point shall be within ± 25 mm or ± 2 per cent of the roller diameter, whichever is smaller, measured from the top of the roller.

6.3.4. Vehicle warming up

[The power-absorption unit of the chassis dynamometer shall be set as specified in 7.1.1.1. or 7.2.1.1., so that an adequate load will be applied to the test vehicle during warming up.

Prior to the test, the vehicle shall be warmed up appropriately until normal vehicle operating temperatures have been reached. This condition is deemed to be fulfilled when three consecutive coastdowns are completed within the given tolerance of Annex/chapter [XXX]. The dynamometer load for the vehicle warm-up shall be set as described in 7.1.1.1.

It is recommended that the vehicle should be driven at the most appropriate reference speed for a period of 30 min. During this warming up period, the vehicle speed shall not exceed the highest reference speed.]

6.3.4.1. Cold and warm vehicles

6.3.4.1.1. Warm up the vehicle at the steady speed used to stabilise for road load determination. It is recommended to warm-up a cold vehicle for at least 20 minutes.

6.3.4.1.2. If the manufacturer develops a different warm up cycle/procedure and equivalency can be shown, it shall be notified to the responsible authority.

6.3.4.2. Criteria for stable condition

6.3.4.2.1. Two consecutive coastdowns within a tolerance of ± 10 N after a regression of the coastdown times.

7. Chassis dynamometer load setting

7.1. Chassis dynamometer setting by coastdown method

This method is applicable when the road load is determined using the coastdown method as specified in 4.3.

7.1.1. Initial load setting

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

$$F_d = A_d + B_d v + C_d v^2$$

where:

F_d is the chassis dynamometer setting load, N;

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

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

a) $A_d = 0.5 \times A_t$, $B_d = 0.2 \times B_t$, $C_d = C_t$, for single-axis chassis dynamometers, or

$Ad = 0.1 \times A_t$, $B_d = 0.2 \times B_t$, $C_d = C_t$, for dual-axis chassis dynamometers,

where A_t, B_t and C_t 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 speed point shall be set to the chassis dynamometer power-absorption unit.

7.1.2. Coastdown

The coastdown test on the chassis dynamometer shall be performed once with the procedure given in 4.3.1.3.1 and 4.3.1.3.2. Then proceed to 7.1.3.

7.1.3. Verification

7.1.3.1. The target road load value shall be calculated using the target road load coefficient A_t, B_t and C_t for each reference speed V_j.

$$F_{tj} = A_t + B_t v_j + C_t v_j^2$$

where

F_{tj} is the target road load at reference speed v_j, in newtons (N);

v_j is the j^{th} reference speed, in kilometres per hour (km/h).

7.1.3.2. The error, ε_j , in per cent of the simulated road load F_{sj}, shall be calculated using the method specified in Appendix I of this Annex for target road load F_{tj} at each reference speed v_j, using the following equation:

$$\varepsilon_j = \frac{F_{sj} - F_{tj}}{F_{tj}} \times 100$$

F_{mj}, obtained in Appendix I section 1.1, may be used in the above equation instead of F_{sj}.
Verify whether errors at all reference speeds satisfy the following error criteria in two consecutive coastdown runs, unless otherwise specified by regulations:

[$\varepsilon_j \leq 3$ per cent for $v_j \geq 50$ km/h
$\square_j \leq 2$ per cent for $v_j \geq 50$ km/h

$\varepsilon_j \leq 5$ per cent for 20 km/h $< v_j <$ 50 km/h
$\square_j \leq 3$ per cent for 20 km/h $< v_j <$ 50 km/h

$\varepsilon_j \leq 10$ per cent for $v_j = 20$ km/h]

If an error at any reference speed does not satisfy the criteria, 7.1.4. shall be used to adjust the chassis dynamometer load setting.

7.1.4. Adjustment
Adjust the chassis dynamometer setting load in accordance with the procedure specified in Appendix 2, section 1 of this Annex. 7.1.2. and 7.1.3. shall be repeated.

7.2. Chassis dynamometer load setting using torque meter method
This method is applicable when the road load is determined using the torque meter method, as specified in section 4.4.

7.2.1. Initial load setting
For a chassis dynamometer of coefficient control, the chassis dynamometer power absorption unit shall be adjusted with the arbitrary initial coefficients, A_d, B_d and C_d, of the following equation:

$$F_d = A_d + B_d v + C_d v^2$$

where

F_d is the chassis dynamometer setting load, N;
v is the speed of the chassis dynamometer roller, km/h.

The following coefficients are recommended for the initial load setting:

a) $A_d = 0.5 \times a_t/r'$, $B_d = 0.2 \times b_t/r'$, $C_d = c_t/r'$, for single-axis chassis dynamometers, or
$A_d = 0.1 \times a_t/r'$, $B_d = 0.2 \times b_t/r'$, $C_d = c_t/r'$, for dual-axis chassis dynamometers,

where:

a_t, b_t and c_t are the coefficients for the target torque;
r' is the dynamic radius of the tyre on the chassis dynamometer, in metres (m) that is obtained by averaging the r_j' values calculated in Appendix I section 2.1;

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 speed point shall be set for the chassis dynamometer power-absorption unit.

7.2.2. Wheel torque measurement
The torque measurement test on the chassis dynamometer shall be performed with the procedure defined in 4.4.2. The torque meter(s) shall be identical with the one(s) used in the preceding road test.

7.2.3. Verification

7.2.3.1. The target road load value shall be calculated using the target torque coefficients a_t, b_t, and c_t for each reference speed v_j.

$$F_{tj} = \frac{a_t + b_t * V_j + c_t * V_j^2}{r'}$$

where

F_{tj} is the target road load at reference speed v_j, N;
v_j is the j^{th} reference speed, km/h;
r' is the dynamic radius of the tyre on the chassis dynamometer, m, that is obtained by averaging the r_j' values calculated in Appendix I section 2.1 of this Annex.

7.2.3.2. The error, ε_j, in per cent of the simulated road load F_{si} shall be calculated. F_{sj} is determined according to the method specified in Appendix I section 2, for target road load F_{tj} at each reference speed v_j.

$$\varepsilon_j = \frac{F_{sj} - F_{tj}}{F_{tj}} \times 100$$

C_j m/r′ obtained in Appendix I section 2.1 and 7.2.3.1., respectively, may be used in the above equation instead of F_{sj}.

Verify whether errors at all reference speeds satisfy the following error criteria in two consecutive coastdown runs, unless otherwise specified by regulations.

$\varepsilon_j \leq 3$ per cent for $V_j \geq 50$ km/h
[$\varepsilon_j \leq 2$ per cent for $V_j \geq 50$ km/h]

$\varepsilon_j \leq 5$ per cent for 20 km/h < V_j < 50 km/h
[$\varepsilon_j \leq 3$ per cent for 20 km/h < V_j < 50 km/h]

$\varepsilon_j \leq 10$ per cent for V_j = 20 km/h
[$\varepsilon_j \leq 10$ per cent for V_j = 20 km/h]

If the error at any reference speed does not satisfy the criteria, then proceed to 7.2.1.4 for the adjustment of the chassis dynamometer setting load.

7.2.3.3. Adjustment
The chassis dynamometer setting load shall be adjusted according to the procedure specified in Appendix 2 section 2. Paragraphs 7.2.2 and 7.2.3. shall be repeated.

NOTE: The following section (§7.3.) is under development

7.3. Dynamometer preparation for settings derived from a running resistance table

7.3.1. Specified speed for the chassis dynamometer

The running resistance on the chassis dynamometer shall be verified at the specified speed v. At least four specified speeds should be verified. The range of specified speed points (the interval between the maximum and minimum points) shall extend either side of the reference speed or the reference speed range, if there is more than one reference speed, by at least Δv. The specified speed points, including the reference speed point(s), shall be no greater than 20 km/h apart and the interval of specified speeds should be the same.

7.3.2. Verification of chassis dynamometer

Immediately after the initial setting, the coastdown time on the chassis dynamometer corresponding to the specified speed shall be measured. The vehicle shall not be set up on the chassis dynamometer during the coastdown time measurement. When the chassis dynamometer speed exceeds the maximum speed of the test cycle, the coastdown time measurement shall start.

The measurement shall be carried out at least three times, and the mean coastdown time Δt_E shall be calculated from the results.

The set running resistance force $F_E(v_j)$ at the specified speed on the chassis dynamometer shall be calculated by the following equation:

$$F_E(v_j) = \frac{1}{3.6} \times m_i \times \frac{2 \times \Delta v}{\Delta t_E}$$

The setting error ε at the specified speed is calculated by the following equation:

$$\varepsilon = \frac{\left|F_E(v_j) - F_T\right|}{F_T} \times 100$$

The chassis dynamometer shall be readjusted if the setting error does not satisfy the following criteria:

[$\varepsilon \leq 2$ per cent for $v \geq 50$ km/h
$\varepsilon \leq 3$ per cent for 30 km/h $\leq v < 50$ km/h
$\varepsilon \leq 10$ per cent for $v < 30$ km/h]

The procedure described above shall be repeated until the setting error satisfies the criteria. The chassis dynamometer setting and the observed errors shall be recorded. An example of the record form is given in Annex 10.

7.3.3. Chassis dynamometer setting based on [provisional] running resistance table

Test Mass (TM)	Power and load absorbed by the dynamometer at 80 km/h		Coefficients		
			a	b	c
Kg	kW	N	N	N/(km/h)	N/(km/h)²
1400	10,6	478	114,0	0,1	0,0556
1500	10,7	484	120,0	0,1	0,0556
1600	10,9	492	126,0	0,1	0,0559
1700	11,2	502	132,0	0,1	0,0566
1800	11,4	515	138,0	0,1	0,0577
1900	11,8	530	144,0	0,1	0,0591
2000	12,2	547	150,0	0,1	0,0608
2100	12,6	567	156,0	0,1	0,0629
2200	13,1	588	162,0	0,1	0,0654
2300	13,6	612	168,0	0,1	0,0682
2400	14,2	638	174,0	0,1	0,0713
2500	14,8	667	180,0	0,1	0,0748
2600	15,5	697	186,0	0,1	0,0787
2700	16,2	730	192,0	0,1	0,0829
2800	17,0	765	198,0	0,1	0,0874
2900	17,8	803	204,0	0,1	0,0923
3000	18,7	842	210,0	0,1	0,0975
3100	19,6	884	216,0	0,1	0,1031
3200	20,6	928	222,0	0,1	0,1091
3300	21,7	974	228,0	0,1	0,1154

Appendix I

Calculation of road load for the dynamometer test

1. Calculation of simulated road load using the coastdown method

When the road load is measured by the coastdown method as specified in 4.3of this Annex, calculation of the simulated road load F_{sj} for each reference speed v_j, in kilometres per hour, shall be conducted as described in 1.1. to 1.3. of this Appendix.

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

$$F_{mj} = \frac{1}{3.6} \times (m_d + m'_r) \times \frac{2 \times \Delta v}{\Delta T_j}$$

where

F_{mj} is the measured road load for each reference speed v_j, N;

m_d is the equivalent inertia-mass of the chassis dynamometer, kg;

m'_r is the equivalent effective mass of drive wheels and vehicle components rotating with the wheels during coastdown on the dynamometer, kg; m'_r may be measured or calculated by an appropriate technique. As an alternative, m'_r may be estimated as 3 per cent of the unladen vehicle mass for a permanent four-wheel-drive vehicle, and 1.5 per cent of the unladen vehicle mass for a two-wheel drive vehicle;

ΔT_j is the coastdown time corresponding to speed Vj, s.

1.2. The coefficients A_s, B_s and C_s of the following approximate equation shall be determined using least-square regression using the calculated F_{mj} :

$$F_s = A_s + B_s v + C_s v^2$$

1.3. The simulated road load for each reference speed v_j shall be determined using the following equation, using the calculated A_s, B_s and C_s:

$$F_{sj} = A_s + B_s v_j + C_s v_j^2$$

2. Calculation of simulated road load using the torque meter method

When the road load is measured by the torque meter method as specified in 4.4., calculation of the simulated road load F_{sj} for each reference speed V_j, in kilometres per hour, shall be conducted as described in 2.1. to 2.3. of this appendix.

2.1. The mean speed V_{jm}, in kilometres per hour, and the mean torque C_{jm}, in newton-metres, for each reference speed V_j shall be calculated using the following equations:

$$v_{jm} = \frac{1}{k \sum_{i=1}^{k} v_{ji}}$$

and

$$C_{jm} = \frac{1}{k}\sum_{i=1}^{k} C_{ji} - C_{jc}$$

where:

v_{ji} is the vehicle speed of the i^{th} data set, km/h;
K is the number of data sets;
C_{ji} is the torque of the i^{th} data set, Nm;
C_{jc} is the compensation term for the speed drift, Nm, given by the following equation:

$$C_{jc} = (m_d + m_r') \alpha_j r'_j$$

C_{jc} shall be no greater than 5 per cent of the mean torque before compensation, and may be neglected if $|\alpha_j|$ is no greater than 0,005 m/s^2.

m_d and m'_r are the equivalent inertia mass of the chassis dynamometer and the equivalent effective mass of drive wheels and vehicle components rotating with the wheel during coastdown on the chassis dynamometer, respectively, both in kilograms (kg), as defined in section 1 of this Appendix;

α_j is the mean acceleration, in metres per second squared (m/s^2), which shall be calculated by the equation:

$$\alpha_j = \frac{1}{3.6} \times \frac{k \sum_{1=1}^{k} t_i v_{ij} - \sum_{i=1}^{k} t_i \sum_{i=1}^{k} v_{ji}}{k \sum_{i=1}^{k} t_i^2 - \left(k \sum_{i=1}^{k} t_i\right)^2}$$

where

t_i is the time at which the i^{th} data set was sampled, s;
r'_j is the dynamic radius of the tyre, m, given by the equation:

$$r'_j = \frac{1}{3.6} \times \frac{v_{jm}}{2 \times \pi N}$$

N is the rotational frequency of the driven tyre, s^{-1}.

2.2. The coefficients a_s, b_s and c_s of the following approximate equation shall be determined by the least-square regression shall be calculated using the calculated $v_{j\,m}$ and the $C_{j\,m}$.

$$F_s = \frac{f_s}{r'} = \frac{a_s + b_s v + c_s v^2}{r'}$$

2.3. The simulated road load for each reference speed v_j shall be determined using the following equation and the calculated a_s, b_s and c_s:

$$F_{sj} = \frac{f_{sj}}{r'} = \frac{a_s + b_s v_j + c_s v_j^2}{r'}$$

Appendix II

Adjustment of chassis dynamometer load setting

1. Adjustment of chassis dynamometer load setting using the coastdown method
   The chassis dynamometer load setting shall be adjusted using the following equations:

$$
\begin{aligned}
F^*_{dj} &= F_{dj} - F_j \\
&= F_{dj} - F_{sj} + F_{tj} \\
&= (A_d + B_d v_j + C_d v_j^2) - (A_s + B_s v_j + C_s v_j^2) + (A_t + B_t v_j + C_t v_j^2) \\
&= (A_d + A_t - A_s) + (B_d + B_t + B_s)\, v_j + (C_d + C_t - C_s)\, v_j^2 \\
&\qquad \therefore A_d^* = A_d + A_t - A_s \\
&\qquad \therefore B_d^* = B_d + B_t - B_s \\
&\qquad \therefore C_d^* = C_d + C_t - C_s
\end{aligned}
$$

where

$F_{d\,j}^*$ is the new chassis dynamometer setting load, N;
F_j is the adjustment road load, which is equal to $F_{sj} - F_{tj}$, N;
F_{sj} is the simulated road load at reference speed v_j, N;
F_{tj} is the target road load at reference speed v_j, N;
A_d^*, B_d^* and C_d^* are the new chassis dynamometer setting coefficients.

2. Adjustment of chassis dynamometer load setting using the torque meter method
   The chassis dynamometer load setting shall be adjusted using the following equation:

$$
\begin{aligned}
F^*_{dj} &= F_{dj} - F_{ej} / r' \\
&= F_{dj} - F_{sj} + F_{tj} / r' \\
&= (A_d + B_d v_j + C_d v_j^2) - (a_s + b_s v_j + c_s v_j^2) / r' + (a_t + b_t v_j + c_t v_j^2) / r' \\
&= \{A_d + (a_t - a_s) / r'\} + \{B_d + (b_t + b_s) / r'\}\, v_j + \{C_d + (c_t - c_s) / r'\}\, v_j^2 \\
&\qquad \therefore A_d^* = A_d + (a_t - a_s) / r' \\
&\qquad \therefore B_d^* = B_d + (b_t - b_s) / r' \\
&\qquad \therefore C_d^* = C_d + (c_t - c_s) / r'
\end{aligned}
$$

where

F^*_{dj} is the new chassis dynamometer setting load, N;
f_{ej} is the adjustment road load, which is equal to $f_{sj} - f_{tj}$, N;
f_{sj} is the simulated road load at reference speed v_j, N;
f_{tj} is the target road load at reference speed v_j, N;
A_d^*, B_d^* and $C_d^*$are the new chassis dynamometer setting coefficients.
r' is the dynamic radius of the tyre on the chassis dynamometer, m, that is obtained by averaging the r'_j values calculated in Appendix 1, section 2.1.

ANNEX 5: TEST EQUIPMENT AND CALIBRATIONS

1.0 Test bench specifications and settings

1.1 Cooling fan specifications

1.1.1. 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 roller speed above roller speeds of 5 km/h. The deviation of the linear velocity of the air at the blower outlet shall remain within ± 5 km/h or ± 10 % of the corresponding roller speed, whichever is greater.

1.1.2. The above mentioned air velocity shall be determined as an averaged value of a number of measuring points which:

(a) for fans with rectangular outlets, are located at the centre of each rectangle dividing the whole of the fan outlet into 9 areas (dividing both horizontal and vertical sides of the fan outlet into 3 equal parts). The centre area shall not be measured (as shown in the diagram below).

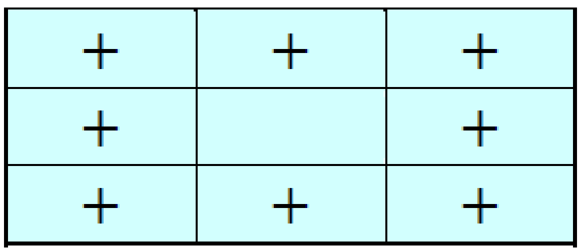


Figure 1: Fan with rectangular outlet

(b) for circular fan outlets, the outlet shall be divided into 8 equal sections by vertical, horizontal and 45° lines. The measurement points lie on the radial centre line of each arc (22.5°) at a radius of two thirds of the total (as shown in the diagram below).

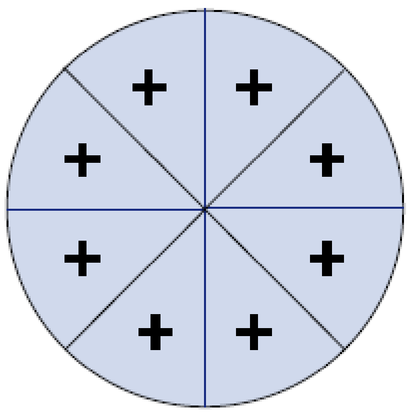


Figure 2: Fan with circular outlet

These measurements shall be made with no vehicle or other obstruction in front of the fan. The device used to measure the linear velocity of the air shall be located between 0 and 20 cm from the air outlet.

1.1.3. The final selection of the fan shall have the following characteristics:

(a) an area of at least 0.3 m^2, and,
(b) a width/diameter of at least 0.8 m

1.1.4. The position of the fan shall be as follows:

(a) height of the lower edge above ground: approximately 20 cm;
(b) distance from the front of the vehicle: approximately 30 cm.

1.1.5. The height and lateral position of the cooling fan may be modified at the request of the manufacturer and if considered appropriate by the responsible authority.

1.1.6. In the cases described above, the cooling fan position (height and distance) shall be recorded in the approval test report and shall be used for any subsequent testing.

2.0. Chassis dynamometer

2.1. General requirements

2.1.1. The dynamometer shall be capable of simulating road load with at least three road load parameters that can be adjusted to shape the load curve.

2.1.2. Dynamometers with electric inertia simulation shall be demonstrated to be equivalent to mechanical inertia systems.

2.1.3. The chassis dynamometer may have one or two rollers. In the case of twin-roll dynamometers, the rollers shall be permanently coupled or the front roller shall-drive, directly or indirectly, any inertial masses and the power absorption device.

2.2. Specific requirements
The following specific requirements relate to the dynamometer manufacturer's specifications.

2.2.1. The roll run-out shall be less than 0.25 mm at all measured locations.

2.2.2. The roller diameter shall be within ± 1.0 mm of the specified nominal value at all measurement locations.

2.2.3. The dynamometer shall have a time measurement system for use in determining acceleration rates and for measuring vehicle/dynamometer coastdown times. This time measurement system shall have an accuracy of at least ± 0.001 per cent.

2.2.4. The dynamometer shall have a speed measurement system with an accuracy of at least ± 0.080 km/h.

2.2.5. The dynamometer shall have a response time (90% response to a tractive effort step change) of less than 100 ms with instantaneous accelerations which are at least 3m/s^2.

2.2.6. The base inertia weight of the dynamometer shall be stated by the dynamometer vendor, and must be confirmed to within ± 0.5 per cent for each measured base inertia and ± 0.2

per cent relative to any mean value by dynamic derivation from trials at constant acceleration, deceleration and force.

2.2.7. Roller speed shall be recorded at a frequency of not less than 1 Hz.

2.3. Additional specific requirements for 4WD chassis dynamometers

2.3.1. The 4WD control system shall be designed such that the following requirements are met when tested with a vehicle driven over the WLTP driving cycle :

2.3.1.1. Road load simulation shall be applied such that operation in 4WD mode reproduces the same proportioning of forces as would be encountered when driving the vehicle on a smooth, dry, level road surface.

2.3.1.2. All roll speeds shall be synchronous to within ± 0.16 km/h. This may be assessed by applying a 1s moving average filter to roll speed data acquired at 20 Hz. This has to be checked for new dynamometer instalment and after major repair or maintenance

2.3.1.3. The difference in distance between front and rear rolls shall be less than 0.1 m in any 200 ms time period. If it can be demonstrated that this criteria is met, then the speed synchronicity requirement above is not required.

2.3.1.4. The difference in distance covered by the front and rear rolls shall be less than 0.2 per cent of the driven distance over the WLTC.

2.4. Chassis dynamometer calibration

2.4.1. Force measurement system.
The accuracy and linearity of the force transducer shall be at least ± 10 N for all measured increments. This shall be verified upon initial installation, after major maintenance and within 370 days before testing.

2.4.2. Parasitic loss calibration.
The dynamometer's parasitic losses shall be measured and updated if any measured value differs from the current loss curve by more than 2.5 N. This shall be verified upon initial installation, after major maintenance and within 35 days before testing.

2.4.3. The dynamometer performance shall be verified by performing an unloaded coastdown test upon initial installation, after major maintenance, and within 7 days before testing. The average coastdown force error shall be less than 10 N or 2 per cent (whatever is greater) at each measured point (10 km/h speed intervals) over the 20 – 130 km/h speed range.

3.0 Exhaust gas dilution system

3.1. System specification

3.1.1. Overview

3.1.1.1. A full-flow exhaust dilution system shall be used. This requires that the vehicle exhaust be continuously diluted with ambient air under controlled conditions using a constant volume sampler. A critical flow venturi (CFV) or multiple critical flow venturis arranged in parallel, a positive displacement pump (PDP), a subsonic venturi (SSV), or an ultrasonic flow meter (USM) may be used. The total volume of the mixture of exhaust and dilution air shall be measured and a continuously proportional sample of the volume shall be collected for analysis. The quantities of exhaust gas species are determined from the sample concentrations, corrected for the species content of the ambient air and the totalised flow over the test period.

3.1.1.2. The exhaust dilution system shall consist of a connecting tube, a mixing chamber and dilution tunnel, dilution air conditioning, a suction device and a flow measurement device. Sampling probes shall be fitted in the dilution tunnel as specified in paragraphs 4.1., 4.2. and 4.3.

3.1.1.3. The mixing chamber described in 3.1.1.2. shall be a vessel such as that illustrated in Figure 3 in which vehicle exhaust gases and the dilution air are combined so as to produce a homogeneous mixture at the at the sampling position.

3.2. General requirements

3.2.1. The vehicle exhaust gases shall be diluted with a sufficient amount of ambient air to prevent any water condensation in the sampling and measuring system at all conditions which may occur during a test.

3.2.2. The mixture of air and exhaust gases shall be homogeneous at the point where the sampling probes are located (§3.3.3. below). The sampling probes shall extract representative samples of the diluted exhaust gas.

3.2.3. The system shall enable the total volume of the diluted exhaust gases to be measured.

3.2.4. The sampling system shall be gas-tight. The design of the variable-dilution sampling system and the materials used in its construction shall be such that they do not affect the species concentration in the diluted exhaust gases. Should any component in the system (heat exchanger, cyclone separator, suction device, etc.) change the concentration of any of the exhaust gas species in the diluted exhaust gases and the fault cannot be corrected, sampling for that species shall be carried out upstream from that component.

3.2.5. All parts of the dilution system in contact with raw and diluted exhaust gas shall be designed to minimise deposition or alteration of the particulates or particles. All parts shall be made of electrically conductive materials that do not react with exhaust gas components, and shall be electrically grounded to prevent electrostatic effects.

3.2.6. If the vehicle being tested is equipped with an exhaust pipe comprising several branches, the connecting tubes shall be connected as near as possible to the vehicle without adversely affecting its operation.

3.3. Specific requirements

3.3.1. Connection to vehicle exhaust

3.3.1.1. The start of the connecting tube should be specified as the exit of the tailpipe. The end of the connecting tube should be specified as the sample point, or first point of dilution. For multiple tailpipe configurations where all the tailpipes are combined, the start of the connecting tube may be taken at the last joint of where all the tailpipes are combined.

3.3.1.2. The connecting tube between the vehicle and dilution system shall be designed so as to minimize heat loss.

3.3.1.3. The connecting tube between the sample point and the dilution system shall satisfy the following requirements:

(a) shall be less than 3.6 m long, or less than 6.1 m long if heat-insulated. Its internal diameter may not exceed 105 mm; the insulating materials shall have a thickness of at least 25mm and thermal conductivity not exceeding 0.1 $W/m^{-1}K^{-1}$ at 400°C. Optionally, the tube may be heated to a temperature above the dew point. This may be assumed to be achieved if the tube is heated to 70°C;

(b) shall not cause the static pressure at the exhaust outlets on the vehicle being tested to differ by more than ±0.75 kPa at 50 km/h, or more than ±1.25 kPa or the whole duration of the test from the static pressures recorded when nothing is connected to the vehicle exhaust outlets. The pressure shall be measured in the exhaust outlet or in an extension having the same diameter, as near as possible to the end of the pipe. Sampling systems capable of maintaining the static pressure to within ±0.25 kPa may be used if a written request from a manufacturer to the responsible authority substantiates the need for the closer tolerance;

(c) no component of the connecting tube shall be of a material which might affect the gaseous or solid composition of the exhaust gas. To avoid generation of any particles from elastomer connectors, elastomers employed shall be as thermally stable as possible and shall not be used to bridge the connection between the vehicle exhaust and the connecting tube.

3.3.2. Dilution air conditioning

3.3.2.1. The dilution air used for the primary dilution of the exhaust in the CVS tunnel shall be passed through a medium capable of reducing particles in the most penetrating particle size of the filter material by ≥ 99.95 [> 99.97] per cent, or through a filter of at least class H13 of EN 1822:2009. This represents the specification of High Efficiency Particulate Air (HEPA) filters. The dilution air may optionally be charcoal scrubbed before being passed to the HEPA filter. It is recommended that an additional coarse particle filter be situated before the HEPA filter and after the charcoal scrubber, if used.

3.3.2.2. At the vehicle manufacturer's request, the dilution air may be sampled according to good engineering practice to determine the tunnel contribution to background particulate mass levels, which can then be subtracted from the values measured in the diluted exhaust. See 1.2.1.4. in Annex 6 “Test Procedures”.

3.3.3. Dilution tunnel

3.3.3.1. Provision shall be made for the vehicle exhaust gases and the dilution air to be mixed. A mixing orifice may be used.

3.3.3.2. The homogeneity of the mixture in any cross-section at the location of the sampling probe shall not vary by more than ± 2 per cent from the average of the values obtained for at least five points located at equal intervals on the diameter of the gas stream.

3.3.3.4. For particulate and particle emissions sampling, a dilution tunnel shall be used which:

(a) consists of a straight tube of electrically-conductive material, which shall be earthed;

(b) shall cause turbulent flow (Reynolds number ≥ 4000) and be of sufficient length to cause complete mixing of the exhaust and dilution air;

(c) shall be at least 200 mm in diameter;

(d) may be insulated.

3.3.4. Suction device

3.3.4.1. This device may have a range of fixed speeds to ensure sufficient flow to prevent any water condensation. This result is obtained if the flow is either:
(a) twice as high as the maximum flow of exhaust gas produced by accelerations of the driving cycle; or
(b) sufficient to ensure that the CO_2 concentration in the dilute exhaust sample bag is less than 3 per cent by volume for petrol and diesel, less than 2.2 per cent by volume for LPG and less than 1.5 per cent by volume for NG/biomethane.

3.3.4.2. Compliance with the above requirements may not be necessary if the CVS system is designed to inhibit condensation by such techniques, or combination of techniques, as:
(a) reducing water content in the dilution air (dilution air dehumidification)
(b) heating of the CVS dilution air and of all components up to the diluted exhaust flow measurement device, and optionally, the bag sampling system including the sample bags and also the system for the measurement of the bag concentrations.
In such cases, the selection of the CVS flow rate for the test shall be justified by showing that condensation of water cannot occur at any point within the CVS, bag sampling or analytical system.

3.3.5. Volume measurement in the primary dilution system

3.3.5.1. The method of measuring total dilute exhaust volume incorporated in the constant volume sampler shall be such that measurement is accurate to ± 2 per cent under all operating conditions. If the device cannot compensate for variations in the temperature of the mixture of exhaust gases and dilution air at the measuring point, a heat exchanger shall be used to maintain the temperature to within ± 6 K of the specified operating temperature for a PDP-CVS, ± 11 K for a CFV CVS, ± 6 K for a USM CVS, and ± 11 K for an SSV CVS.

3.3.5.2. If necessary, some form of protection for the volume measuring device may be used e.g. a cyclone separator, bulk stream filter, etc.

3.3.5.3. A temperature sensor shall be installed immediately before the volume measuring device. This temperature sensor shall have an accuracy and a precision of ±1 K and a response time of 0.1 s at 62 per cent of a given temperature variation (value measured in silicone oil).

3.3.5.4. Measurement of the pressure difference from atmospheric pressure shall be taken upstream from and, if necessary, downstream from the volume measuring device.

3.3.5.5. The pressure measurements shall have a precision and an accuracy of ±0.4 kPa during the test.

3.3.6. Recommended system description

Figures 3 is a schematic drawing of exhaust dilution systems which meet the requirements of this Annex.

The following components are recommended:

(a) a dilution air filter, which can be preheated if necessary. This filter shall consist of the following filters in sequence: an optional activated charcoal filter (inlet side), and a HEPA filter (outlet side). It is recommended that an additional coarse particle filter is situated before the HEPA filter and after the charcoal filter, if used. The purpose of the charcoal filter is to reduce and stabilize the hydrocarbon concentrations of ambient emissions in the dilution air;

(b) a connecting tube by which vehicle exhaust is admitted into a dilution tunnel;

(c) an optional heat exchanger as described in §3.3.5.1;

(d) a mixing chamber in which exhaust gas and air are mixed homogeneously, and which may be located close to the vehicle so that the length of the connecting tube is minimized;

(e) a dilution tunnel from which particulates and particles are sampled;

(f) some form of protection for the measurement system may be used e.g. a cyclone separator, bulk stream filter, etc.;

(g) a suction device of sufficient capacity to handle the total volume of diluted exhaust gas.

Since various configurations can produce accurate results, exact conformity with these figures is not essential. Additional components such as instruments, valves, solenoids and switches may be used to provide additional information and co-ordinate the functions of the component system.

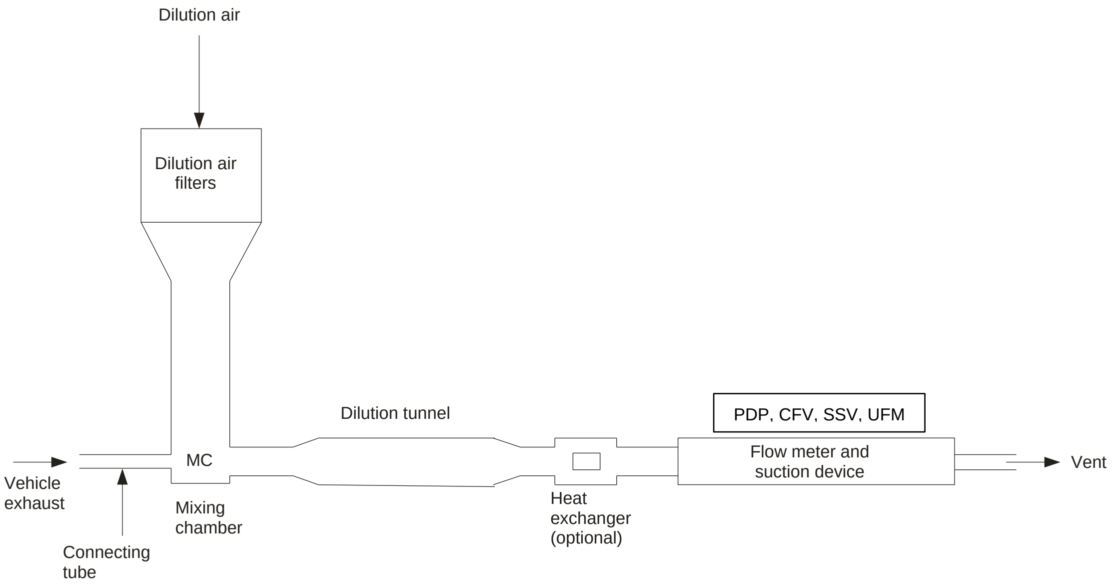


Figure 3: Exhaust Dilution System

3.3.6.1. Positive displacement pump (PDP)

3.3.6.1.1. A positive displacement pump (PDP) full flow dilution system satisfies the requirements of this Annex by metering the flow of gas through the pump at constant temperature and pressure. The total volume is measured by counting the revolutions made by the calibrated positive displacement pump. The proportional sample is achieved by sampling with pump, flow-meter and flow control valve at a constant flow rate.

3.3.6.1.2. A positive displacement pump (PDP) produces a constant-volume flow of the air/exhaust gas mixture. The PDP revolutions, together with associated temperature and pressure measurement are used to determine the flow rate.

3.3.6.2. Critical flow venturi (CFV)

3.3.6.2.1. The use of a critical flow venturi (CFV) for the full-flow dilution system is based on the principles of flow mechanics for critical flow. The variable mixture flow rate of dilution and exhaust gas is maintained at sonic velocity which is directly proportional to the square root of the gas temperature. Flow is continually monitored, computed and integrated throughout the test.

3.3.6.2.2. The use of an additional critical flow sampling venturi ensures the proportionality of the gas samples taken from the dilution tunnel. As both pressure and temperature are equal at the two venturi inlets, the volume of the gas flow diverted for sampling is proportional to the total volume of diluted exhaust-gas mixture produced, and thus the requirements of this Annex are met.

3.3.6.2.3. A measuring critical flow venturi tube (CFV) shall measure the flow volume of the diluted exhaust gas.

3.3.6.3. Subsonic flow venturi (SSV)

3.3.6.3.1. The use of a subsonic venturi (SSV) for a full-flow dilution system is based on the principles of flow mechanics. The variable mixture flow rate of dilution and exhaust gas is maintained at a subsonic velocity which is calculated from the physical dimensions of the subsonic venturi and measurement of the absolute temperature and pressure at the venturi inlet and the pressure in the throat of the venturi. Flow is continually monitored, computed and integrated throughout the test.

3.3.6.3.2. A measuring SSV shall measure the flow volume of the diluted exhaust gas.

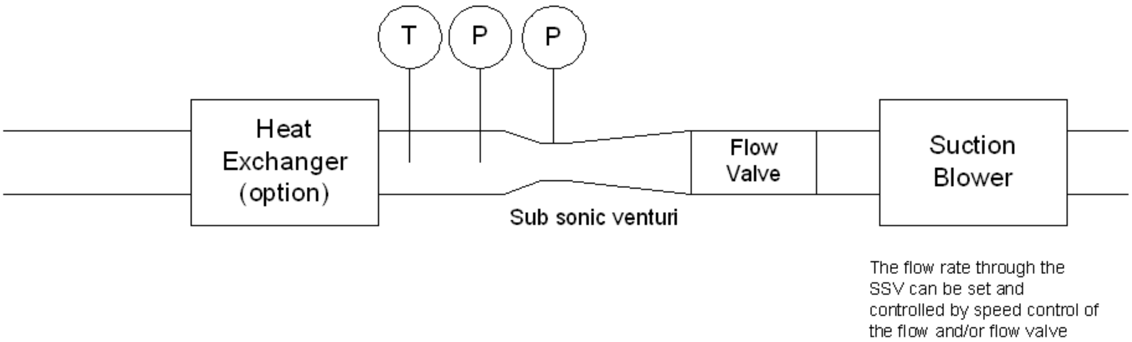


Figure 4: Schematic of a supersonic venture tube (SSV)

3.3.6.4. Ultrasonic flow meter (USM)

3.3.6.4.1. A USM measures the velocity of the diluted exhaust gas using ultra-sonic transmitters/detectors as in Figure 5. The gas velocity is converted to standard volumetric flow using a calibration factor for the tube diameter with real time corrections for the diluted exhaust temperature and absolute pressure.

3.3.6.4.2. Components of the system include:

(a) a suction device fitted with speed control, flow valve or other method for setting the CVS flow rate and also for maintaining constant volumetric flow at standard conditions;

(b) a USM;

(c) temperature (T) and pressure (P) measurement devices required for flow correction;

(d) an optional heat exchanger for controlling the temperature of the diluted exhaust to the USM. If installed, the heat exchanger should be capable of controlling the temperature of the diluted exhaust to that specified in 3.3.5.1. Throughout the test, the temperature of the air/exhaust gas mixture measured at a point immediately upstream of the suction device shall be within ± 6 K of the average operating temperature during the test.

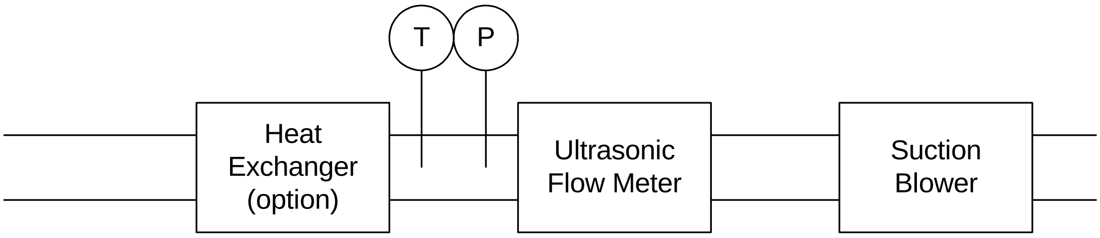


Figure 5: Schematic of an ultrasonic flow meter (USM)

3.3.6.4.3. The following conditions shall apply to the design and use of the USM type CVS:

(a) the velocity of the diluted exhaust gas shall provide a Reynolds number higher than 4000 in order to maintain a consistent turbulent flow before the ultrasonic flow meter;

(b) an ultrasonic flow meter shall be installed in a pipe of constant diameter with a length of 10 times the internal diameter upstream and 5 times the diameter downstream;

(c) a temperature sensor for the diluted exhaust shall be installed immediately before the ultrasonic flow meter. This sensor shall have an accuracy and a precision of ±1 K and a response time of 0.1 s at 62 per cent of a given temperature variation (value measured in silicone oil);

(d) the absolute pressure of the diluted exhaust shall be measured immediately before the ultrasonic flow meter to an accuracy of less than ± 0.3 kPa;

(e) if a heat exchanger is not installed upstream of the ultrasonic flow meter, the flow rate of the diluted exhaust, corrected to standard conditions shall be maintained at a constant level during the test. This may be achieved by control of the suction device, flow valve or other method.

3.4. CVS calibration procedure

3.4.1. General requirements

3.4.1.1. The CVS system shall be calibrated by using an accurate flow meter and a restricting device. The flow through the system shall be measured at various pressure readings and the control parameters of the system measured and related to the flows. The flow metering device shall be dynamic and suitable for the high flow rate encountered in constant volume sampler testing. The device shall be of certified accuracy traceable to an approved national or international standard.

3.4.1.1.1. Various types of flow meters may be used, e.g. calibrated venturi, laminar flowmeter, calibrated turbine-meter, provided that they are dynamic measurement systems and can meet the requirements of paragraph 3.3.5. of this Annex.

3.4.1.1.2. The following paragraphs give details of methods of calibrating PDP and CFV units, using a laminar flow meter, which gives the required accuracy, together with a statistical check on the calibration validity.

3.4.2. Calibration of a positive displacement pump (PDP)

3.4.2.1. The following calibration procedure outlines the equipment, the test configuration and the various parameters that are measured to establish the flow-rate of the CVS pump. All the parameters related to the pump are simultaneously measured with the parameters related to the flow-meter which is connected in series with the pump. The calculated flow rate (given in m^3/min at pump inlet, absolute pressure and temperature) can then be plotted versus a correlation function that is the value of a specific combination of pump parameters. The linear equation that relates the pump flow and the correlation function is then determined. In the event that a CVS has a multiple speed drive, a calibration for each range used shall be performed.

3.4.2.2. This calibration procedure is based on the measurement of the absolute values of the pump and flow-meter parameters that relate the flow rate at each point. Three conditions shall be maintained to ensure the accuracy and integrity of the calibration curve:

3.4.2.2.1. The pump pressures shall be measured at tappings on the pump rather than at the external piping on the pump inlet and outlet. Pressure taps that are mounted at the top centre and bottom centre of the pump drive headplate are exposed to the actual pump cavity pressures, and therefore reflect the absolute pressure differentials;

3.4.2.2.2. Temperature stability shall be maintained during the calibration. The laminar flow-meter is sensitive to inlet temperature oscillations which cause the data points to be scattered. Gradual changes of ±1 K in temperature are acceptable as long as they occur over a period of several minutes;

3.4.2.2.3. All connections between the flow-meter and the CVS pump shall be free of any leakage.

3.4.2.3. During an exhaust emission test, the measurement of these same pump parameters enables the user to calculate the flow rate from the calibration equation.

3.4.2.4. Figure 6 of this Annex shows one possible test set-up. Variations are permissible, provided that the responsibleauthority approves them as being of comparable accuracy. If the set-up shown in Figure 6 is used, the following data shall be found within the limits of accuracy given:

Barometric pressure (corrected) (P_b)	± 0.03 kPa
Ambient temperature (T)	± 0.2 K
Air temperature at LFE (ETI)	± 0.15 K
Pressure depression upstream of LFE (EPI)	± 0.01 kPa
Pressure drop across the LFE matrix (EDP)	± 0.0015 kPa
Air temperature at CVS pump inlet (PTI)	± 0.2 K
Air temperature at CVS pump outlet (PTO)	± 0.2 K
Pressure depression at CVS pump inlet (PPI)	± 0.22 kPa
Pressure head at CVS pump outlet (PPO)	± 0.22 kPa
Pump revolutions during test period (n)	± 1 min^{-1}
Elapsed time for period (minimum 250 s) (t)	± 0.1 s

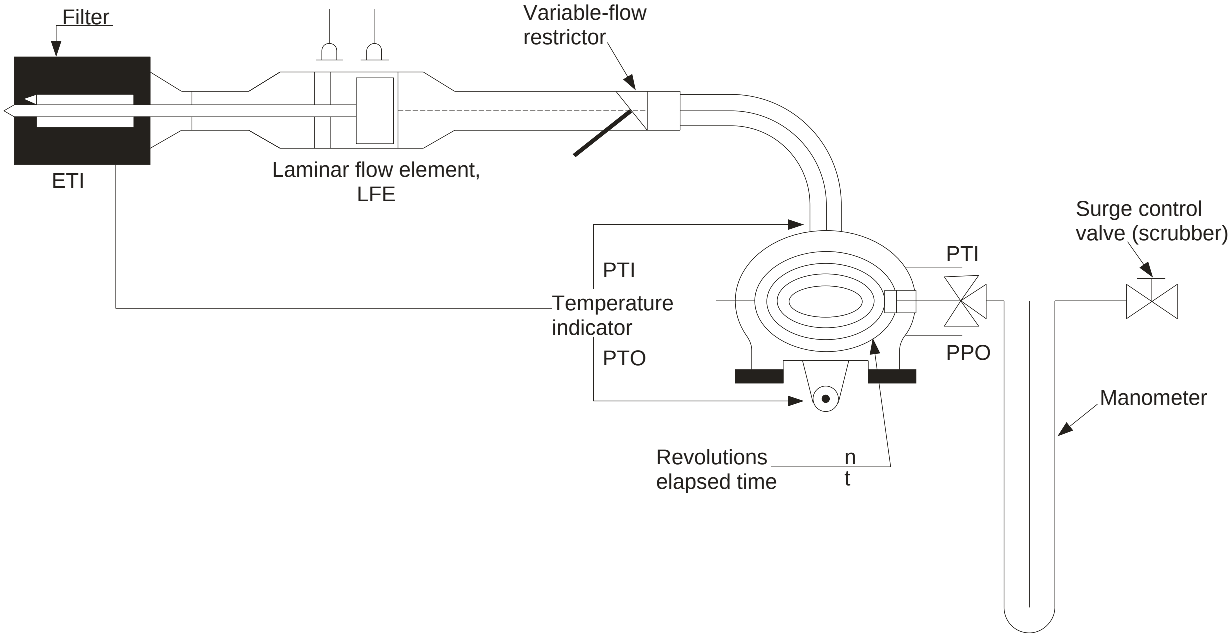


Figure 6: PDP Calibration Configuration

3.4.2.5. After the system has been connected as shown in Figure 6 of this Annex, the variable restrictor shall be set in the wide-open position and the CVS pump shall run for 20 minutes before starting the calibration.

3.4.2.5.1. The restrictor valve shall be reset to a more restricted condition in an increment of pump inlet depression (about 1 kPa) that will yield a minimum of six data points for the total calibration. The system shall be allowed to stabilize for three minutes and repeat the data acquisition.

3.4.2.5.2 The air flow rate (Q_s) at each test point shall be calculated in standard m^3/min from the flow-meter data using the manufacturer's prescribed method.

3.4.2.5.3. The air flow-rate shall then be converted to pump flow (V_0) in m^3/rev at absolute pump inlet temperature and pressure.

$$V_0 = \frac{Q_s}{n} \cdot \frac{T_p}{273.2} \cdot \frac{101.33}{P_p}$$

where:

V_0	is pump flow rate at T_p and P_p, m^3/rev;
Q_s	is air flow at 101.325 kPa and 273.15 K, m^3/min;
T_p	is pump inlet temperature, K;
P_p	is absolute pump inlet pressure, kPa;
N	is pump speed, min^{-1}.

3.4.2.5.4. To compensate for the interaction of pump speed pressure variations at the pump and the pump slip rate, the correlation function (x_0) between the pump speed (n), the pressure differential from pump inlet to pump outlet and the absolute pump outlet pressure shall be calculated as follows:

$$x_0 = \frac{1}{n}\sqrt{\frac{\Delta P_p}{P_e}}$$

where:

x_0 is the correlation function,

ΔP_p is the pressure differential from pump inlet to pump outlet, kPa;

$P_e =$ absolute outlet pressure (PPO + P_b), kPa.

A linear least-square fit is performed to generate the calibration equations which have the equation:

$$V_0 = D_0 - M\,(x_0)$$

$$n = A - B\,(\Delta P_p)$$

D_0, M, A and B are the slope-intercept constants describing the lines.

3.4.2.6. A CVS system having multiple speeds shall be calibrated at each speed used. The calibration curves generated for the ranges shall be approximately parallel and the intercept values (D_0) shall increase as the pump flow range decreases.

3.4.2.7. The calculated values from the equation shall be within 0.5 per cent of the measured value of V_0. Values of M will vary from one pump to another. A calibration shall be performed at pump start-up and after major maintenance.

3.4.3. Calibration of a critical flow venturi (CFV)

3.4.3.1. Calibration of the CFV is based upon the flow equation for a critical venturi:

$$Q_s = \frac{K_v P}{\sqrt{T}}$$

where:

Q_s is the flow, m^3/min;

K_v is the calibration coefficient;

P is the absolute pressure,kPa;

T is the absolute temperature, K.

Gas flow is a function of inlet pressure and temperature.

The calibration procedure described below establishes the value of the calibration coefficient at measured values of pressure, temperature and air flow.

3.4.3.2. The manufacturer's recommended procedure shall be followed for calibrating electronic portions of the CFV.

3.4.3.3. Measurements for flow calibration of the critical flow venturi are required and the following data shall be found within the limits of precision given:

Barometric pressure (corrected) (P_b)	± 0.03 kPa,
LFE air temperature, flow-meter (ETI)	± 0.15 K,
Pressure depression upstream of LFE (EPI)	± 0.01 kPa,
Pressure drop across (EDP) LFE matrix	± 0.0015 kPa,

Air flow (Q_s)	± 0.5 per cent,
CFV inlet depression (PPI)	± 0.02 kPa,
Temperature at venturi inlet (T_v)	± 0.2 K.

3.4.3.4. The equipment shall be set up as shown in Figure 7 and checked for leaks. Any leaks between the flow-measuring device and the critical flow venturi will seriously affect the accuracy of the calibration.

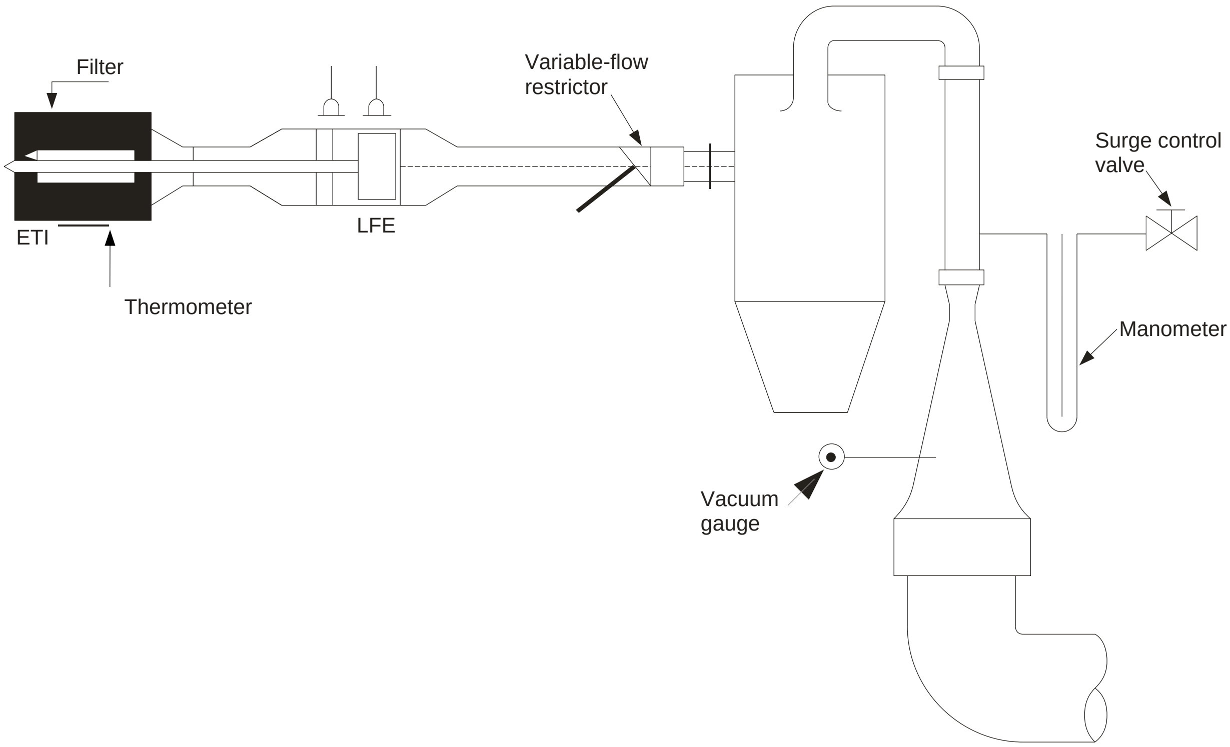


Figure 7: CFV Calibration Configuration

3.4.3.4.1. The variable-flow restrictor shall be set to the open position, the suction device shall be started and the system stabilized. Data from all instruments shall be recorded.

3.4.3.4.2. The flow restrictor shall be varied and at least eight readings across the critical flow range of the venturi shall be made.

3.4.3.4.3. The data recorded during the calibration shall be used in the following calculation:

3.4.3.4.3.1. The air flow-rate (Q_s) at each test point shall be calculated from the flow-meter data using the manufacturer's prescribed method.

Calculate values of the calibration coefficient for each test point:

$$K_v = \frac{Q_s\sqrt{T_v}}{P_v}$$

where:

Q_s is the flow rate, m^3/min at 273.15 K and 101.325, kPa;
T_v is the temperature at the venturi inlet, K;
P_v is the absolute pressure at the venturi inlet, kPa.

3.4.3.4.3.2. K_v shall be plotted as a function of venturi inlet pressure. For sonic flow, K_v will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and K_v decreases. The resultant K_v changes are not permissible.

3.4.3.4.3.3. For a minimum of eight points in the critical region, an average K_v and the standard deviation shall be calculated.

3.4.3.4.3.4. If the standard deviation exceeds 0.3 per cent of the average K_v, corrective action must be taken.

3.4.4. Calibration of a subsonic venturi (SSV)

3.4.4.1. Calibration of the SSV is based upon the flow equation for a subsonic venturi. Gas flow is a function of inlet pressure and temperature, pressure drop between the SSV inlet and throat.

3.4.4.2. Data analysis

3.4.4.2.1. The airflow rate (Q_{SSV}) at each restriction setting (minimum 16 settings) shall be calculated in standard m^3/s from the flow meter data using the manufacturer's prescribed method. The discharge coefficient shall be calculated from the calibration data for each setting as follows:

$$C_d = \frac{Q_{SSV}}{d_V^2 \times p_p \times \sqrt{\left\{\frac{1}{T} \times \left(r_p^{1.426} - r_p^{1.713}\right) \times \left(\frac{1}{1 - r_D^4 \times r_p^{1.426}}\right)\right\}}}$$

where:

Q_{SSV} is the airflow rate at standard conditions (101.325 kPa, 273.15 K), m^3/s;
T is the temperature at the venturi inlet, K;
d_V is the diameter of the SSV throat, m;
r_p is the ratio of the SSV throat to inlet absolute static pressure, $1 - \frac{\Delta p}{p_p}$
r_D is the ratio of the SSV throat diameter, d_V, to the inlet pipe inner diameter D

To determine the range of subsonic flow, C_d shall be plotted as a function of Reynolds number Re, at the SSV throat. The Re at the SSV throat shall be calculated with the following equation:

$$Re = A_1 \times \frac{Q_{SSV}}{d_V \times \mu}$$

where:

$$\mu = \frac{b \times T^{1.5}}{S + T}$$

A_1	is 25.55152 in SI, $\left(\frac{1}{m^3}\right)\left(\frac{min}{s}\right)\left(\frac{mm}{m}\right)$;
Q_{SSV}	is the airflow rate at standard conditions (101.325 kPa, 273.15 K), m^3/s;
d_V	is the diameter of the SSV throat, m;
μ	is the absolute or dynamic viscosity of the gas, kg/ms;
b	is 1.458 x 10^6 (empirical constant), kg/ms $K^{0.5}$;
S	is 110.4 (empirical constant), K.

3.4.4.2.2. Because Q_{SSV} is an input to the Re equation, the calculations must be started with an initial guess for Q_{SSV} or C_d of the calibration venturi, and repeated until Q_{SSV} converges. The convergence method shall be accurate to 0.1 per cent of point or better.

3.4.4.2.3 For a minimum of sixteen points in the region of subsonic flow, the calculated values of C_d from the resulting calibration curve fit equation must be within ± 0.5 per cent of the measured C_d for each calibration point.

3.4.5. Calibration of an ultrasonic flow meter (UFM)

3.4.5.1. The UFM must be calibrated against a suitable reference flow meter.

3.4.5.2. The UFM must be calibrated in the CVS configuration as it will be used in the test cell (diluted exhaust piping, suction device) and checked for leaks. Refer to Figure 8.

3.4.5.3. A heater shall be installed to condition the calibration flow in the event that the UFM system does not include a heat exchanger.

3.4.5.4. For each CVS flow setting that will be used, the calibration shall be performed at temperatures from room temperature to the maximum that will be experienced during vehicle testing.

3.4.5.5. The manufacturer's recommended procedure shall be followed for calibrating the electronic portions of the UFM.

3.4.5.6. Measurements for flow calibration of the ultrasonic flow meter are required and the following data (in the case of the use of a laminar flow element) shall be found within the limits of precision given:

(a) barometric pressure (corrected) (P_b)	± 0.03 kPa,
(b) LFE air temperature, flow-meter (ETI)	± 0.15 K,
(c) pressure depression upstream of LFE (EPI)	± 0.01 kPa,
(d) pressure drop across (EDP) LFE matrix	± 0.0015 kPa,
(e) air flow (Q_s)	± 0.5 per cent,

(f) UFM inlet depression (P_{act}) ± 0.02 kPa,
(g) temperature at UFM inlet (T_{act}) ± 0.2 K.

3.4.5.7. Procedure

3.4.5.7.1. The equipment shall be set up as shown in Figure 8 and checked for leaks. Any leaks between the flow-measuring device and the UFM will seriously affect the accuracy of the calibration.

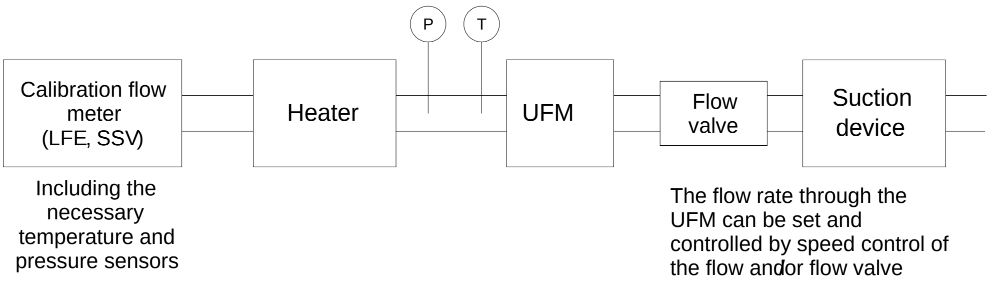


Figure 8: USM Calibration Configuration

3.4.5.7.2. The suction device shall be started. The suction device speed and/or the flow valve should be adjusted to provide the set flow for the validation and the system stabilised. Data from all instruments shall be recorded.

3.4.5.7.3. For UFM systems without heat exchanger, the heater shall be operated to increase the temperature of the calibration air, allowed to stabilise and data from all the instruments recorded. The temperature shall be increased in reasonable steps until the maximum expected diluted exhaust temperature expected during the emissions test is reached.

3.4.5.7.4. The heater shall then be turned off and the suction device speed and/or flow valve then be adjusted to the next flow setting that might be used for vehicle emissions testing and the calibration sequence repeated.

3.4.5.8. The data recorded during the calibration shall be used in the following calculations. The air flow-rate (Q_s) at each test point is calculated from the flow-meter data using the manufacturer's prescribed method.

$$K_v = Q_{reference} / Q_s$$

where:

Q_s is the air flow rate at standard conditions (101.325 kPa, 273.15 K), m^3/s;

$Q_{reference}$ is the air flow rate of the calibration flow meter at standard conditions (101.325 kPa, 273.15 K), m^3/s;

K_v is the calibration coefficient.

For UFM systems without a heat exchanger, K_v shall be plotted as a function of T_{act}.

The maximum variation in K_v shall not exceed 0.3 per cent of the mean K_v value of all the measurements taken at the different temperatures.

3.5. System Verification Procedure

3.5.1. General Requirements

3.5.1.1. The total accuracy of the CVS sampling system and analytical system shall be determined by introducing a known mass of an emissions gas species into the system whilst it is being operated as if during a normal test and then analysing and calculating the emission gas species according to the equations in Annex 7 except that the density of propane shall be taken as 1.967 grams per litre at standard conditions. The CFO (3.5.1.1.1.) and gravimetric methods (3.5.1.1.2.) are known to give sufficient accuracy.

The maximum permissible deviation between the quantity of gas introduced and the quantity of gas measured is 2 per cent.

3.5.1.1.1. CFO Method
The CFO method meters a constant flow of pure gas (CO, CO_2, or C_3H_8) using a critical flow orifice device.

3.5.1.1.1.1 A known quantity of pure gas (CO, CO_2 or C_3H_8) shall be fed into the CVS system through the calibrated critical orifice. If the inlet pressure is high enough, the flow-rate (q), which is adjusted by means of the critical flow orifice, is independent of orifice outlet pressure (critical flow). If deviations exceed 2 per cent, the cause of the malfunction shall be determined and corrected. The CVS system shall be operated as in a normal exhaust emission test for 5 to 10 minutes. The gas collected in the sampling bag is analysed by the usual equipment and the results compared to the concentration of the gas samples which was known beforehand.

3.5.1.1.2. Gravimetric Method
The gravimetric method weighs a limited quantity of pure gas (CO, CO_2, or C_3H_8).

3.5.1.1.2.1. The weight of a small cylinder filled with either carbon monoxide or propane shall determined with a precision of ± 0.01 g. For 5 to 10 minutes, the CVS system operates as in a normal exhaust emission test while CO or propane is injected into the system. The quantity of pure gas involved shall be determined by means of differential weighing. The gas accumulated in the bag shall be analysed by means of the equipment normally used for exhaust gas analysis. The results shall then compared to the concentration figures computed previously.

4.0 Emissions measurement equipment

4.1. Gaseous emissions measurement equipment

4.1.1. System overview

4.1.1.1. A continuously proportional sample of the diluted exhaust gases and the dilution air shall be collected for analysis.

4.1.1.2. Mass gaseous emissions shall be determined from the proportional sample concentrations and the total volume measured during the test. The sample concentrations shall be corrected to take account of the species content of the ambient air.

4.1.2. Sampling system requirements

4.1.2.1. The sample of dilute exhaust gases shall be taken upstream from the suction device.
4.1.2.1.1. With the exception of §4.1.3.1. (hydrocarbon sampling system), §4.2. (particulate mass emissions measurement equipment) and §4.3. (particulate number emissions measurement equipment), the dilute exhaust gas sample may be taken downstream of the conditioning devices (if any).

4.1.2.2. The sampling rate shall not fall below 5 litres per minute and shall not exceed 0.2 per cent of the flow rate of the dilute exhaust gases. An equivalent limit shall apply to constant-mass sampling systems.

4.1.2.3. A sample of the dilution air shall be taken near the ambient air inlet (after the filter if one is fitted).

4.1.2.4. The dilution air sample shall not be contaminated by exhaust gases from the mixing area.

4.1.2.5. The sampling rate for the dilution air shall be comparable to that used for the dilute exhaust gases.

4.1.2.6. The materials used for the sampling operations shall be such as not to change the concentration of the emissions species.

4.1.2.7. Filters may be used in order to extract the solid particles from the sample.

4.1.2.8. Any valve used to direct the exhaust gases shall be of a quick-adjustment, quick-acting type.

4.1.2.9. Quick-fastening, gas-tight connections may be used between three-way valves and the sampling bags, the connections sealing themselves automatically on the bag side. Other systems may be used for conveying the samples to the analyser (three-way stop valves, for example).

4.1.2.10. Sample storage

4.1.2.10.1. The gas samples shall be collected in sampling bags of sufficient capacity not to impede the sample flow.
4.1.2.10.2. The bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples by more than ±2 per cent after 20 minutes (e.g.: laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).

4.1.3. Sampling systems

4.1.3.1. Hydrocarbon sampling system (HFID)

4.1.3.1.1. The hydrocarbon sampling system shall consist of a heated sampling probe, line, filter and pump. The sample shall be taken upstream of the heat exchanger (if fitted). The sampling probe shall be installed at the same distance from the exhaust gas inlet as the particulate sampling probe, in such a way that neither interferes with samples taken by the other. It shall have a minimum internal diameter of 4 mm.

4.1.3.1.2. All heated parts shall be maintained at a temperature of 463 K (190 °C) ± 10 K by the heating system.

4.1.3.1.3. The average concentration of the measured hydrocarbons shall be determined by integration.

4.1.3.1.4. The heated sampling line shall be fitted with a heated filter (F_H) 99 per cent efficient with particles ≥ 0.3 μm to extract any solid particles from the continuous flow of gas required for analysis.

4.1.3.1.5. The sampling system response time (from the probe to the analyser inlet) shall be no more than four seconds.

4.1.3.1.6. The HFID shall be used with a constant mass flow (heat exchanger) system to ensure a representative sample, unless compensation for varying CFV or CFO flow is made.

4.1.3.2. NO or NO_2 sampling system (if applicable)

4.1.3.2.1. A continuous sample flow of diluted exhaust gas shall be supplied to the analyser.

4.1.3.2.2. The average concentration of the NO or NO_2 shall be determined by integration.

4.1.3.2.3. The continuous NO or NO_2 measurement shall be used with a constant flow (heat exchanger) system to ensure a representative sample, unless compensation for varying CFV or CFO flow is made.

4.1.4. Analysers

4.1.4.1. General requirements for gas analysis

4.1.4.1.1. The analysers shall have a measuring range compatible with the accuracy required to measure the concentrations of the exhaust gas sample species.

4.1.4.1.2. If not defined otherwise, measurement errors shall not exceed ±2 per cent (intrinsic error of analyser) disregarding the reference value for the calibration gases.

4.1.4.1.3. The ambient air sample shall be measured on the same analyser with an identical range.

4.1.4.1.4. No gas drying device shall be used before the analysers unless shown to have no effect on the species content of the gas stream.

4.1.4.2. Carbon monoxide (CO) and carbon dioxide (CO_2) analysis

4.1.4.2.1. Analysers shall be of the non-dispersive infrared (NDIR) absorption type.

4.1.4.3. Hydrocarbons (HC) analysis for all fuels other than diesel fuel

4.1.4.3.1. The analyser shall be of the flame ionisation (FID) type calibrated with propane gas expressed equivalent to carbon atoms (C_1).

4.1.4.4. Hydrocarbons (HC) analysis for diesel fuel and optionally for other fuels

4.1.4.4.1. The analyser shall be of the heated flame ionisation type with detector, valves, pipework, etc., heated to 463 K (190 °C) ±10 K. It shall be calibrated with propane gas expressed equivalent to carbon atoms (C_1).

4.1.4.5. Methane (CH_4) analysis

4.1.4.5.1. The analyser shall be either a gas chromatograph combined with a flame ionisation detector (FID), or a flame ionisation detector (FID) with a non-methane cutter type, calibrated with methane gas expressed equivalent to carbon atoms (C_1).

4.1.4.6. Nitrogen oxide (NO_x) analysis

4.1.4.6.1. The analyser shall be either a chemiluminescent (CLA) or a non-dispersive ultraviolet resonance absorption (NDUV).

4.1.4.7. Nitrogen oxide (NO) analysis (where applicable)

4.1.4.7.1. The analyser shall be a chemiluminescent (CLA) or an ultra-violet resonance absorption (NDUV).

4.1.4.8. Nitrogen oxide (NO_2) analysis (where applicable)

4.1.4.8.1. §4.1.4.8.1. An ultra-violet resonance absorption (NDUV) or QCL-IR analyser may be used to measure NO_2 concentrations of diluted exhaust.

4.1.4.9. Nitrous oxide (N_2O) analysis with GC ECD (where applicable)

4.1.4.9.1. A gas chromatograph with an electron-capture detector (GC–ECD) may be used to measure N_2O concentrations of diluted exhaust by batch sampling from exhaust and ambient bags. Refer to §7.2. in this Annex.

4.1.4.10. Nitrous oxide (N_2O) analysis with IR-absorption spectrometry (where applicable)
The analyser shall be a laser infrared spectrometer defined as modulated high resolution narrow band infrared analyser. An NDIR or FTIR may also be used but water, CO and CO_2 interference must be taken into consideration.

4.1.4.10.1. If the analyser shows interference to compounds present in the sample, this interference can be corrected. Analysers must have combined interference that is within 0.0 ± 0.1 ppm.

4.1.5. Recommended system descriptions

4.1.5.1. Figure 9 is a schematic drawing of the gaseous emissions sampling system.

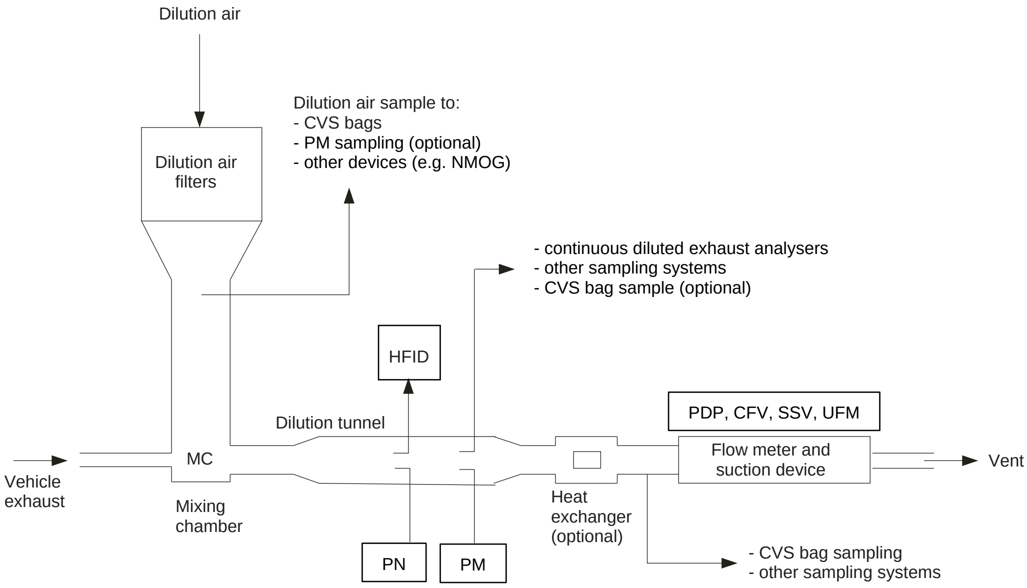


Figure 9: Gaseous Emissions Sampling System

4.1.5.2. The system components are as follows:

4.1.5.2.1. Two sampling probes for continuous sampling of the dilution air and of the diluted exhaust-gas/air mixture;

4.1.5.2.2. A filter to extract solid particles from the flows of gas collected for analysis;

4.1.5.2.3. Pumps to collect a constant flow of the dilution air as well as of the diluted exhaust-gas/air mixture during the test;

4.1.5.2.4. Flow controller to ensure a constant uniform flow of diluted exhaust gas and dilution air samples taken during the course of the test from sampling probes (PDP-CVS) and flow of the gas samples shall be such that, at the end of each test, the quantity of the samples is sufficient for analysis;

4.1.5.2.5. Flow meters for adjusting and monitoring the constant flow of diluted exhaust gas and dilution air samples during the test;

4.1.5.2.6. Quick-acting valves to divert a constant flow of gas samples into the sampling bags or to the outside vent;

4.1.5.2.7. Gas-tight, quick-lock coupling elements between the quick-acting valves and the sampling bags; the coupling shall close automatically on the sampling-bag side; as an alternative, other ways of transporting the samples to the analyser may be used (three-way stopcocks, for instance);

4.1.5.2.8. Bags for collecting samples of the diluted exhaust gas and of the dilution air during the test;

4.1.5.2.9. A sampling critical flow venturi to take proportional samples of the diluted exhaust gas at sampling probe S_2 (CFV-CVS only);

4.1.5.2.10. Components for hydrocarbon sampling using an HFID:

Fh	heated filter,
S_3	sampling point close to the mixing chamber,
V_h	heated multi-way valve,
Q	quick connector to allow the ambient air sample BA to be analysed on the HFID,
HFID	heated flame ionisation analyser,
R and I	a means of integrating and recording instantaneous hydrocarbon concentrations,
L_h	heated sample line.

4.2. Particulate mass emissions measurement equipment

4.2.1. Specification

4.2.1.1. System overview

4.2.1.1.1. The particulate sampling unit shall consist of a sampling probe located in the dilution tunnel, a particle transfer tube, a filter holder(s), pump(s), flow rate regulators and measuring units.

4.2.1.1.2. A particle size pre-classifier (e.g. cyclone or impactor) may be used. In such case, it is recommended that it be employed upstream of the filter holder. However, a sampling probe, acting as an appropriate size-classification device such as that shown in Figure 10, is acceptable.

4.2.1.2. General requirements

4.2.1.2.1. The sampling probe for the test gas flow for particulates shall be so arranged within the dilution tract that a representative sample gas flow can be taken from the homogeneous air/exhaust mixture and shall be upstream of a heat exchanger (if any).

4.2.1.2.2. The particulate sample flow rate shall be proportional to the total mass flow of diluted exhaust gas in the dilution tunnel to within a tolerance of ± 5 per cent of the particulate sample flow rate. The verification of the proportionality of the PM sampling should be made during the commissioning of the system and as required by the responsible authority.

4.2.1.2.3. The sampled dilute exhaust gas shall be maintained at a temperature above 293 K (20° C) and below 325 K (52° C) within 20 cm upstream or downstream of the particulate filter face. Heating or insulation of components of the PM sampling system to achieve this is permissible.
In the event that the 52° C limit is exceeded during a test where periodic regeneration event does not occur, the CVS flow rate should be increased or double dilution should be applied (assuming that the CVS flow rate is already sufficient so as not to cause condensation within the CVS, sample bags or analytical system).

4.2.1.2.4. The particulate sample shall be collected on a single filter mounted within a holder in the sampled dilute exhaust gas flow.

4.2.1.2.5. All parts of the dilution system and the sampling system from the exhaust pipe up to the filter holder, which are in contact with raw and diluted exhaust gas, shall be designed to minimise deposition or alteration of the particulates. All parts shall be made of electrically conductive materials that do not react with exhaust gas components, and shall be electrically grounded to prevent electrostatic effects.

4.2.1.2.6. If it is not possible to compensate for variations in the flow rate, provision shall be made for a heat exchanger and a temperature control device as specified in §3.3.5.1. or §3.3.6.4.2. so as to ensure that the flow rate in the system is constant and the sampling rate accordingly proportional.

4.2.1.2.7. Temperatures required for the PM mass measurement should be measured with an accuracy of ± 1 deg C and a response time ($t_{10} - t_{90}$) of 15 seconds or less.

4.2.1.2.8. The PM sample flow from the dilution tunnel should be measured with an accuracy of ± 2.5 per cent of reading or ± 1.5 per cent full scale, whichever is the least.

The above accuracy of the PM sample flow from the CVS tunnel is also applicable where double dilution is used. Consequently, the measurement and control of the secondary dilution air flow and diluted exhaust flow rates through the PM filter must be of a higher accuracy.

4.2.1.2.9. All data channels required for the PM mass measurement shall be logged at a frequency of 1 Hz or faster. Typically these would include :
(a) diluted exhaust temperature at the PM filter
(b) PM sampling flow rate
(c) PM secondary dilution air flow rate (if secondary dilution is used)
(d) PM secondary dilution air temperature (if secondary dilution is used)

4.2.1.2.10. For double dilution systems, the accuracy of the diluted exhaust transferred from the dilution tunnel, V_{ep} in the equation is not measured directly but determined by differential flow measurement:

$$V_{ep} = V_{set} - V_{ssd}$$

where

V_{ep}	is the volume of diluted exhaust gas flowing through particulate filter under standard conditions
V_{set}	is the volume of the double diluted exhaust gas passing through the particulate collection filters
V_{ssd}	is the volume of secondary dilution air

The accuracy of the flow meters used for the measurement and control of the double diluted exhaust passing through the particulate collection filters and for the measurement/control of secondary dilution air shall be sufficient so that the differential volume (V_{ep}) shall meet the accuracy and proportional sampling requirements specified for single dilution.

The requirement that no condensation of the exhaust gas should occur in the CVS dilution tunnel, diluted exhaust flow rate measurement system, CVS bag collection or analysis systems shall also apply in the case of double dilution systems.

4.2.1.2.11. Each flow meter used in a particulate sampling and double dilution system shall be subjected to a linearity verification as required by the instrument manufacturer.

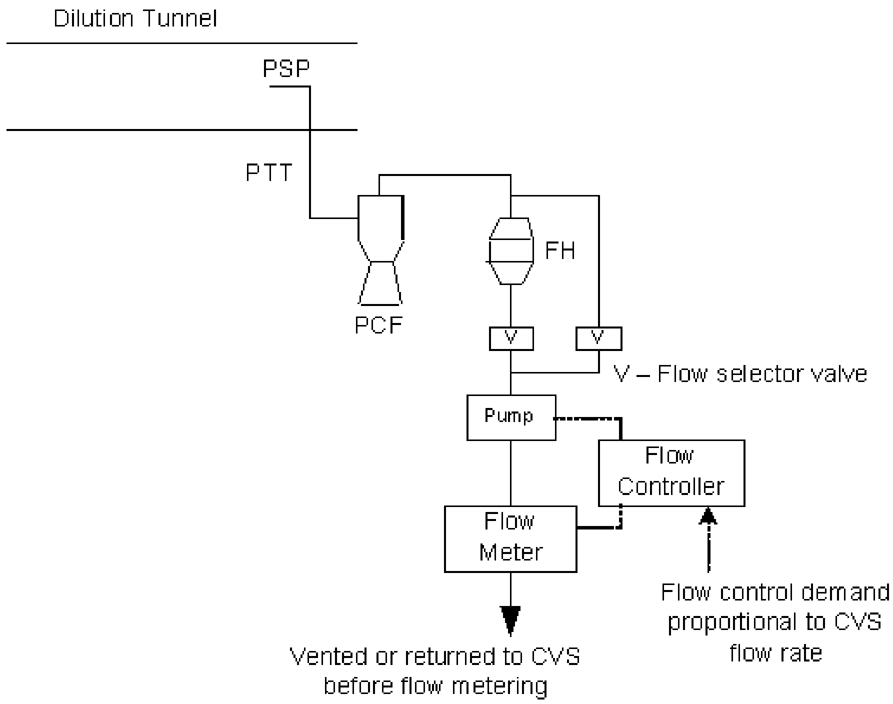


Figure 10: Particulate Sampling System

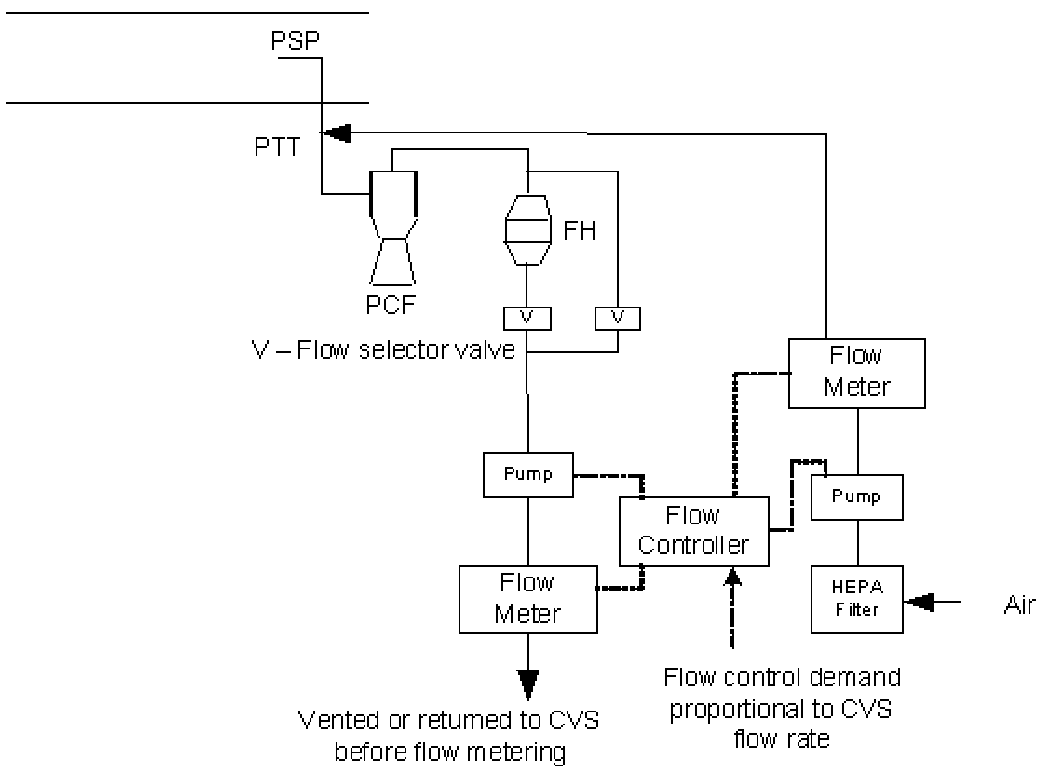


Figure 11: Double Dilution Particulate Sampling System

4.2.1.3. Specific requirements

4.2.1.3.1. PM sampling probe

4.2.1.3.1.1. The sample probe shall deliver the particle-size classification performance described in paragraph 4.2.1.3.1.4. It is recommended that this performance be achieved by the use of a sharp-edged, open-ended probe facing directly into the direction of flow plus a pre-classifier (cyclone impactor, etc.). An appropriate sampling probe, such as that indicated in Figure 12, may alternatively be used provided it achieves the preclassification performance described in paragraph 4.2.1.3.1.4.

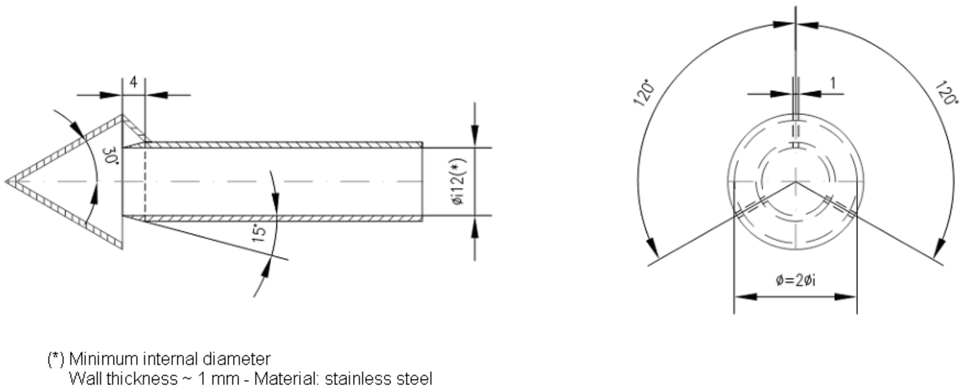


Figure 12: Alternative particulate sampling probe configuration

4.2.1.3.1.2. The sample probe shall be installed between 10 and 20 tunnel diameters downstream of the exhaust gas inlet to the tunnel and have an internal diameter of at least 8 mm. If more than one simultaneous sample is drawn from a single sample probe, the flow drawn from that probe shall be split into identical sub-flows to avoid sampling artifacts.
If multiple probes are used, each probe shall be sharp-edged, open-ended and facing directly into the direction of flow. Probes shall be equally spaced around the central longitudinal axis of the dilution tunnel, with the spacing between probes at least 5 cm.

4.2.1.3.1.3. The distance from the sampling tip to the filter mount shall be at least five probe diameters, but shall not exceed 2,000 mm.

4.2.1.3.1.4. The pre-classifier (e.g. cyclone, impactor, etc.) shall be located upstream of the filter holder assembly. The pre-classifier 50 per cent cut point particle diameter shall be between 2.5 µm and 10 µm at the volumetric flow rate selected for sampling particulate mass emissions. The pre-classifier shall allow at least 99 per cent of the mass concentration of 1 µm particles entering the pre-classifier to pass through the exit of the pre-classifier at the volumetric flow rate selected for sampling particulate mass emissions. However, a sampling probe, acting as an appropriate size-classification device, such as that shown in Figure 12, is acceptable as an alternative to a separate preclassifier.

4.2.1.3.2 Particle transfer tube (PTT)

4.2.1.3.2.1 Any bends in the PTT shall be smooth and have the largest possible curvarure radii.

4.2.1.3.3 Secondary dilution

4.2.1.3.3.1 As an option, the sample extracted from the CVS for the purpose of PM measurement may be diluted at a second stage, subject to the following requirements:

4.2.1.3.3.1.1. Secondary dilution air shall be filtered through a medium capable of reducing particles in the most penetrating particle size of the filter material by ≥ 99.95 per cent, or through a HEPA filter of at least class H13 of EN 1822:2009. The dilution air may optionally be charcoal scrubbed before being passed to the HEPA filter. It is recommended that an additional coarse particle filter is situated before the HEPA filter and after the charcoal scrubber, if used.

4.2.1.3.3.1.2. The secondary dilution air should be injected into the PTT as close to the outlet of the diluted exhaust from the dilution tunnel as possible.

4.2.1.3.3.1.3. The residence time from the point of secondary diluted air injection to the filter face shall be at least 0.25 seconds, but no longer than 5 seconds.

4.2.1.3.3.1.4. The diluted exhaust flow extracted from the dilution tunnel shall remain proportional to the CVS flow rate, as required for the single dilution method.

4.2.1.3.3.1.5. If the double diluted PM sample is returned to the CVS, the location of the sample return shall be selected so that it does not interfere with the extraction of other samples from the CVS.

4.2.1.3.4. Sample pump and flow meter

4.2.1.3.4.1. The sample gas flow measurement unit shall consist of pumps, gas flow regulators and flow measuring units.

4.2.1.3.4.2. The temperature of the gas flow in the flow meter may not fluctuate by more than ± 3 K except:
(a) when the PM sampling flow meter has real time monitoring and flow control operating at 1 Hz or faster;
(b) during regeneration tests on vehicles equipped with periodically regenerating aftertreatment devices.

In addition, the sample mass flow rate shall remain proportional to the total flow of diluted exhaust gas to within a tolerance of ± 5 per cent of the particulate sample mass flow rate. Should the volume of flow change unacceptably as a result of excessive filter loading, the test shall be invalidated. When it is repeated, the rate of flow shall be decreased.

4.2.1.3.5. Filter and filter holder

4.2.1.3.5.1. A valve shall be located downstream of the filter in the direction of flow. The valve shall open and close within 1 s of the start and end of test.

4.2.1.3.5.3. For a given test, the gas filter face velocity shall be set to a single value within the range 20 cm/s to 105 cm/s and should be set at the start of the test so that 105 cm/s will not be exceeded when the dilution system is being operated with sampling flow proportional to CVS flow rate.

4.2.1.3.5.4. Fluorocarbon coated glass fibre filters or fluorocarbon membrane filters are required.
All filter types shall have a 0.3 µm DOP (di-octylphthalate) or PAO (poly-alpha-olefin) CS 68649-12-7 or CS 68037-01-4 collection efficiency of at least 99 per cent at a gas filter face velocity of 5.33cm/s measured according to one of the following standards:

(1) U.S.A. Department of Defense Test Method Standard, MIL-STD-282 method 102.8: DOP-Smoke Penetration of Aerosol-Filter Element
(2) U.S.A. Department of Defense Test Method Standard, MIL-STD-282 method 502.1.1: DOP-Smoke Penetration of Gas-Mask Canisters
(3) Institute of Environmental Sciences and Technology, IEST-RP-CC021: Testing HEPA and ULPA Filter Media.

4.2.1.3.5.5. The filter holder assembly shall be of a design that provides an even flow distribution across the filter stain area. The filter shall be round and have a stain area of at least 1075 mm^2.

4.2.2. Weighing chamber and analytical balance specifications

4.2.2.1. Weighing chamber conditions

(a) The temperature of the chamber (or room) in which the particulate filters are conditioned and weighed shall be maintained to within 295 K ± 2 K (22 °C ± 2 °C, 22 °C ± 1 °C if possible) during all filter conditioning and weighing.

(b) The humidity shall be maintained to a dew point of less than 283.5 K (10.5 °C) and a relative humidity of 45 per cent ± 8 per cent. For sensitive balances, it is recommended that the tolerance for the weighing chamber room air temperature be ± 1 K.

(c) The levels of ambient contaminants in the chamber (or room) environment that would settle on the particulate filters during their stabilisation shall be minimised. Limited deviations from weighing room temperature and humidity specifications will be allowed provided their total duration does not exceed 30 minutes in any one filter conditioning period.

(d) The weighing room should meet the required specifications prior to personal entrance into the weighing room.

(e) During the weighing operation no deviations from the specified conditions are permitted.

4.2.2.2. Analytical balance

The analytical balance used to determine the filter weight shall meet the linearity verification criterion of table 1 below. This implies a precision (standard deviation) of at least 2 µg and a resolution of at least 1 µg (1 digit = 1 µg).

Measurement system	Intercept b	Slope m	Standard error SEE	Coefficient of determination r^2
PM Balance	≤ 1% max	0.99 – 1.01	≤ 1% max	≥ 0.998

Table 1. Analytical balance verification criteria

4.2.2.3. Elimination of static electricity effects

The effects of static electricity shall be nullified. This may be achieved by grounding the balance through placement upon an antistatic mat and neutralisation of the particulate filters prior to weighing using a polonium neutraliser or a device of similar effect. Alternatively nullification of static effects may be achieved through equalisation of the static charge.

4.2.2.4. Buoyancy correction

The sample and reference filter weights shall be corrected for their buoyancy in air. The buoyancy correction is a function of sampling filter density, air density and the density of the balance calibration weight, and does not account for the buoyancy of the PM itself.

If the density of the filter material is not known, the following densities shall be used:
(a) PTFE coated glass fiber filter: 2,300 kg/m^3
(b) PTFE membrane filter: 2,144 kg/m^3
(c) PTFE membrane filter with polymethylpentene support ring: 920 kg/m^3

For stainless steel calibration weights, a density of 8,000 kg/m^3 shall be used. If the material of the calibration weight is different, its density must be known.

The following equation shall be used:

$$m_f = m_{uncorr} \times \left(\frac{1 - \frac{\rho_a}{\rho_w}}{1 - \frac{\rho_a}{\rho_f}} \right)$$

where:

$$\rho_a = \frac{p_b \times 28.836}{8.3144 \times T_a}$$

where:

m_{uncor} is the uncorrected particulate sample mass, mg;
ρ_a is the density of the air, kg/m^3;
ρ_w is the density of balance calibration weight, kg/m^3;
ρ_f is the density of the particulate sampling filter, kg/m^3;
p_b is the total atmospheric pressure, kPa;
T_a is the air temperature in the balance environment, K.

NOTE: The following section (§4.3.) is under review

[4.3. Particle number emissions measurement equipment
4.3.1. Specification
4.3.1.1. System overview

4.3.1.1.1. The particle sampling system shall consist of a probe or sampling point extracting a sample from a homogenously mixed flow in a dilution system, a volatile particle remover (VPR) upstream of a particle number counter (PNC) and suitable transfer tubing.

4.3.1.1.2. It is recommended that a particle size pre-classifier (e.g. cyclone, impactor, etc.) be located prior to the inlet of the VPR. However, a sample probe acting as an appropriate size-classification device, such as that shown in Figure 12, is an acceptable alternative to the use of a particle size pre-classifier.

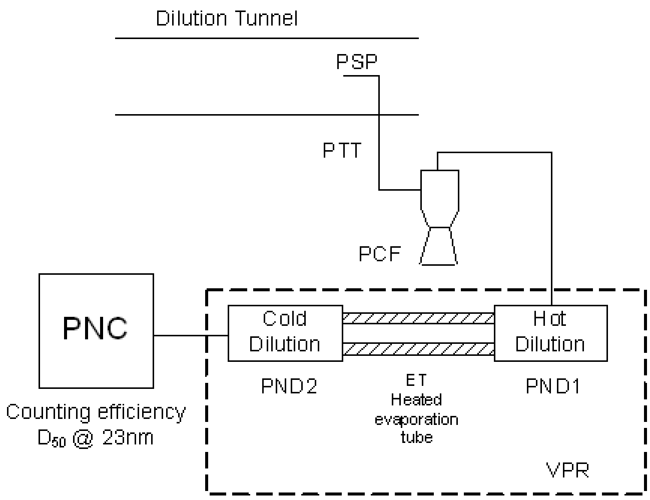


Figure 13: A recommended particle sampling system

4.3.1.2. General requirements

4.3.1.2.1. The particle sampling point shall be located within a dilution system. In the case of double dilution systems, the particle sampling point shall be located within the primary dilution system.

4.3.1.2.1.1. The sampling probe tip or particle sampling point (PSP) and particle transfer tube (PTT) together comprise the particle transfer system (PTS). The PTS conducts the sample from the dilution tunnel to the entrance of the VPR. The PTS shall meet the following conditions:

(a) the sampling probe shall be installed 10 to 20 tunnel diameters downstream of the gas inlet, facing upstream into the tunnel gas flow with its axis at the tip parallel to that of the dilution tunnel;
(b) the sampling probe shall be upstream of any conditioning device (e.g. heat exchanger);
(c) the sampling probe shall be positioned within the dilution tract so that the sample is taken from a homogeneous diluent/exhaust mixture.

4.3.1.2.1.2. Sample gas drawn through the PTS shall meet the following conditions:

(a) in the case of full flow dilution systems, it shall have a flow Reynolds number, Re, of < 1700;

(b) in the case of double dilution dilution systems, it shall have a flow Reynolds number (Re) of < 1700 in the PTT i.e. downstream of the sampling probe or point;

(c) shall have a residence time of ≤ 3 seconds.

4.3.1.2.1.3. Any other sampling configuration for the PTS for which equivalent particle penetration at 30 nm can be demonstrated will be considered acceptable.

4.3.1.2.1.4. The outlet tube (OT) conducting the diluted sample from the VPR to the inlet of the PNC shall have the following properties:

(a) an internal diameter of ≥ 4mm;

(b) a sample gas flow residence time of ≤ 0.8 seconds.

4.3.1.2.1.5. Any other sampling configuration for the OT for which equivalent particle penetration at 30 nm can be demonstrated will be considered acceptable.

4.3.1.2.2. The VPR shall include devices for sample dilution and for volatile particle removal.

4.3.1.2.3. All parts of the dilution system and the sampling system from the exhaust pipe up to the PNC, which are in contact with raw and diluted exhaust gas, shall be designed to minimize deposition of the particles. All parts shall be made of electrically conductive materials that do not react with exhaust gas components, and shall be electrically grounded to prevent electrostatic effects.

4.3.1.2.4. The particle sampling system shall incorporate good aerosol sampling practice that includes the avoidance of sharp bends and abrupt changes in cross-section, the use of smooth internal surfaces and the minimisation of the length of the sampling line. Gradual changes in the cross-section are permissible.

4.3.1.3. Specific requirements

4.3.1.3.1. The particle sample shall not pass through a pump before passing through the PNC.

4.3.1.3.2. A sample pre-classifier is recommended.

4.3.1.3.3. The sample preconditioning unit shall:

(a) be capable of diluting the sample in one or more stages to achieve a particle number concentration below the upper threshold of the single particle count mode of the PNC and a gas temperature below 35 °C at the inlet to the PNC;

(b) include an initial heated dilution stage which outputs a sample at a temperature of ≥ 150 °C and ≤ 400 °C, and dilutes by a factor of at least 10;

(c) control heated stages to constant nominal operating temperatures, within the range ≥ 150°C and ≤ 400°C, to a tolerance of ±10 °C;

(d) provide an indication of whether or not heated stages are at their correct operating temperatures;

e) be designed to achieve a solid particle penetration efficiency of at least [70 per cent] for particles of 100nm electrical mobility diameter,

(f) achieve a particle concentration reduction factor ($f_r(d_i)$), as calculated below, for particles of 30 nm and 50 nm electrical mobility diameters, that is no more than [30 per cent and 20 per cent] respectively higher, and no more than [5] per cent lower than that for particles of 100 nm electrical mobility diameter for the VPR as a whole;

The particle concentration reduction factor at each particle size (fr(di)) shall be calculated as follows:

$$f_r(d_i) = \frac{N_{in}(d_i)}{N_{out}(d_i)}$$

where:

$N_{in}(d_i)$	is the upstream particle number concentration for particles of diameter d_i;
$N_{out}(d_i)$	is the downstream particle number concentration for particles of diameter d_i;
d_i	is the particle electrical mobility diameter (30, 50 or 100 nm).

$N_{in}(d_i)$ and $N_{out}(d_i)$ shall be corrected to the same conditions.

The mean particle concentration reduction, $\overline{f_r}$, at a given dilution setting shall be calculated as follows:

$$\overline{f_r} = \frac{f_r\,(30\text{ nm}) + f_r\,(50\text{ nm}) + f_r\,(100\text{ nm})}{3}$$

It is recommended that the VPR is calibrated and validated as a complete unit;

(g) be designed according to good engineering practice to ensure particle concentration reduction factors are stable across a test;

(h) also achieve > 99.0 per cent vaporisation of 30 nm tetracontane ($CH_3(CH_2)_{38}CH_3$) particles, with an inlet concentration of ≥ 10,000 cm^{-3}, by means of heating and reduction of partial pressures of the tetracontane.

4.3.1.3.4. The PNC shall:

(a) operate under full flow operating conditions;

(b) have a counting accuracy of ± 10 per cent across the range 1 cm^{-3} to the upper threshold of the single particle count mode of the PNC against a traceable standard. At concentrations below 100 cm^{-3} measurements averaged over extended sampling periods may be required to demonstrate the accuracy of the PNC with a high degree of statistical confidence;

(c) have a readability of at least 0.1 particles cm^{-3} at concentrations below 100 cm^{-3};

(d) have a linear response to particle concentrations over the full measurement range in single particle count mode;

(e) have a data reporting frequency equal to or greater than 0.5 Hz;

(f) have a t_{90} response time over the measured concentration range of less than 5 s;

(g) incorporate a coincidence correction function up to a maximum 10 per cent correction, and may make use of an internal calibration factor as determined in [5.8.2.1.3.] but shall not make use of any other algorithm to correct for or define the counting efficiency;

h) have counting efficiencies at the different particle sized as specified below:

Particle size electrical mobility diameter (nm)	CPC counting efficiency (per cent)
23 ± 1	50 ± 12
41 ± 1	> 90

4.3.1.3.5. If the PNC makes use of a working liquid, it shall be replaced at the frequency specified by the instrument manufacturer.

4.3.1.3.6. Where they are not held at a known constant level at the point at which PNC flow rate is controlled, the pressure and/or temperature at inlet to the PNC shall be measured and reported for the purposes of correcting particle concentration measurements to standard conditions.

4.3.1.3.7. The sum of the residence time of the PTS, VPR and OT plus the t_{90} response time of the PNC shall be no greater than 20 s.

4.3.1.3.8. The transformation time of the entire particle number sampling system (PTS, VPR, OT and PNC) shall be determined by aerosol switching directly at the inlet of the PTS. The aerosol switching shall be done in less than 0.1 s. The aerosol used for the test shall cause a concentration change of at least 60 per cent full scale (FS).
The concentration trace shall be recorded. For time alignment of the particle number concentration and exhaust flow signals, the transformation time is defined as the time from the change (t_0) until the response is 50 per cent of the final reading (t_{50}).

4.3.1.4. Recommended system description
The following paragraph contains the recommended practice for measurement of particle number. However, any systems meeting the performance specifications in paragraphs 4.2.1.2. and 4.2.1.3. are acceptable.

4.3.1.4.1. Sampling system description

4.3.1.4.1.1. The particle sampling system shall consist of a sampling probe tip or particle sampling point in the dilution system, a particle transfer tube (PTT), a particle pre-classifier (PCF) and a volatile particle remover (VPR) upstream of the particle number concentration measurement (PNC) unit.

4.3.1.4.1.2. The VPR shall include devices for sample dilution (particle number diluters: PND_1 and PND_2) and particle evaporation (evaporation tube, ET).

4.3.1.4.1.3. The sampling probe or sampling point for the test gas flow shall be so arranged within the dilution tract that a representative sample gas flow is taken from a homogeneous diluent/exhaust mixture.

4.3.1.4.1.4. The sum of the residence time of the system plus the t_{90} response time of the PNC shall be no greater than 20 s.

4.3.1.4.2. Particle transfer system (PTS)

The sampling probe tip or particle sampling point and particle transfer tube (PTT) together comprise the particle transfer system. The PTS conducts the sample from the dilution tunnel to the entrance to the first particle number diluter.

4.3.1.4.2.1. The PTS shall meet the following conditions:

(a) the sampling probe shall be installed 10 to 20 tunnel diameters downstream of the gas inlet, facing upstream into the tunnel gas flow with its axis at the tip parallel to that of the dilution tunnel.

(b) the sampling probe shall be positioned within the dilution tract so that the sample is taken from a homogeneous diluent/exhaust mixture.

4.3.1.4.2.2. Sample gas drawn through the PTS shall meet the following conditions:

(a) have a flow Reynolds number (Re) of < 1700;

(b) have a residence time in the PTS of ≤ 3 seconds.

4.3.1.4.2.3. Any other sampling configuration for the PTS for which equivalent particle penetration for particles of 30 nm electrical mobility diameter can be demonstrated will be considered acceptable.

4.3.1.4.2.4. The outlet tube (OT) conducting the diluted sample from the VPR to the inlet of the PNC shall have the following properties:

(a) an internal diameter of ≥ 4 mm;

(b) sample gas flow residence time of ≤ 0.8 seconds.

4.3.1.4.2.5. Any other sampling configuration for the OT for which equivalent particle penetration for particles of 30 nm electrical mobility diameter can be demonstrated will be considered acceptable.

4.3.1.4.3. Particle pre-classifier

4.3.1.4.3.1. The recommended particle pre-classifier shall be located upstream of the VPR.

4.3.1.4.3.2. The pre-classifier 50 per cent cut point particle diameter shall be between 2.5 µm and 10 µm at the volumetric flow rate selected for sampling particle number emissions.

4.3.1.4.3.3. The pre-classifier shall allow at least 99 per cent of the mass concentration of 1 µm particles entering the pre-classifier to pass through the exit of the pre-classifier at the volumetric flow rate selected for sampling particle number emissions.

4.3.1.4.4. Volatile particle remover (VPR)

4.3.1.4.4.1. The VPR shall comprise one particle number diluter (PND_1), an evaporation tube and a second diluter (PND_2) in series. This dilution function is to reduce the number concentration of the sample entering the particle concentration measurement unit to less than the upper threshold of the single particle count mode of the PNC and to suppress nucleation within the sample.

4.3.1.4.4.2. The VPR shall provide an indication of whether or not PND_1 and the evaporation tube are at their correct operating temperatures.

4.3.1.4.4.3. The VPR shall achieve > 99.0 per cent vaporisation of 30 nm tetracontane ($CH_3(CH_2)_{38}CH_3$) particles, with an inlet concentration of ≥ 10,000 cm^{-3}, by means of heating and reduction of partial pressures of the tetracontane.

4.3.1.4.4.4. The VPR shall be designed to achieve a solid particle penetration efficiency of at least [70 per cent] for particles of 100nm electrical mobility diameter.

4.3.1.4.4.5. The VPR shall also achieve a particle concentration reduction factor (fr) for particles of 30 nm and 50 nm electrical mobility diameters, that is no more than [30 per cent and 20 per cent] respectively higher, and no more than 5 per cent lower than that for particles of 100 nm electrical mobility diameter for the VPR as a whole. It shall be designed according to good engineering practice to ensure particle concentration reduction factors are stable across a test.

4.3.1.4.5. First particle number dilution device (PND_1)

4.3.1.4.5.1. The first particle number dilution device shall be specifically designed to dilute particle number concentration and operate at a (wall) temperature of 150 °C to 400 °C.

4.3.1.4.5.1.1. The wall temperature set point should be held at a constant nominal operating temperature, within this range, to a tolerance of ±10 °C and not exceed the wall temperature of the ET described in§ 4.3.1.4.6.

4.3.1.4.5.1.2. The diluter should be supplied with HEPA filtered dilution air and be capable of a dilution factor of 10 to 200 times.

4.3.1.4.6. Evaporation tube (ET)

4.3.1.4.6.1. The entire length of the ET shall be controlled to a wall temperature greater than or equal to that of the first particle number dilution device and the wall temperature held at a fixed nominal operating temperature of 350 °C, to a tolerance of ± 10 °C.

4.3.1.4.6.2. The residence time within the ET shall be in the range 0.25 – 0.4 seconds.

4.3.1.4.7. Second particle number dilution device (PND_2)

4.3.1.4.7.1. PND_2 shall be specifically designed to dilute particle number concentration. The diluter shall be supplied with HEPA filtered dilution air and be capable of maintaining a single dilution factor within a range of 10 to 30 times.

4.3.1.4.7.2. The dilution factor of PND_2 shall be selected in the range between 10 and 15 such that particle number concentration downstream of the second diluter is less than the upper threshold of the single particle count mode of the PNC and the gas temperature prior to entry to the PNC is < 35 °C.]

5.0 Calibration intervals and procedures

5.1. Calibration intervals

Instrument Checks	Interval	Criteria
Linearisation (calibration)	Every 6 months	± 2 % of reading
Mid Span	Monthly	± 2 %
CO NDIR: CO_2/H_2O interference	Monthly	-1 to 3 ppm
NO_x converter check	Monthly	> 95 %
CH_4 cutter check	Yearly	98% of Ethane
FID CH_4 response	Yearly	See 5.4.3.
FID air/fuel flow	At major maintenance	According to instrument mfr.
NO/NO_2 NDUV: H_2O, HC interference	At major maintenance	According to instrument mfr.
Laser infrared spectrometers (modulated high resolution narrow band infrared analysers)	Yearly or at major maintenance	According to instrument mfr.
GC methods	See 7.2. and 7.3.	See 7.2. and 7.3.
FTIR	See 7.1.5.2.	See 7.1.5.2.
Diode laser	See 7.1.5.1.	See 7.1.5.1.
Microgram balance linearity	Yearly or at major maintenance	See 4.2.2.2.

Table 2: Instrument Calibration Intervals

CVS	Interval	Criteria
CFV Flow	After Overhaul	± 2 %
Dilution Flow	Yearly	± 2 %
Temperature Sensor	Yearly	± 1 °C
Pressure Sensor	Yearly	± 0.4 kPa
Injection Check	Weekly	± 2 %

Table 3: CVS Calibration Intervals

Climate	Interval	Criteria
Temperature	Yearly	± 1 °C
Moisture Dew	Yearly	± 5 per cent RH
Ambient pressure	Yearly	± 0.4 kPa
Wind Speed Fan	After Overhaul	According to chapter 6.3.1.2

Table 4: Environmental data calibration intervals

5.2. Analyser calibration procedures

5.2.1. Each analyser shall be calibrated as specified by the instrument manufacturer or at least as often as described in Table 2.
5.2.2. Each normally used operating range shall be linearised by the following procedure:

5.2.2.1. The analyser linearisation curve shall be established by at least five calibration points spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be not less than 80 per cent of the full scale.

5.2.2.2. The calibration gas concentration required may be obtained by means of a gas divider, diluting with purified N_2 or with purified synthetic air. The accuracy of the mixing device shall be such that the concentrations of the diluted calibration gases may be determined to within ±2 per cent.

5.2.2.3. The linearisation curve shall be calculated by the least squares method. If the resulting polynomial degree is greater than 3, the number of calibration points shall be at least equal to this polynomial degree plus 2.

5.2.2.4. The linearisation curve shall not differ by more than ±2 per cent from the nominal value of each calibration gas.

5.2.2.5. From the trace of the linearisation curve and the linearisation points, it is possible to verify that the calibration has been carried out correctly. The different characteristic parameters of the analyser shall be indicated, particularly:
(a) scale;
(b) sensitivity;
(c) zero point;
(d) date of the linearisation.

5.2.2.6. If it can be shown to the satisfaction of the responsible authority that alternative technologies (e.g. computer, electronically controlled range switch, etc.) can give equivalent accuracy, these alternatives may be used.

5.3. Analyser zero and span verification procedure

5.3.1. Each normally used operating range shall be checked prior to each analysis in accordance with the following:

5.3.1.1. The calibration shall be checked by use of a zero gas and by use of a span gas that has a nominal value within 80 - 95 per cent of the supposed value to be analysed.

5.3.1.2. If, for the two points considered, the value found does not differ by more than ± 5 per cent of the full scale from the theoretical value, the adjustment parameters may be modified. Should this not be the case, a new calibration curve shall be established in accordance with paragraph 5.2. of this Annex.

5.3.1.3. After testing, zero gas and the same span gas are used for re-checking. The analysis is considered acceptable if the difference between the two measuring results is less than 2 per cent.

5.4. FID hydrocarbon response check procedure

5.4.1. Detector response optimisation

The FID shall be adjusted, as specified by the instrument manufacturer. Propane in air should be used, to optimise the response, on the most common operating range.

5.4.2. Calibration of the HC analyser

5.4.2.1. The analyser shall be calibrated using propane in air and purified synthetic air.

5.4.2.2. A calibration curve as described in paragraph 5.2.2.of this Annex shall be established.

5.4.3. Response factors of different hydrocarbons and recommended limits

5.4.3.1. The response factor (R_f), for a particular hydrocarbon species is the ratio of the FID C_1 reading to the gas cylinder concentration, expressed as ppm C_1.
The concentration of the test gas shall be at a level to give a response of approximately 80 per cent of full-scale deflection, for the operating range. The concentration shall be known to an accuracy of ± 2 per cent in reference to a gravimetric standard expressed in volume. In addition, the gas cylinder shall be pre-conditioned for 24 hours at a temperature between 293 K and 303 K (20 and 30 °C).

5.4.3.2. Response factors shall be determined when introducing an analyser into service and at major service intervals thereafter. The test gases to be used and the recommended response factors are:

Methane and purified air:	$1.00 < R_f < 1.15$
Propylene and purified air:	$0.90 < R_f < 1.10$
Toluene and purified air:	$0.90 < R_f < 1.10$

These are relative to a response factor (R_f) of 1.00 for propane and purified air.

5.5. NO_x converter efficiency test procedure

5.5.1. Using the test set up as shown in Figure 14 and procedure described below, the efficiency of converters for the conversion of NO_2 into NO shall be tested by means of an ozonator as follows:

5.5.1.1. The analyser shall be calibrated in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which shall amount to approximately 80 per cent of the operating range and the NO_2 concentration of the gas mixture shall be less than 5 per cent of the NO concentration). The NO_x analyser shall be in the NO mode so that the span gas does not pass through the converter. The indicated concentration shall be recorded.

5.5.1.2. Via a T-fitting, oxygen or synthetic air shall be added continuously to the span gas flow until the concentration indicated is approximately 10 per cent less than the indicated calibration concentration given in paragraph 5.5.1.1. above. The indicated concentration (c) shall be recorded. The ozonator shall be kept deactivated throughout this process.

5.5.1.3. The ozonator shall now be activated to generate enough ozone to bring the NO concentration down to 20 per cent (minimum 10 per cent) of the calibration concentration given in paragraph 5.5.1.1. above. The indicated concentration (d) shall be recorded.

5.5.1.4. The NO_x analyser shall then be switched to the NO_x mode, whereby the gas mixture (consisting of NO, NO_2, O_2 and N_2) now passes through the converter. The indicated concentration (a) shall be recored.

5.5.1.5. The ozonator shall now be deactivated. The mixture of gases described in paragraph 5.5.1.2. above shall pass through the converter into the detector. The indicated concentration (b) shall be recorded.

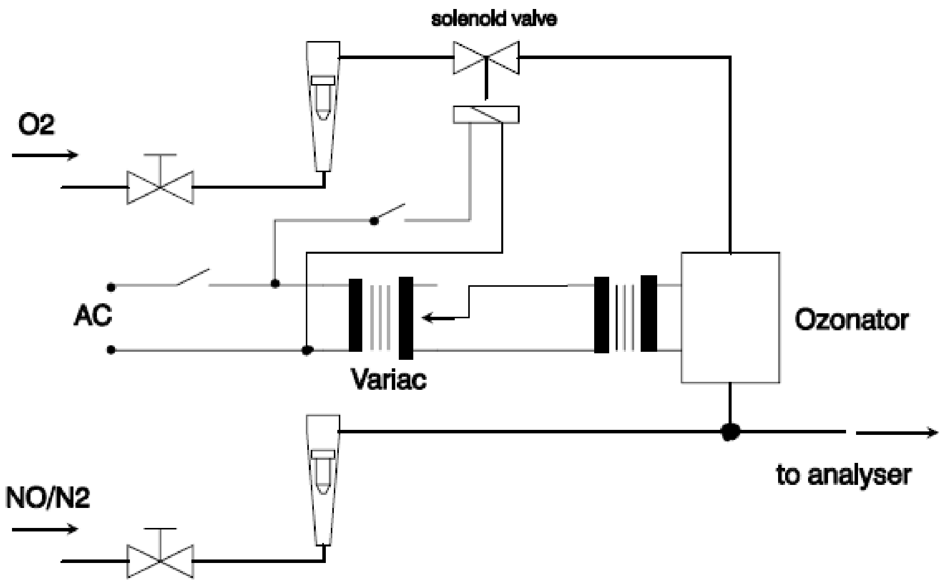


Figure 14: NOx Converter Efficiency Test Configuration

5.5.1.6. With the ozonator deactivated, the flow of oxygen or synthetic air shall be shut off. The NO_2 reading of the analyser shall then be no more than 5 per cent above the figure given in paragraph 5.5.1.1. above.

5.5.1.7. The efficiency of the NO_x converter shall be calculated as follows:

$$\text{Efficiency (per cent)} = \left(1 + \frac{a - b}{c - d}\right) \times 100$$

5.5.1.7.1. The efficiency of the converter shall not be less than 95 per cent. The efficiency of the converter shall be tested in the frequency defined in Table 2.

5.6. Calibration of the microgram balance

5.6.1. The calibration of the microgram balance used for particulate filter weighing shall be traceable to a national or international standard. The balance shall comply with the linearity requirements given in paragraph 4.2.2.2. The linearity verification shall be performed at least every 12 months or whenever a system repair or change is made that could influence the calibration.

5.7. Calibration and validation of the particle sampling system[1]

5.7.1. Calibration of the particle number counter

5.7.1.1. The responsible authority shall ensure the existence of a calibration certificate for the PNC demonstrating compliance with a traceable standard within a 13-month period prior to the emissions test. Between calibrations either the counting efficiency of the PNC should be monitored for deterioration or the PNC wick should be routinely changed every 6 months. PNC counting efficiency may be monitored against a reference PNC or against at least two other measurement PNCs. If the PNC reports particle concentrations within ± 5% of the average of the concentrations from the reference PNC, or group of three or more PNCs, then the PNC shall be considered stable, otherwise maintenance of the PNC is required. Where the PNC is monitored against two or more other measurement PNCs it is permissible to use a reference vehicle running sequentially in different test cells each with its own PNC.

5.7.1.2. The PNC shall also be recalibrated and a new calibration certificate issued following any major maintenance.

5.7.1.3. Calibration shall be traceable to a standard calibration method by comparing the response of the PNC under calibration with that of:
(a) a calibrated aerosol electrometer when simultaneously sampling electrostatically classified calibration particles, or
(b) a second PNC which has been directly calibrated by the above method.

5.7.1.3.1. In case §5.7.1.3.(a), calibration shall be undertaken using at least six standard concentrations spaced as uniformly as possible across the PNC's measurement range.

5.7.1.3.2. In case §5.7.1.3.(b), calibration shall be undertaken using at least six standard concentrations across the PNC's measurement range. At least 3 points shall be at concentrations below 1,000 cm^{-3}, the remaining concentrations shall be linearly spaced between 1,000 cm^{-3} and the maximum of the PNC's range in single particle count mode.

5.7.1.3.3. In cases §5.7.1.3.(a) and §5.7.1.3.(b), the selected points shall include a nominal zero concentration point produced by attaching HEPA filters of at least class H13 of EN 1822:2008, or equivalent performance, to the inlet of each instrument. With no calibration factor applied to the PNC under calibration, measured concentrations shall be within ± 10 per

[1] Example calibration/validation methods are available at: http://www.unece.org/trans/main/wp29/wp29wgs/wp29grpe/pmpFCP.html

cent of the standard concentration for each concentration, with the exception of the zero point, otherwise the PNC under calibration shall be rejected. The gradient from a linear regression of the two data sets shall be calculated and recorded. A calibration factor equal to the reciprocal of the gradient shall be applied to the PNC under calibration. Linearity of response is calculated as the square of the Pearson product moment correlation coefficient (R^2) of the two data sets and shall be equal to or greater than 0.97. In calculating both the gradient and R^2 the linear regression shall be forced through the origin (zero concentration on both instruments).

5.7.1.4. Calibration shall also include a check, according to the requirements in paragraph 4.3.1.3.4.(h), on the PNC's detection efficiency with particles of 23 nm electrical mobility diameter. A check of the counting efficiency with 41 nm particles is not required.

5.7.2. Calibration/validation of the volatile particle remover

5.7.2.1. Calibration of the VPR's particle concentration reduction factors across its full range of dilution settings, at the instrument's fixed nominal operating temperatures, shall be required when the unit is new and following any major maintenance. The periodic validation requirement for the VPR's particle concentration reduction factor is limited to a check at a single setting, typical of that used for measurement on diesel particulate filter equipped vehicles. The responsible authority shall ensure the existence of a calibration or validation certificate for the volatile particle remover within a 6-month period prior to the emissions test. If the volatile particle remover incorporates temperature monitoring alarms, a 13 month validation interval shall be permissible.
It is recommended that the VPR is calibrated and validated as a complete unit.
The VPR shall be characterised for particle concentration reduction factor with solid particles of 30 nm, 50 nm and 100 nm electrical mobility diameter. Particle concentration reduction factors ($f_r(d)$) for particles of 30 nm and 50 nm electrical mobility diameters shall be no more than 30 per cent and 20 per cent higher respectively, and no more than 5 per cent lower than that for particles of 100 nm electrical mobility diameter. For the purposes of validation, the mean particle concentration reduction factor shall be within ±10 per cent of the mean particle concentration reduction factor ($\bar{\mathbf{f}}_{\mathbf{r}}$) determined during the primary calibration of the VPR.

5.7.2.2. The test aerosol for these measurements shall be solid particles of 30, 50 and 100 nm electrical mobility diameter and a minimum concentration of 5,000 particles cm^{-3} at the VPR inlet. As an option, a polydisperse aerosol with a modal concentration at 50 nm electrical mobility diameter may be used for validation. The test aerosol shall be thermally stable at the VPR operating temperatures. Particle concentrations shall be measured upstream and downstream of the components.

The particle concentration reduction factor for each monodisperse particle size ($f_r(d_i)$) shall be calculated as follows;

$$f_r(d_i) = \frac{N_{in}(d_i)}{N_{out}(d_i)}$$

where:

$N_{in}(d_i)$ is the upstream particle number concentration for particles of diameter d_i;
$N_{out}(d_i)$ is the downstream particle number concentration for particles of diameter d_i;
d_i is the particle electrical mobility diameter (30, 50 or 100 nm).
$N_{in}(d_i)$ and $N_{out}(d_i)$ shall be corrected to the same conditions.

The mean particle concentration reduction factor, $(\overline{f_r})$, at a given dilution setting shall be calculated as follows;

$$\overline{f_r} = \frac{f_r(30nm) + f_r(50nm) + f_r(100nm)}{3}$$

Where a polydisperse 50nm aerosol is used for validation, the mean particle concentration reduction factor ($\overline{f_v}$) at the dilution setting used for validation shall be calculated as follows;

$$\overline{f_v} = \frac{N_{in}}{N_{out}}$$

where:

N_{in} is the upstream particle number concentration;

N_{out} is the downstream particle number concentration

5.7.2.3. A validation certificate for the VPR demonstrating effective volatile particle removal efficiency within a 6 month period prior to the emissions test shall be presented upon request.

5.7.2.3.1. If the volatile particle remover incorporates temperature monitoring alarms, a 13 month validation interval shall be permissible.

5.7.2.3.2. The VPR shall demonstrate greater than 99.0 per cent removal of tetracontane (CH3(CH2)38CH3) particles of at least 30 nm electrical mobility diameter with an inlet concentration of ≥ 10,000 cm-3 when operated at its minimum dilution setting and manufacturers recommended operating temperature.

5.7.3. Particle number system check procedures

5.7.3.1. On a monthly basis, the flow into the particle counter shall report a measured value within 5 per cent of the particle counter nominal flow rate when checked with a calibrated flow meter.

6.0. Reference gases

6.1. Pure gases

6.1.1. All values in ppm mean V-ppm (vpm)

6.1.2. The following pure gases shall be available, if necessary, for calibration and operation:

6.1.2.1. Nitrogen: (purity: ≤ 1 ppm C, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0.1 ppm NO, < 0.1 ppm NO_2, < 0.1 ppm N_2O, < 0,1 ppm NH_3)

6.1.2.2. Synthetic air: (purity: ≤ 1 ppm C, ≤ 1 ppm CO, ≤ 400 ppm CO_2, ≤ 0.1 ppm NO); oxygen content between 18 and 21 per cent volume;

6.1.2.3. Oxygen: (purity: > 99.5 per cent vol. O_2);

6.1.2.4. Hydrogen (and mixture containing helium): (purity: ≤ 1 ppm C,
≤ 400 ppm CO_2);

6.1.2.5. Carbon monoxide: (minimum purity 99.5 per cent);

6.1.2.6. Propane: (minimum purity 99.5 per cent).

6.2. Calibration and span gases

6.2.1. The true concentration of a calibration gas shall be within ±1 per cent of the stated figure or as given below :

Mixtures of gases having the following compositions shall be available with a bulk gas specifications according 6.1.2.1 or 6.1.2.2
:

(a) C_3H_8 in synthetic air (see paragraph 6.1.2.2. above);
(b) CO in nitrogen;
(c) CO_2 in nitrogen.
(d) CH_4 in synthetic air
(e) NO in nitrogen (the amount of NO_2 contained in this calibration gas shall not exceed 5 per cent of the NO content).
(f) NO_2 in nitrogen (tolerance ± 2 %)
(g) N_2O in nitrogen (tolerance ± 2 %)
(h) C_2H_5OH in synthetic air or nitrogen (tolerance ± 2 %)

7.0 Additional sampling and analysis methods

7.1. Fourier transform infrared (FTIR) analyser

7.1.1. Measurement principle

7.1.1.1. An FTIR employs the broad waveband infrared spectroscopy principle. It allows simultaneous measurement of exhaust components whose standardized spectra are available in the instrument. The absorption spectrum (intensity/wavelength) is calculated from the measured interferogram (intensity/time) by means of the Fourier transform method.

7.1.1.2. The internal analyser sample stream up to the measurement cell and the cell itself shall be heated to the same temperature condition as defined in 10.1.1 (extractive sampling)

7.1.1.3. Measurement cross interference

7.1.1.3.1. The spectral resolution of the target wavelength shall be within 0.5 cm^{-1} in order to minimize cross interference from other gases present in the exhaust gas.

7.1.1.3.2. Analyser response should not exceed ± 2 ppm at the maximum CO_2 and H_2O concentration expected during the vehicle test.

7.2. Sampling and analysis methods for N_2O

7.2.1. Gas chromatographic method

7.2.1.1 General description

Followed by the gas chromatographic separation, N_2O shall be analysed by an appropriate detector. This shall be an electron-capture detector (ECD).

7.2.1.2. Sampling

From each phase of the test, a gas sample shall be taken from the corresponding diluted exhaust bag and dilution air bag for analysis. A single composite dilution background sample can be analysed instead (not possible for phase weighing).

7.2.1.2.1. Sample transfer

Secondary sample storage media may be used to transfer samples from the test cell to the GC lab. Good engineering judgement shall be used to avoid additional dilution when transferring the sample from sample bags to secondary sample bags.

7.2.1.2.1.1. Secondary sample storage media.
Gas volumes shall be stored in sufficiently clean containers that minimally off-gas or allow permeation of gases. Good engineering judgment shall be used to determine acceptable thresholds of storage media cleanliness and permeation. In order to clean a container, it may be repeatedly purged, evacuated and heated.

7.2.1.2.2. Sample storage
Secondary sample storage bags must be analysed within 24 hours and must be stored at room temperature.

7.2.1.3. Instrumentation and apparatus
7.2.1.3.1. A gas chromatograph with an electron-capture detector (GC-ECD) may be used to measure N_2O concentrations of diluted exhaust for batch sampling.

7.2.1.3.2. The sample may be injected directly into the GC or an appropriate preconcentrator may be used. In case of preconcentration, this must be used for all necessary verifications and quality checks.

7.2.1.3.3. A packed or porous layer open tubular (PLOT) column phase of suitable polarity and length may be used to achieve adequate resolution of the N_2O peak for analysis.

7.2.1.3.4. Column temperature profile and carrier gas selection must be taken into consideration when setting up the method to achieve adequate N_2O peak resolution. Whenever possible, the operator must aim for baseline separated peaks.

7.2.1.3.5. Good engineering judgement shall be used to zero the instrument and to correct for drift.

Example: A span gas measurement may be performed before and after sample analysis without zeroing and using the average area counts of the pre-span and post-span measurements to generate a response factor (area counts/span gas concentration), which are then multiplied by the area counts from the sample to generate the sample concentration.

7.2.1.4. Reagents and material
All reagents, carrier and make up gases shall be of 99.995% purity. Make up gas shall be N_2 or Ar/CH_4

7.2.1.5. Peak integration procedure

7.2.1.5.1. Peak integrations are corrected as necessary in the data system. Any misplaced baseline segments are corrected in the reconstructed chromatogram.
7.2.1.5.2. Peak identifications provided by a computer shall be checked and corrected if necessary.
7.2.1.5.3. Peak areas shall be used for all evaluations. Peak heights may be used alternatively with approval of the responsible authority.

7.2.1.6. Linearity
A multipoint calibration to confirm instrument linearity shall be performed for the target compound:
(a) for new instruments,
(b) after doing instrument modifications that can affect linearity, and
(c) at least once per year.

7.2.1.6.1. The multipoint calibration consists of at least 3 concentrations, each above the LoD, distributed over the range of expected sample concentration.

7.2.1.6.2. Each concentration level is measured at least twice.

7.2.1.6.3. A linear regression analysis is performed using concentration and average area counts to determine the regression correlation coefficient (r). The regression correlation coefficient must be greater than 0.995 to be considered linear for one point calibrations.
If the weekly check of the instrument response indicates that the linearity may have changed, a multipoint calibration must be done.

7.2.1.7. Quality control

7.2.1.7.1. The calibration standard shall be analysed each day of analysis to generate the response factors used to quantify the sample concentrations.

7.2.1.7.2. A quality control standard shall be analysed within 24 hours before the analysis of the sample.

7.2.1.8. Calculations

$$\text{Conc. } N_2O = \text{PeakArea}_{sample} * \text{ResponseFactor}_{sample}$$

$$\text{ResponseFactor}_{sample} = \text{Concentration}_{standard}\ (\text{ppb}) / \text{PeakArea}_{standard}$$

7.2.1.9. Limit of detection, limit of quantification
The determination limit is based on the noise measurement close to the retention time of N_2O (reference DIN 32645, 01.11.2008):

Limit of Detection: LoD = avg. (noise) + 3 x std. dev.
where std. dev. is considered to be equal to noise.

Limit of Quantification: LoQ = 3 x LoD

For the purpose of calculating the mass of N_2O, the concentration below LoD is considered to be zero.

7.2.1.10. Interference verification.
An interference is any component present in the sample with a retention time similar to that of the target compound described in this method. To reduce interference error, proof of chemical identity may require periodic confirmations using an alternate method or instrumentation.

ANNEX 6: TEST PROCEDURE AND TEST CONDITIONS

1.0. Test procedures and test conditions

1.1 Description of tests

1.1.1 The tests verify the emissions of gaseous species, particulate matter, particle number, CO_2 emissions, fuel consumption, energy consumption and electric range in a characteristic driving cycle.

1.1.1.1. The tests shall be carried out by the method described in paragraph 1.2. and 1.3. to this regulation. Gases, particulate matter and particle number shall be sampled and analysed by the prescribed methods.

1.1.1.2 The number of tests shall be determined as shown in Figure 1. R_{i1} to R_{i3} describe the final measurement results of three tests to determine gaseous and particulate emissions species, carbon dioxide emission, fuel consumption and range, where applicable. L are limit values as defined in [§ unknown].

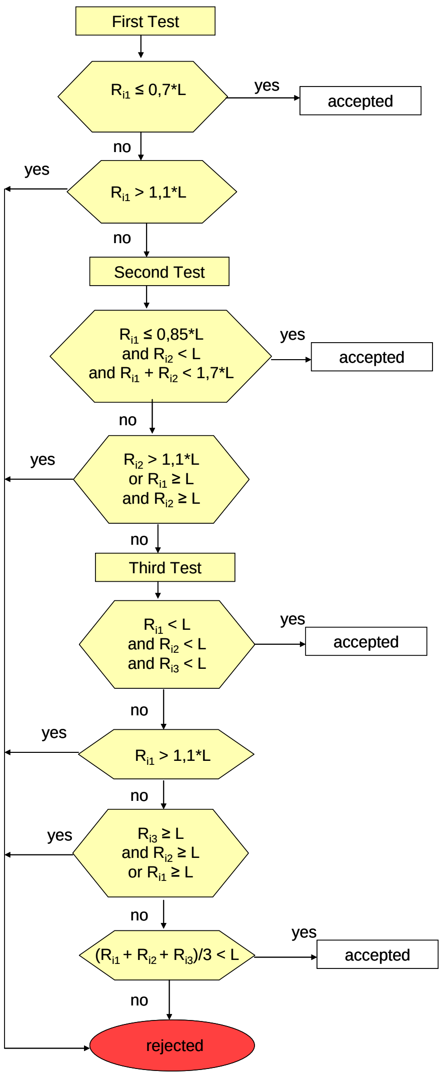


Figure 1: Flowchart for the number of Type I tests

1.2. Type I test conditions

1.2.1. Overview

1.2.1.1. The Type I test consists of prescribed sequences of dynamometer preparation, fuelling, soaking, and operating conditions.

1.2.1.2. The test consists of engine start-ups and vehicle operation on a chassis dynamometer through a specified driving cycle. A proportional part of the diluted exhaust emissions is collected continuously for subsequent analysis, using a constant volume sampler or other suction device.

1.2.1.3. Except in cases of component malfunction or failure, all emission control systems installed on or incorporated in a tested vehicle shall be functioning during all procedures.

1.2.1.4. Background concentrations are measured for all species for which dilute mass emissions measurements are conducted. For exhaust testing, this requires sampling and analysis of the dilution air.

1.2.1.4.1. Background particulate mass measurement

1.2.1.4.1.1. Where the manufacturer requests and the Contracting Party permits subtraction of either dilution air or dilution tunnel particulate matter background from emissions measurements, these background levels shall be determined according to the following procedures:
1.2.1.4.1.1.1. The maximum permissible background correction shall be a mass on the filter equivalent to 1 mg/km at the flow rate of the test.
1.2.1.4.1.1.2. If the background exceeds this level, the default figure of 1 mg/km shall be subtracted.
1.2.1.4.1.1.3. Where subtraction of the background contribution gives a negative result, the particulate mass result shall be considered to be zero.

1.2.1.4.1.2. Dilution air particulate matter background level shall be determined by passing filtered dilution air through the particulate filter. This shall be drawn from a point immediately downstream of the dilution air filters. [Background levels in $\mu g/m^3$ shall be updated daily and determined as a rolling average, of at least 20 measurements, with at least one measurement per week.]

1.2.1.4.1.3. Dilution tunnel particulate matter background level shall be determined by passing filtered dilution air through the particulate filter. This shall be drawn from the same point as the particulate matter sample. Where secondary dilution is used for the test the secondary dilution system should be active for the purposes of background measurement. One measurement may be performed on the day of test, either prior to or after the test.

1.2.1.4.2. Background particle number measurements

1.2.1.4.2.1. Where the contracting party permits subtraction of either dilution air or dilution tunnel particle number background from emissions measurements or a manufacturer requests a background sample, these background levels shall be determined as follows:

1.2.1.4.2.1.1. The maximum permissible background correction shall be equivalent to $2x10^9$ particles/km.

1.2.1.4.2.1.2. If the background exceeds this level, the default figure of $2x10^9$ particles/km may be subtracted.

1.2.1.4.2.1.3. Where subtraction of the background contribution gives a negative result, the particle number result shall be considered to be zero.

1.2.1.4.2.2. Dilution air particle number background level shall be determined by sampling filtered dilution air. This shall be drawn from a point immediately downstream of the dilution air filters into the particle number measurement system. [Background levels in $\#/m^3$ shall be updated daily and determined as a rolling average, of least 20 measurements with at least one measurement per week.]

1.2.1.4.2.3. Dilution tunnel particle number background level shall be determined by sampling filtered dilution air. This shall be drawn from the same point as the particle number sample. Where secondary dilution is used for the test the secondary dilution system should be active for the purposes of background measurement. One measurement may be performed on the day of test, either prior to or after the test.

1.2.2. General test cell equipment

1.2.2.1. Parameters to be measured

1.2.2.1.1. The following temperatures shall be measured with an accuracy of ± 1.5 K:
(a) test cell ambient air
(b) dilution and sampling system temperatures as required for emissions measurement systems defined in Annex 5 Test Equipment and Calibration.

1.2.2.1.2. Atmospheric pressure shall be measurable to within ± 0.1 kPa.

1.2.2.1.3. Absolute humidity (H_a) shall be measurable to within ±1 g H_2O/kg dry air.

1.2.2.2. Test cell and soak area

1.2.2.2.1. Test cell

1.2.2.2.1.1. The test cell shall have a temperature set point of 296 K. The tolerance of the actual value shall be within ± 5 K. The air temperature and humidity shall be measured at the vehicle cooling fan at a rate of 1 Hz.

1.2.2.2.1.2. The absolute humidity (H_a) of either the air in the test cell or the intake air of the engine shall be such that:

$$5.5 \leq H_a \leq 12.2 \qquad (\text{g } H_2O/\text{kg dry air})$$

1.2.2.2.1.3. Humidity shall be measured continuously at a minimum of 1 Hz.

1.2.2.2.2. Soak area

1.2.2.2.2.1. The soak area shall have a temperature set point of 296 K and the tolerance of the actual value shall be within ± 3 K. The temperature shall be measured continuously at a minimum of 1 Hz.

NOTE: Paragraphs §1.2.3.1. and §1.2.3.2. areunder development

1.2.3. Test vehicle

[1.2.3.1. The test vehicle shall conform in all its components with the production series, or, if the vehicle is different from the production series, a full description shall be given in the test report. For the measurement of CO_2 and species emissions the vehicle with the highest mass (TM_H) [and the worst-case road load (RL_{HH})] will be selected.

1.2.3.2. At the request of the manufacturer, the vehicle may be tested in addition at a test mass of TM_L [and at different road load settings (RL_{HH}, RL_{HL} and RL_{LH})] to determine the CO_2 emission value for individual vehicles in the vehicle family according to the CO_2 regression method in Annex 7 (insert reference). These additional tests are allowed if OM_H for the vehicle family is 100 kg or higher. If OM_H is lower than 100 kg, additional testing is allowed if OM_H is set to 100 kg.
For all additional tests, no species emissions and particulates must to be measured.]

1.2.3.3. Run-in
The vehicle must be presented in good mechanical condition. It must have been run-in and driven between 3,000 km and 15,000 km before the test. The engine, transmission and vehicle shall be run-in in accordance with the manufacturer’s requirements.

1.2.4. Settings

1.2.4.1. Dynamometer settings and verification (see Annex 4 Road Load Determination)

1.2.4.2. Dynamometer operation mode

1.2.4.2.1. Vehicle dynamometer operation mode can be activated at the manufacturer’s request.

1.2.4.2.2. A dynamometer operation mode, if any, shall be activated by using a manufacturer's instruction (e.g. using vehicle steering buttons in a special pressing order, by using the manufacturer’s work shop tester, or by the removal of a fuse).
The manufacturer shall provide the responsible authority a list of the deactivated devices and justification of the deactivation.
Auxiliaries shall be switched off/deactivated during dynamometer operation.

1.2.4.2.3. Dynamometer operation mode shall not activate, modulate, delay or deactivate the operation of any part that affects the emissions and fuel consumption under the test conditions. Any device that affects the operation on a chassis dynamometer can be set in a certain condition to ensure a proper operation.
Activation or deactivation of the mode shall be recorded in the test report.

1.2.4.3. The vehicle’s exhaust system shall not exhibit any leak likely to reduce the quantity of gas collected.

1.2.4.5. The settings of the engine and of the vehicle's controls shall be those prescribed by the manufacturer.

1.2.4.6. Tyres shall be of a type specified as original equipment by the vehicle manufacturer. Tyre pressure may be increased by up to 50 per cent above the pressure specified in §4.2.2.3. of Annex 4 Road and Dynamometer Load. The same tyre pressure shall be used for the setting of the dynamometer and for all subsequent testing. The tyre pressure used shall be recorded in the test report.

1.2.4.7. Specification of the reference fuel

1.2.4.7.1. The appropriate reference fuel as defined in Annex 3 Reference Fuels to this Regulation shall be used for testing.

1.2.4.8. Test vehicle preparation

1.2.4.8.1. The vehicle shall be approximately horizontal during the test so as to avoid any abnormal distribution of the fuel.

1.2.4.8.2. At the manufacturer’s request and upon approval of the responsible authority, if the test vehicle is equipped with a dynamometer operation mode and/or coastdown mode, it shall be switched on.

1.2.4.8.3. If necessary, the manufacturer shall provide additional fittings and adapters, as required to accommodate a fuel drain at the lowest point possible in the tank(s) as installed on the vehicle, and to provide for exhaust sample collection.

1.2.5. Preliminary testing cycles

1.2.5.1. Preliminary testing cycles may be carried out if requested by the manufacturer to follow the speed trace within the prescribed limits.

1.2.6. Test vehicle preconditioning

1.2.6.1. The fuel tank or fuel tanks shall be filled with the specified test fuel. If the existing fuel in the fuel tank or fuel tanks does not meet the specifications contained in paragraph 1.2.4.8. above, the existing fuel shall be drained prior to the fuel fill. For the above operations, the evaporative emission control system shall neither be abnormally purged nor abnormally loaded.

1.2.6.2. Battery charging
Before the preconditioning test cycle, the battery may be fully charged. The battery shall not be charged again before the official testing.

1.2.6.3. The test vehicle shall be moved to the test cell and the following operations performed:

1.2.6.3.1. The test vehicle shall be placed, either by being driven or pushed, on a dynamometer and operated through the cycles as specified in Annex 1 for that class of vehicle. The vehicle need not be cold, and may be used to set dynamometer power.

1.2.6.3.2. The dynamometer shall be set according to §7.0. in Annex 4.

1.2.6.3.3. During preconditioning, the test cell temperature shall be the same as defined for the Type I test (§1.2.2.2.1. of this Annex).

1.2.6.3.4. The drive-wheel tyre pressure shall be set in accordance with the provisions of §4.2.1.2. of Annex 4 Road Load Determination.

1.2.6.3.5. Between the tests on the first gaseous reference fuel and the second gaseous reference fuel, for positive-ignition engined vehicles fuelled with LPG or NG/biomethane or so equipped that they can be fuelled with either petrol or LPG or NG/biomethane, the vehicle shall be preconditioned again before the test on the second reference fuel.

1.2.6.3.6. For the purpose of measuring particulates, at most 36 hours and at least 6 hours before testing, the complete cycle for that class of vehicle as described in Annex 1 of this GTR shall be used for vehicle pre-conditioning. Three consecutive complete cycles shall be driven. The dynamometer setting shall be indicated as in §1.2.4. above.

1.2.6.4. The engine shall be started up by means of the devices provided for this purpose according to the manufacturer's instructions.

1.2.6.4.1. If the vehicle does not start, the test is void, precondition tests must be repeated and a new test must be driven.

1.2.6.4.2. The cycle starts on the initiation of the engine start-up procedure.

1.2.6.4.3. In cases where LPG or NG/biomethane is used as a fuel, it is permissible that the engine is started on petrol and switched automatically to LPG or NG/biomethane after a predetermined period of time which cannot be changed by the driver.

1.2.6.4.4. Stationary/idling vehicle phase

During stationary/idling vehicle phases, the brakes shall be applied with appropriate force to prevent the drive wheels from turning.

1.2.6.5. Use of the gearbox

1.2.6.5.1. Manual shift gearbox

The gear shift prescriptions described in Annex 2 shall be followed.

Vehicles which do not attain the acceleration and maximum speed values required in the driving cycle shall be operated with the accelerator control fully activated until they once again reach the required driving curve. Speed trace violations under these circumstances shall not void a test. Deviations from the operating cycle shall be recorded in the test report.

1.2.6.5.1.1. The tolerances given in §1.2.6.6.below shall apply.
1.2.6.5.1.2. The gear change must be started and completed within ±1.0 s of the prescribed gear shift point.
1.2.6.5.1.3. The clutch must be pressed within ±1.0 s of the prescribed clutch operating point.

1.2.6.5.2. Semi-automatic gearbox

Vehicles equipped with semi-automatic gearboxes shall be tested using the gears normally employed for driving, and the gear shift used in accordance with the manufacturer's instructions.
The shift points shall be those determined by the gearshift calculation tool.

1.2.6.5.2.1. The tolerances given in §1.2.6.6. below shall apply.

1.2.6.5.3. Automatic-shift gearbox
Vehicles equipped with automatic-shift gearboxes shall be tested in the predominant drive mode. The accelerator control shall be used in such a way as to accurately follow the speed trace.
The tolerances given in §1.2.6.6. below shall apply.
After initial engagement, the selector shall not be operated at any time during the test.

1.2.6.5.4. Use of multi-mode gearboxes

1.2.6.5.4.1. In the case of emissions testing, emission standards shall be fulfilled in all modes.

1.2.6.5.4.2. In the case of CO_2/fuel consumption testing, the vehicle shall be tested in the default mode.

If the vehicle has no default mode, the vehicle shall be tested in the best case mode and worst case mode, and the CO_2 and fuel consumption results shall be the average of both modes.

Vehicles with an automatic transmission with a manual mode shall be tested according §1.2.6.5.3. of this Annex.

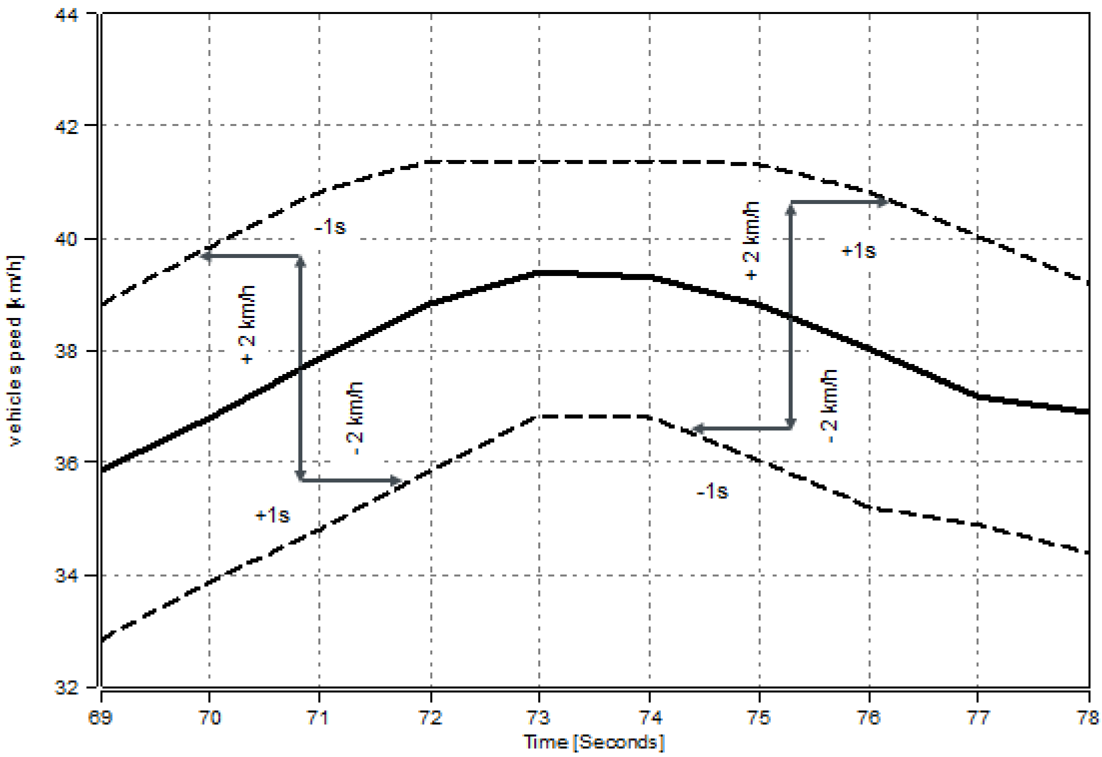
1.2.6.6. Speed trace tolerances

The following tolerances shall be allowed between the indicated speed and the theoretical speed of the respective WLTC:

(1) The upper limit may be 2.0 km/h higher than the trace within ± 1.0 s of the given point in time;
(2) The lower limit may be 2.0 km/h lower than the trace within ± 1.0 s of the given time.

If the vehicle decelerates more rapidly without the use of the brakes, the provisions of paragraph §1.2.6.8.1. below shall apply. Speed tolerances greater than those prescribed shall be accepted provided the tolerances are never exceeded for more than [0.5] s on any one occasion.

There shall be no more than [10] such deviations per test.



1.2.6.7. Accelerations
The vehicle shall be operated with the appropriate accelerator control movement necessary to accurately follow the speed trace.
The vehicle shall be operated smoothly, following representative shift speeds and procedures.
For manual transmissions, the operator shall release the accelerator controller during each shift and accomplish the shift in minimum time.

If the vehicle cannot follow the speed trace, it shall be operated at maximum available power until the vehicle speed reaches the value prescribed for that time in the driving schedule.

1.2.6.8. Decelerations

1.2.6.8.1. All decelerations of the cycle shall be effected by deactivating the accelerator control with the clutch remaining engaged.

1.2.6.8.1.1. If the vehicle decelerates quicker than prescribed by the drive trace, the vehicle shall be operated with the appropriate accelerator controller movement necessary to accurately follow the speed trace.

1.2.6.8.1.2. If the vehicle decelerates too slowly to follow the intended deceleration, the brakes shall be applied such, that is possible to accurately follow the speed trace.

1.2.6.9. Unexpected engine stop
1.2.6.9.1. If the engine stops unexpectedly during the test, the test shall be declared void.

1.2.6.10. After completion of the preconditioning cycle, the engine shall be switched off.

1.2.6.10.1. If requested by the manufacturer and approved by the responsible authority, additional WLTC preconditioning cycles may be driven to bring the vehicle and its control systems to a stabilised condition.

At request of the manufacturer or [responsible authority] additional wltc cycles can be performed in order to bring the vehicle and its control systems in a stabilised condition.

1.2.6.10.2. The additional preconditioning shall consist of driving the cycle for that class of vehicle as defined in Annex 1.

1.2.6.10.3. The extent of such additional preconditioning shall be recorded in the test report.

1.2.6.10.4. In a test facility in which there may be possible contamination of a low particulate emitting vehicle test with residue from a previous test on a high particulate emitting vehicle, it is recommended, for the purpose of sampling equipment pre-conditioning, that a 120 km/h steady state drive cycle of 20 minutes duration be driven by a low particulate emitting vehicle. Longer and/or higher speed running is permissible for sampling equipment pre-conditioning if required. Where dilution tunnel background measurements are used they shall be taken after the tunnel pre-conditioning running, and prior to any subsequent vehicle testing.

1.2.7. Soak

1.2.7.1 After this preconditioning, and before testing, vehicles shall be kept in a room in which ambient conditions are described in 1.2.2.2.2.

1.2.7.2. The vehicle shall be soaked for a minimum of 6 hours and a maximum of 36 hours with the bonnet opened or closed.

1.2.7.3. If not excluded by specific provisions for a particular vehicle, cooling may be accomplished by forced cooling down to the setpoint temperature. If cooling is accelerated by fans, the fans shall be placed so that the maximum cooling of the drive train, engine and exhaust aftertreatment system is achieved in a homogeneous manner. This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant temperature, if any, are within ± 2 K of the setpoint.

1.2.8. Emissions Test

1.2.8.1. The test vehicle shall be pushed onto a dynamometer and operated through the cycles as specified in Annex 1 for that class of vehicle.

1.2.8.1.1. The drive wheels of the vehicle shall be placed on the dynamometer without starting the engine.

1.2.8.1.2. The drive-wheel tyre pressures shall be set in accordance with the provisions of paragraph 1.2.6.3.4.

1.2.8.1.3. The bonnet shall be closed.

1.2.8.1.4. An exhaust connecting tube shall be attached to the vehicle tailpipe(s) immediately before starting the engine.

1.2.8.2. Engine starting and driving

1.2.8.2.1. The engine shall be started up by means of the devices provided for this purpose according to the manufacturer's instructions.

1.2.8.2.2. The vehicle shall be driven as described in paragraph 1.2.6.4.

1.2.8.3. During the test, speed shall be recorded against time or collected by the data acquisition system at a rate of no less than 1 Hz so that the driven speed can be assessed.

1.2.8.4. Before starting a new cycle part, dynamometer distance shall be recorded

1.2.9. Gaseous Sampling
Gaseous samples shall be collected in bags and the compounds analysed at the end of the test, or the compounds may be analysed continuously and integrated over the cycle.

1.2.9.1. The following steps shall be taken prior to each test:

1.2.9.1.1. The purged, evacuated sample bags shall be connected to the dilute exhaust and dilution air sample collection systems.

1.2.9.1.2. Measuring instruments shall be started according to the instrument manufacturers' instructions.

1.2.9.1.3. The CVS heat exchanger (if installed) shall be pre-heated or pre-cooled to within its operating test temperature tolerance as specified in Annex 5 §3.3.5.1.

1.2.9.1.4. Components such as sample lines, filters, chillers and pumps shall be heated or cooled as required until stabilised operating temperatures are reached.

1.2.9.1.5. CVS flow rates shall be set according to §3.3.4. in Annex 5, and sample flow rates shall be set to the appropriate levels.

1.2.9.1.6. Any electronic integrating device shall be zeroed and may be re-zeroed before the start of any cycle phase.

1.2.9.1.7. For all continuous gas analysers, the appropriate ranges shall be selected. These may be switched during a test only if switching is performed by changing the span over which the digital resolution of the instrument is applied. The gains of an analyser's analogue operational amplifiers may not be switched during a test.

1.2.9.1.8. All continuous gas analysers shall be zeroed and spanned using gases fulfilling the requirements of §6.0. in Annex 5.

1.2.10. Particulate Mass Sampling

1.2.10.1. The following steps shall be taken prior to each test:

1.2.10.1.1. Filter Selection

1.2.10.1.1.1. A single particulate filter without back-up shall be employed for the complete test cycle driven for that class of vehicle.

1.2.10.1.2. Filter Preparation

1.2.10.1.2.1. At least one hour before the test, the filter shall be placed in a petri dish protecting against dust contamination and allowing air exchange, and placed in a weighing chamber for stabilization.
At the end of the stabilization period, the filter shall be weighed and its weight shall be recorded. The filter shall then be stored in a closed petri dish or sealed filter holder until needed for testing. The filter shall be used within eight hours of its removal from the weighing chamber.
The filter shall be returned to the stabilisation room within 1 hour after the test and shall be conditioned for at least one hour before weighing.

1.2.10.1.2.2. The particulate sample filter shall be carefully installed into the filter holder. The filter shall be handled only with forceps or tongs. Rough or abrasive filter handling will result in erroneous weight determination. The filter holder assembly shall be placed in a sample line through which there is no flow.

1.2.10.1.2.3. It is recommended that the microbalance be checked at the start of each weighing session within 24 hours of the sample weighing by weighing one reference weight of 100 mg. This weight shall be weighed three times and the average result recorded. If the average result of the weighings is ± 5 μg of the result from the previous weighing session then the weighing session and balance are considered valid.

1.2.11. Particle Number Sampling

1.2.11.1. The following steps shall be taken prior to each test:

1.2.11.1.1. The particle specific dilution system and measurement equipment shall be started and made ready for sampling.

1.2.11.1.2. The correct function of the particle counter and volatile particle remover elements of the particle sampling system shall be confirmed according to the following procedures:

1.2.11.1.2.1. A leak check, using a filter of appropriate performance attached to the inlet of the entire particle number measurement system (VPR and PNC), shall report a measured concentration of less than 0.5 particles cm^{-3}.

1.2.11.1.2.2. Each day, a zero check on the particle counter, using a filter of appropriate performance at the counter inlet, shall report a concentration of ≤ 0.2 particles cm^{-3}. Upon removal of the filter, the particle counter shall show an increase in measured concentration to at least 100 particles cm^{-3} when sampling ambient air and a return to ≤ 0.2 particles cm^{-3} on replacement of the filter.

1.2.11.1.2.3. It shall be confirmed that the measurement system indicates that the evaporation tube, where featured in the system, has reached its correct operating temperature.

1.2.11.1.2.4. It shall be confirmed that the measurement system indicates that the diluter PND_1 has reached its correct operating temperature.

1.2.12. Sampling during the test

1.2.12.1. The dilution system, sample pumps and data collection system shall be started.

1.2.12.2. The particulate mass and particle number sampling systems shall be started.

1.2.12.3. Particle number shall be measured continuously. The average concentrations shall be determined by integrating the analyser signals over the test cycle.

1.2. 12.4. Sampling shall begin (BS) before or at the initiation of the engine start up procedure and end on conclusion of the cycle.

1.2.12.6. Sample switching

1.2.12.6.1. Gaseous emissions
1.2.12.7.1.1 Sampling from the diluted exhaust and dilution air shall be switched from one pair of sample bags to subsequent bag pairs (if necessary) at the end of each part of the cycle to be driven for that class of vehicle. The diluted exhaust and dilution air bags shall be measured by the analytical system as soon as possible.

1.2.12.6.2. Particulate matter
1.2.12.6.2.1. Particulate matter shall be collected on a single sample filter over the duration of the cycle.

1.2.12.6.3. Particulate number
1.2.12.6.3.1. Particles number shall be measured continuously over the duration of the cycle.

1.2.12.7. Before starting a new cycle part, dynamometer distance shall be recorded

1.2.13. Ending the test
1.2.13.1. The engine shall be turned off immediately after the end of the last part of the test.

1.2.13.2. The constant volume sampler (CVS) or other suction device shall be turned off, or the exhaust tube from the tailpipe or tailpipes of the vehicle shall be disconnected.
[Should the test include a hot start, the transfer tube shall be disconnected but the CVS shall remain in operation.]

1.2.13.3. The vehicle may be removed from the dynamometer.

1.2.14. Post-test procedures

1.2.14.1. Gas analyser check

1.2.14.1.1. Zero and span gas reading of the analysers used for continuous diluted measurement shall be checked. The test shall be considered acceptable if the difference between the pre-test and post-test results is less than 2 per cent of the span gas value.

1.2.14.2. Bag analysis

1.2.14.2.1. The exhaust gases contained in the bag shall be analysed as soon as possible and in any event not later than [30] minutes after the end of the cycle phase.
[However, the gas reactivity time for species in the bag shall be ensured.]

1.2.14.2.2. Prior to each sample analysis, the analyser range to be used for each species shall be set to zero with the appropriate zero gas.

1.2.14.2.3. The analysers shall then be set to the calibration curves by means of span gases of nominal concentrations of 70 to 100 per cent of the range.

1.2.14.2.4. The analysers zero settings shall then be rechecked: if any reading differs by more than 2 per cent of the range from that set in paragraph 1.2.14.2.2. above, the procedure shall be repeated for that analyser.

1.2.14.2.5. The samples shall then be analysed.

1.2.14.2.6. After the analysis zero and span points shall be rechecked using the same gases. If these rechecks are within ± 2 per cent of those in paragraph 1.2.14.2.2. above, the analysis shall be considered acceptable.

1.2.14.2.7. At all points in paragraph 1.2.14.2., the flow-rates and pressures of the various gases through analysers shall be the same as those used during calibration of the analysers.

1.2.14.2.8. The figure adopted for the content of the gases in each of the species measured shall be that read off after stabilisation of the measuring device.

1.2.14.2.9. The mass and number of all emissions, where applicable, shall be calculated according to Annex 7 Calculations.

1.2.14.3. Particulate filter weighing

1.2.14.3.1. The particulate filter shall be returned to the weighing chamber no later than one hour after completion of the test. It shall be conditioned in a petri dish, which is protected against dust contamination and allows air exchange, for at least [one hour], and then weighed. The gross weight of the filter shall be recorded.

1.2.14.3.2. At least two unused reference filters shall be weighed within 8 hours of, but preferably at the same time as, the sample filter weighings. Reference filters shall be of the same size and material as the sample filter.

1.2.14.3.3. If the specific weight of any reference filter changes by more than ± 5µg between sample filter weighings, then the sample filter and reference filters shall be reconditioned in the weighing room and then reweighed.

1.2.14.3.4. The comparison of reference filter weighings shall be made between the specific weights and the rolling average of that reference filter's specific weights. The rolling average shall be calculated from the specific weights collected in the period since the reference filters were placed in the weighing room. The averaging period shall be at least 1 day but not exceed 15 days.

1.2.14.3.5. Multiple reconditionings and reweighings of the sample and reference filters are permitted until a period of 80 h has elapsed following the measurement of gases from the emissions test. If, prior to or at the 80 h point, more than half the number of reference filters meet the ± 5 µg criterion, then the sample filter weighing can be considered valid. If, at the 80 h point, two reference filters are employed and one filter fails the ± 5 µg criterion, the sample filter weighing can be considered valid under the condition that the sum of the absolute differences between specific and rolling averages from the two reference filters must be less than or equal to 10 µg.

1.2.14.3.6. In case less than half of the reference filters meet the ± 5 µg criterion, the sample filter shall be discarded, and the emissions test repeated. All reference filters must be discarded and replaced within 48 hours. In all other cases, reference filters must be replaced at least every 30 days and in such a manner that no sample filter is weighed without comparison to a reference filter that has been present in the weighing room for at least 1 day.

1.2.14.3.7. If the weighing room stability criteria outlined in paragraph 4.2.2.1. of Annex 5 Test Equipment and Calibrations are not met, but the reference filter weighings meet the above criteria, the vehicle manufacturer has the option of accepting the sample filter weights or voiding the tests, fixing the weighing room control system and re-running the test.

1.3. Type II test conditions

ANNEX 6, APPENDIX I

EMISSIONS TEST PROCEDURE FOR VEHICLES EQUIPPED WITH PERIODICALLY REGENERATING SYSTEMS

NOTE: This entire annex has yet to be reviewed.

1. General

This Appendix defines the specific provisions regarding type-approval of a vehicle equipped with periodically regenerating systems.

During cycles where regeneration occurs, emission standards can be exceeded. If a regeneration of an anti-pollution device occurs at least once per Type I test and has already regenerated at least once during vehicle preparation cycle, it will be considered as a continuously regenerating system which does not require a special test procedure. Annex 6, Appendix I does not apply to continuously regenerating systems.

At the request of the manufacturer, and subject to the agreement of the responsible technical authority, the test procedure specific to periodically regenerating systems will not apply to a regenerative device if the manufacturer provides data demonstrating that, during cycles where regeneration occurs, emissions remain below the emissions limits applied by the Contracting Party for the relevant vehicle category.

2. Test Procedure

The test vehicle shall be capable of inhibiting or permitting the regeneration process provided that this operation has no effect on original engine calibrations. Prevention of regeneration shall only be permitted during loading of the regeneration system and during the pre-conditioning cycles. It shall not be permitted during the measurement of emissions during the regeneration phase; rather the emission test shall be carried out with the unchanged original equipment manufacturer's (OEM) control unit.

2.1. Exhaust emission measurement between two cycles where regenerative phases occur

2.1.1. Average emissions between regeneration phases and during loading of the regenerative device shall be determined from the arithmetic mean of several approximately equidistant (if more than 2) Type I operating cycles or equivalent engine test bench cycles. As an alternative the manufacturer may provide data to show that the emissions remain constant (±15 per cent) between regeneration phases. In this case, the emissions measured during the regular Type I test may be used. In any other case emissions measurement for at least two Type I operating cycles or equivalent engine test bench cycles must be completed: one immediately after regeneration (before new loading) and one as close as possible prior to a regeneration phase. All emissions measurements shall be carried out according to this Annex and all calculations shall be carried out according to Annex 7.

2.1.2. The loading process and K_i determination shall be made during the Type I operating cycle, on a chassis dynamometer or on an engine test bench using an equivalent test cycle. These cycles may be run continuously (i.e. without the need to switch the engine off between cycles). After any number of completed cycles, the vehicle may be removed from the chassis dynamometer, and the test continued at a later time.

2.1.3. The number of cycles (D) between two cycles where regeneration phases occur, the number of cycles over which emissions measurements are made (n), and each emissions measurement (M'_{sij}) shall be reported in the test report.

2.2. Measurement of emissions during regeneration

2.2.1. Preparation of the vehicle, if required, for the emissions test during a regeneration phase, may be completed using the preparation cycles in paragraph 1.2.6. of this Annex or equivalent engine test bench cycles, depending on the loading procedure chosen in paragraph 2.1.2. above.

2.2.2. The test and vehicle conditions for the Type I test described in Annex 6 apply before the first valid emission test is carried out.

2.2.3. Regeneration must not occur during the preparation of the vehicle. This may be ensured by one of the following methods:

2.2.3.1. A "dummy" regenerating system or partial system may be fitted for the pre-conditioning cycles.

2.2.3.2. Any other method agreed between the manufacturer and the responsible authority.

2.2.4. A cold-start exhaust emission test including a regeneration process shall be performed according to the WLTP-DHC operating cycle for that class of vehicle or equivalent engine test bench cycle. If the emissions tests between two cycles where regeneration phases occur are carried out on an engine test bench, the emissions test including a regeneration phase shall also be carried out on an engine test bench.

2.2.5. If the regeneration process requires more than one operating cycle, subsequent test cycle or cycles shall be driven immediately, without switching the engine off, until complete regeneration has been achieved (each cycle shall be completed). The time necessary to set up a new test should be as short as possible (e.g. particulate matter filter change). The engine must be switched off during this period. [Use of a single particulate matter filter for multiple cycles required to complete regeneration is permissible].

2.2.6. The emission values during regeneration (M_{ri}) shall be calculated according to Annex 7. The number of operating cycles (d) measured for complete regeneration shall be recorded.

3.0. Calculations

3.1. Calculation of the combined exhaust emissions of a single regenerative system

(1) $$M_{si} = \frac{\sum_{j=1}^{n} M'_{sij}}{n} \qquad n \geq 2$$

(2) $$M_{ri} = \frac{\sum_{j=1}^{d} M'_{rij}}{d}$$

(3) $$M_{pi} = \left\{ \frac{M_{si} * D + M_{ri} * d}{D + d} \right\}$$

where for each species (i) considered:

M'_{sij} are the mass emissions of species (i) over an operating cycle (or an equivalent engine test bench cycle) without regeneration, g/km;

M'_{rij} are the mass emissions of species (i) in g/km over an operating cycle (or an equivalent engine test bench cycle) during regeneration. (if d > 1, the first Type I test is run cold, and subsequent cycles are hot), g/km;

M_{si} are the mean mass emission of species (i) without regeneration, g/km;

M_{ri} are the mean mass emission of species (i) during regeneration, g/km;

M_{pi} are the mean mass emission of species (i), g/km;

n is the number of test points at which emissions measurements (WLTC operating cycles or equivalent engine test bench cycles) made between two cycles where regenerative phases occur, ≥ 2;

d is the number of operating cycles required for regeneration;

D is the number of operating cycles between two cycles where regenerative phases occur.

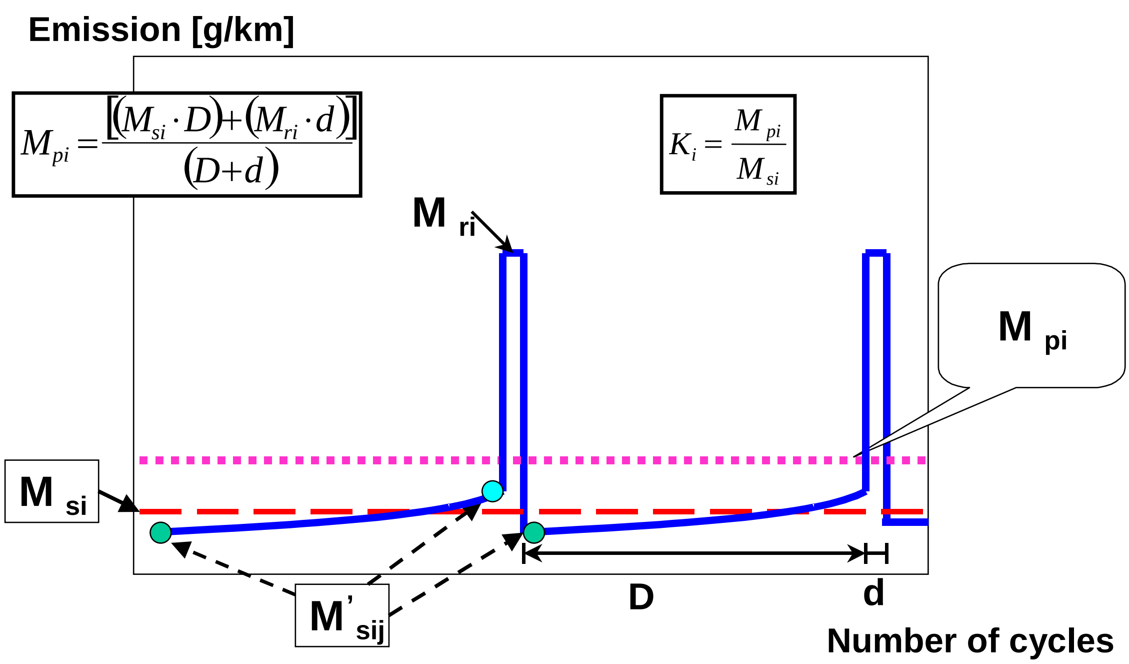


Figure 1: Parameters measured during emissions test during and between cycles where regeneration occurs (schematic example, the emissions during 'D' may increase or decrease)

3.1.1. Calculation of the regeneration factor K for each species (i) considered

The manufacturer may elect to determine either additive or multiplicative factors, For multiplicative factors: $K_i = M_{pi} / M_{si}$

For additive factors: $K_i = M_{pi} - M_{si}$

M_{si}, M_{pi} and K_i results, and the manufacturer's choice of type of factor shall be recorded in the test report.

K_i may be determined following the completion of a single sequence.

3.2. Calculation of combined exhaust emissions of multiple periodic regenerating systems

(1) $$M_{sij} = \frac{\sum_{k=1}^{n_j} M'_{sij,k}}{n_j} \qquad n_j \geq 2$$

(2) $$M_{rij} = \frac{\sum_{k=1}^{d_j} M'_{rij,k}}{d_j}$$

(3) $$M_{si} = \frac{\sum_{j=1}^{x} M_{sij} * D_j}{\sum_{j=1}^{x} D_j}$$

(4) $$M_{ri} = \frac{\sum_{j=1}^{x} M_{rij} * d_j}{\sum_{j=1}^{x} d_j}$$

(5) $$M_{pi} = \frac{M_{si} * \sum_{j=1}^{x} D_j + M_{ri} * \sum_{j=1}^{x} d_j}{\sum_{j=1}^{x} (D_j + d_j)}$$

(6) $$M_{pi} = \frac{\sum_{j=1}^{x} (M_{sij} * D_j + M_{rij} * d_j)}{\sum_{j=1}^{x} (D_j + d_j)}$$

(7) For multiplicative factors: $K_i = \frac{M_{pi}}{M_{si}}$

For additive factors: $K_i = M_{pi} - M_{si}$

where:

M_{si} is the mean mass emission of all events (j) of species (i) without regeneration, g/km;

M_{ri} is the mean mass emission of all events (j) of species (i) during regeneration, g/km;

M_{pi} are the mean mass emission of all events (j) of species (i), g/km;

M_{sij} are the mean mass emission of event (j) of species (i) without regeneration, g/km;

M_{rij} is the mean mass emission of event (j) of species (i) during regeneration, g/km

$M'_{sij,k}$ are the mass emissions of event (j) of species (i) over one [Type I] operating cycle (or equivalent engine test bench cycle) without regeneration; k test points, g/km;

$M'_{rij,k}$ are the mass emissions of event (j) of species (i) over one [Type I] operating cycle (or equivalent engine test bench cycle) during regeneration (when k > 1, the first [Type I] test is run cold, and subsequent cycles are hot); k test points, g/km

n_j are the number of test points of event (j) at which emissions measurements ([Type I operating cycles or equivalent engine test bench cycles]) are made between two cycles where regenerative phases occur, ≥ 2;

d_j number of operating cycles of event (j) required for regeneration;

D_j number of operating cycles of event (j) between two cycles where regenerative phases occur.

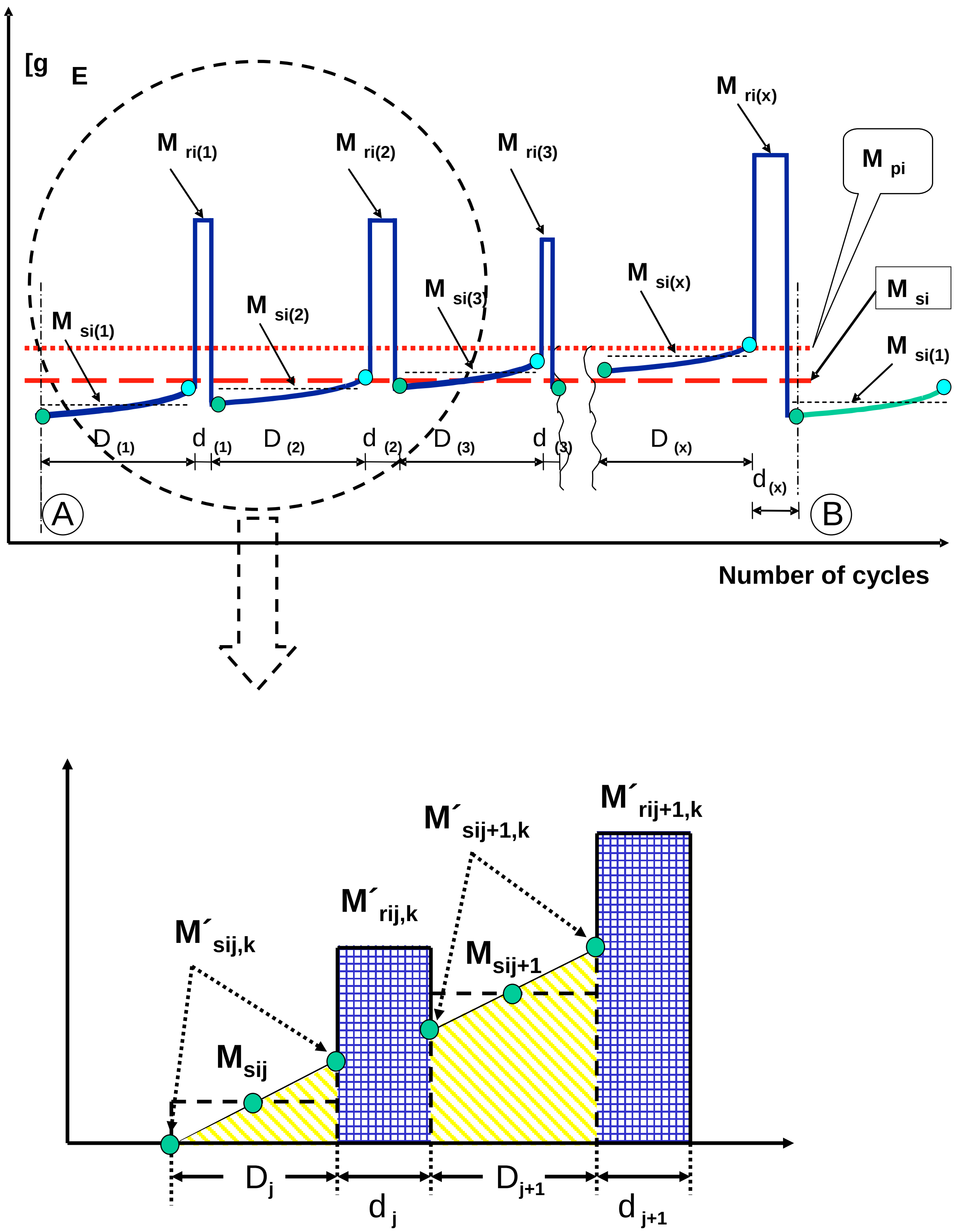


Figure 2: Parameters measured during emissions test during and between cycles where regeneration occurs (schematic example)

For application of a simple and realistic case following example is shown: A system consisting of a particulate trap (DPF) and a NOx storage trap (DeNOx).

DPF: regenerative, equidistant events, similar emissions (± 15%) from event to event

$D_j = D_{j+1} = D_1$
$d_j = d_{j+1} = d_1$
$M_{rij} – M_{sij} = M_{rij+1} – M_{sij+1}$
$n_j = n$

DeNOx: the desulphurisation (SO_2 removal) event is initiated before an influence of sulphur on emissions is detectable (±15% of measured emissions)
"$DeNO_x$": the desulphurisation (SO_2 removal) event is initiated before an influence of sulphur on emissions is detectable (±15 per cent of measured emissions) and in this example for exothermic reason together with the last DPF regeneration event performed.

$M'_{sij,k=1} = \text{const.} \rightarrow M_{sij} = M_{sij+1} = M_{si2}$
$M_{rij} = M_{rij+1} = M_{ri2}$

For SO_2 removal event:
$M_{ri2}, M_{si2}, d_2, D_2, n_2 = 1$

Complete system (DPF + DeNOx):

$M_{si} = n \times M_{si1} \times D_1 + M_{si2} \times D_2$
$M_{ri} = n \times M_{ri1} \times d_1 + M_{ri2} \times d_2$

$$M_{si} = \frac{n \cdot M_{si1} \cdot D_1 + M_{si2} \cdot D_2}{}$$

$$M_{ri} = \frac{n \cdot M_{ri1} \cdot d_1 + M_{ri2} \cdot d_2}{}$$

$$M_{pi} = \frac{M_{si} + M_{ri}}{n*(D_1 + d_1) + D_2 + d_2} = \frac{n*(M_{si1}*D_1 + M_{ri1}*d_1) + M_{si2}*D_2 + M_{ri2}*d_2}{n*(D_1 + d_1) + D_2 + d_2}$$

The calculation of the factor (K_i) for multiple periodic regenerating systems is only possible after a certain number of regeneration phases for each system. After performing the complete procedure (A to B, see Figure 8/2), the original starting conditions A should be reached again.

ANNEX 7: CALCULATIONS

1. Calculations

1.1 General requirements

1.1.1. The final test result shall be rounded in one step to the number of places to the right of the decimal point indicated by the applicable emission standard plus one additional significant figure.

1.1.1.1. The NOx correction factor, KH , shall be shall be rounded to 2 decimal places.

1.1.1.2. The dilution factor, DF, shall be rounded to 2 decimal places

1.1.1.3. For information not related to standards, good engineering judgement shall be used.

2. Determination of diluted exhaust gas volume

2.1 Diluted exhaust volume calculation for a variable dilution device, capable of operating at a constant or variable flow rate.

2.1.1. Record continuously the parameters showing the volumetric flow, and calculate the total volume for the duration of the test.

2.2. Volume calculation for a variable dilution device using a positive displacement pump

2.2.1. The volume is calculated using the following equation:

$$V = V_0 \cdot N$$

where:

V	is the volume of the diluted gas, in litres per test (prior to correction)
V_0	is the volume of gas delivered by the positive displacement pump in testing conditions, l/N
N	is the number of revolutions per test.

2.2.1.1. Correcting the volume to standard conditions

2.2.1.1.1. The diluted exhaust gas volume is corrected to standard conditions by means of the following equation:

$$V_{mix} = V \times K_1 \times \left(\frac{P_B - P_1}{T_p}\right) \quad (1)$$

where:

$$K_1 = \frac{273.15\ (K)}{101.325\ (kPa)} = 2.6961 \quad (2)$$

P_B	is the test room barometric pressure, kPa;
P_1	is the vacuum at the inlet to the positive displacement pump relative to the ambient barometric pressure, kPa;
T_p	is the average temperature of the diluted exhaust gas entering the positive displacement pump during the test, K.

MASS EMISSIONS

3. Mass emissions

3.1. General requirements

3.1.1. Assuming no compressibility effects, all gases involved in the engine intake/combustion/exhaust process can be considered to be ideal according to Avogadro's hypothesis.

3.1.2. The mass M of gaseous species emitted by the vehicle during the test shall be determined by obtaining the product of the volumetric concentration and the volume of the gas in question, with due regard for the following densities under the reference conditions of 101.325 kPa and 273.15 K:

Carbon monoxide (CO):	d = 1.25 g/l
Carbon dioxide (CO_2):	d = 1.964 g/l
Hydrocarbons:	
for petrol (E5) ($C_1H_{1.89}O_{0.016}$)	d = 0.631 g/1
for diesel (B5) ($C_1H_{l.86}O_{0.005}$)	d = 0.622 g/1
for LPG ($CH_{2.525}$)	d = 0.649 g/l
for NG/biomethane (C_1H_4)	d = 0.714 g/l
for ethanol (E85) ($C_1H_{2,74}O_{0.385}$)	d = 0.932 g/l
Nitrogen oxides (NO_x):	d = 2.05 g/1
Nitrogen dioxide (NO_2):	d = 2.05 g/1
Nitrous oxide (N_2O):	d = 1.964 g/1

3.2. Mass emissions calculation

3.2.1. Mass emissions of gaseous species shall be calculated using the following equation:

$$M_i = \frac{V_{mix} \times \rho_i \times KH \times C_i \times 10^{-6}}{d} \quad (3)$$

where:

M_i	is the mass emission of emissions species i, g/km
V_{mix}	is the volume of the diluted exhaust gas expressed in litres per test and corrected to standard conditions (273.15 K and 101.325 kPa)
ρ_i	is the density of emissions species i in grams per litre at normal temperature and

	pressure (273.15 K and 101.325 kPa)
KH	is a humidity correction factor applicable only to the mass emissions of oxides of nitrogen (NO_2 and NO_X)
C_i	is the concentration of emissions species i in the diluted exhaust gas expressed in ppm and corrected by the amount of the emissions species i contained in the dilution air
d	is the distance corresponding to the operating cycle, kilometres.

3.2.1.1. The concentration of a gaseous species in the diluted exhaust gas shall be corrected by the amount of the gaseous species in the dilution air as follows:

$$\mathbf{C_i = C_e - C_d \times \left(1 - \frac{1}{DF}\right)} \qquad (4)$$

where:

C_i	is the concentration of gaseous species (i) in the diluted exhaust gas corrected by the amount of (I) contained in the dilution air, ppm;
C_e	is the measured concentration of gaseous species (i) in the diluted exhaust gas, ppm;
C_d	is the concentration of gaseous species (i) in the air used for dilution, ppm;
DF	is the dilution factor.

3.2.1.1.1. The dilution factor, DF, is calculated as follows:

$$DF = \frac{13.4}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \quad \text{for petrol (E5)} \qquad (5a)$$

$$DF = \frac{13.5}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \quad \text{for diesel (B5)} \qquad (5b)$$

$$DF = \frac{11.9}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \quad \text{for LPG} \qquad (5c)$$

$$DF = \frac{9.5}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \quad \text{for NG/biomethane} \qquad (5d)$$

$$DF = \frac{12.5}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \quad \text{for ethanol (E85)} \qquad (5e)$$

3.2.1.1.2. General equation for dilution factor (DF) for each reference fuel with an average composition of $C_xH_yO_z$:

$$DF = \frac{X}{C_{CO2} + (C_{HC} + C_{CO}) \times 10^{-4}} \qquad (6)$$

where: $$X = 100 \times \frac{x}{x + \frac{y}{2}} + 3.76\left(x + \frac{y}{4} + \frac{z}{2}\right)$$

In these equations:

C_{CO2} is the concentration of CO_2 in the diluted exhaust gas contained in the sampling bag, per cent volume;

C_{HC} is the concentration of HC in the diluted exhaust gas contained in the sampling bag, ppm carbon equivalent;

C_{CO} is the concentration of CO in the diluted exhaust gas contained in the sampling bag, ppm.

3.2.1.1.3. Flow weighted average concentration calculation

When the CVS flow rate q_{vCVS} over the test varies more than +/- 3 per cent of the average flow rate, a flow weighted average has to be used for all continuous diluted measurements including PN:

$$C_e = \frac{\sum_{i=1}^{n} q_{VCVS}(i) \times \Delta t \times C(i)}{V} \qquad (7)$$

where:

C_e is the flow-weighted average concentration;

$q_{vCVS}(i)$ is the CVS flow rate at time t = i * Δt, m³/min;

C(i) is the concentration at time t = i * Δt, ppm;

Δt sampling interval, s;

V total CVS volume, m³.

3.2.1.2. Calculation of the NO_X humidity correction factor

In order to correct the influence of humidity on the results of oxides of nitrogen, the following calculations are applied:

$$KH = \frac{1}{1 - 0.0329 \times (H_a - 10.71)} \qquad (8)$$

where:

$$H_a = \frac{6.211 \times R_a \times P_d}{P_B - P_d \times R_a \times 10^{-2}}$$

and:

H_a is the absolute humidity, grams of water per kilogram of dry air;

R_a is the relative humidity of the ambient air, per cent;

P_d is the saturation vapour pressure at ambient temperature, kPa;

P_B is the atmospheric pressure in the room, kPa.

The KH factor shall be calculated for each phase of the test cycle.
The ambient temperature and relative humidity shall be defined as the average of the continuously measured values during each phase.

3.2.1.3. Determination of NO_2 concentration from NO and NO_X

NO_2 is determined by the difference between NO_X concentration from the bag corrected for dilution air concentration and NO concentration from continuous measurement corrected for dilution air concentration

3.2.1.3.1. NO concentrations

3.2.1.3.1.1. NO concentrations shall be calculated from the integrated NO analyser reading, corrected for varying flow if necessary.

3.2.1.3.1.2. The average NO concentration is calculated as follows:

$$C_e = \frac{\int_{t_1}^{t_2} C_{NO} \cdot dt}{t_2 - t_1}$$

where:

$\int_{t_1}^{t_2} C_{NO} \cdot dt$ is the integral of the recording of the modal NO analyser over the test (t_2-t_1);

C_e is the concentration of NO measured in the diluted exhaust, ppm;

3.2.1.3.1.3. Dilution air concentration of NO is determined from the dilution air bag. Correction is carried out according to 3.2.1.1.

3.2.1.3.2. NO_2 concentrations

3.2.1.3.2.1. Determination NO_2 concentration from direct diluted measurement

3.2.1.3.2.2. NO_2 concentrations shall be calculated from the integrated NO2 analyser reading, corrected for varying flow if necessary.

3.2.1.3.2.3. The average NO_2 concentration is calculated as follows:

$$C_e = \frac{\int_{t_1}^{t_2} C_{NO_2} \cdot dt}{t_2 - t_1}$$

where:

$\int_{t_1}^{t_2} C_{NO2} \cdot dt$ = integral of the recording of the modal NO_2 analyser over the test (t_2-t_1);

C_e is the concentration of NO_2 measured in the diluted exhaust, ppm.

3.2.1.3.2.4. Dilution air concentration of NO_2 is determined from the dilution air bag. Correction is carried out according to 3.2.1.1.

3.2.2. Determination of the HC mass emissions from compression-ignition engines

3.2.2.1. To calculate HC mass emission for compression-ignition engines, the average HC concentration is calculated as follows:

$$C_e = \frac{\int_{t_1}^{t_2} C_{HC} \cdot dt}{t_2 - t_1} \quad (9)$$

where:

$\int_{t_1}^{t_2} C_{HC} \cdot dt$ is the integral of the recording of the heated FID over the test (t_2-t_1);

C_e is the concentration of HC measured in the diluted exhaust in ppm of C_i is substituted for C_{HC} in all relevant equations.

NOTE: Section §3.2.3. is under development

3.2.3. CO_2 emissions using the regression method

3.2.3.1. If no additional tests have taken place at test mass TM_L [and/or at different road load settings (RL_{HH}, RL_{HL} and RL_{LH})], the value M_{CO2} calculated in 3.2.1 shall be attributed to all vehicles in the vehicle family.

3.2.3.2. If additional tests have taken place at test mass TM_L [and/or at different road load settings (RL_{HH}, RL_{HL} and RL_{LH})], $M_{CO2,i}$ for vehicle i in the vehicle family shall be calculated as follows:

$$M_{CO2,i} = M_{CO2,L} + \left(TM_L - TM_{L,actual} + OM_i\right) \times \left(\frac{\Delta M_{CO2}}{\Delta TM}\right)$$

where:

$M_{CO2,i}$ are the mass CO_2 emissions for vehicle (i) in the vehicle family, g/km;

$M_{CO2,L}$ are the mass CO_2 emissions for vehicle (i) at $TM_{L,actual,}$ g/km;

OM_i is the mass of optional equipment installed on vehicle (i);

ΔM_{CO2} is the difference in mass CO_2 emissions at $TM_{H, actual}$ and $TM_{L, actual}$;

ΔTM is mass difference between $TM_{H, actual}$ and $TM_{L, actual}$.

To include any future optional equipment in the same type approval, this calculation may be applied to a maximum of [50 kg] above OM_H.

3.3. Mass of particulate emissions

3.3.1. Particulate emission M_p (g/km) is calculated as follows:

$$M_p = \frac{\left(V_{mix} + V_{ep}\right) \times P_e}{V_{ep} \times d}$$

where exhaust gases are vented outside tunnel;

$$M_p = \frac{V_{mix} \times P_e}{V_{ep} \times d}$$

where exhaust gases are returned to the tunnel;

where:

V_{mix}	is the volume of diluted exhaust gases (see paragraph 2.0.), under standard conditions;
V_{ep}	is the volume of diluted exhaust gas flowing through the particulate filter under standard conditions;
P_e	is the particulate mass collected by one or more filters;
d	distance corresponding to the operating cycle, km;
M_p	is the particulate emission, g/km.

3.3.1.1. Where correction for the particulate background level from the dilution system has been used, this shall be determined in accordance with paragraph 1.2.1.4.1. in Annex 6. In this case, the particulate mass (g/km) shall be calculated as follows:

$$M_p = \left\{\frac{P_e}{V_{ep}} - \left[\frac{P_a}{V_{ap}} \times \left(1 - \frac{1}{DF}\right)\right]\right\} \times \frac{(V_{mix} + V_{ep})}{d}$$

in the case where exhaust gases are vented outside tunnel;

$$M_p = \left\{\frac{P_e}{V_{ep}} - \left[\frac{P_a}{V_{ap}} \times \left(1 - \frac{1}{DF}\right)\right]\right\} \times \frac{(V_{mix})}{d}$$

in the case where exhaust gases are returned to the tunnel;

where:

V_{ap}	is the volume of tunnel air flowing through the background particulate filter under standard conditions;
P_a	is the particulate mass collected by background filter;
P_a	is the rolling average particulate mass collected by the background filter, up to a maximum equivalent to 1mg/km and the flow rates of the test ;
DF	is the dilution factor determined in paragraph 6.6.4.

Where application of a background correction results in a negative particulate mass (in g/km) the result shall be considered to be zero g/km particulate mass.

3.3.2. Calculation of particulate mass emissions using the double dilution method

$$V_{ep} = V_{set} - V_{ssd}$$

where:

V_{ep}	is the volume of diluted exhaust gas flowing through the particulate filter under standard conditions
V_{set}	is the volume of the double diluted exhaust gas passing through the particulate

collection filters

V_{ssd} is the volume of the secondary dilution air

Where the secondary diluted PM sample gas is not returned to the tunnel, the CVS volume should be calculated as in single dilution i.e.

$$V_{mix} = V_{mix\ indicated} + V_{ep}$$

where:

$V_{mix\ indicated}$ is the measured volume of diluted exhaust gas in the dilution system following extraction of particulate sample under standard conditions

4. Determination of particle numbers

4.1. Number emission of particles shall be calculated by means of the following equation:

$$N = \frac{V \times k \times (\overline{C_s} \times \overline{f_r} - C_b \times \overline{f_{rb}}) \times 10^3}{d}$$

where:

N is the particle number emission, particles per kilometre;

V is the volume of the diluted exhaust gas in litres per test (after primary dilution only in the case of double dilution) and corrected to standard conditions (273.15 K and 101.325 kPa);

k is a calibration factor to correct the particle number counter measurements to the level of the reference instrument where this is not applied internally within the particle number counter. Where the calibration factor is applied internally within the particle number counter, the calibration factor shall be 1;

$\overline{C_s}$ is the corrected concentration of particles from the diluted exhaust gas expressed as the average number of particles per cubic centimetre figure from the emissions test including the full duration of the drive cycle. If the volumetric mean concentration results ($\overline{\boldsymbol{C}}$) from the particle number counter are not output at standard conditions (273.15 K and 101.325 kPa), the concentrations shall be corrected to those conditions ($\overline{\boldsymbol{C_s}}$);

C_b is either the dilution air or the dilution tunnel background particle concentration, as permitted by the responsible authority, in particles per cubic centimeter, corrected for coincidence and to standard conditions (273.15 K and 101.325 kPa);

$\overline{f_r}$ is the mean particle concentration reduction factor of the volatile particle remover at the dilution setting used for the test;

$\overline{f_{rb}}$ is the mean particle concentration reduction factor of the volatile particle remover at the dilution setting used for the background measurement;

d is the distance corresponding to the operating cycle, kilometres

$\bar{C}$ shall be calculated from the following equation:

$$\bar{C} = \frac{\sum_{i=1}^{n} C_i}{n}$$

where:

C_i is a discrete measurement of particle concentration in the diluted gas exhaust from the particle counter; particles per cubic centimetre and corrected for coincidence

n is the total number of discrete particle concentration measurements made during the operating cycle and shall be calculated using the following equation:

$$n = T \times f$$

where:

T is the time duration of the operating cycle, s;

f is the data logging frequency of the particle counter, Hz.

ANNEX 8: VEHICLES WITH COMPLETE OR PARTIAL ELECTRIC PROPULSION

NOTE: There are at the moment no paragraphs 1 or 2. This will be corrected for later versions

3. General Requirements

3.1. Electric Energy Consumption and Range Testing

Parameters, units and accuracy of measurements shall be as follows:

Parameter	Units	Accuracy	Resolution
Electrical energy [1]	Wh	± 1 per cent	0.001 Wh [2]
Electrical current	A	± 0.3 per cent FSD or ±1 per cent of reading [3,4]	0.01 A

[1]: Equipment: static meter for active energy
[2]: AC watt-hour meter, Class 1 according to IEC 62053-21 or equivalent
[3]: whichever is greater
[4]: current integration frequency 10 Hz or more

3.2. Emission and Fuel Consumption Testing

Parameters, units and accuracy of measurements shall be the same as those required for conventional combustion engine-powered vehicles as found in Annex 5 Test Equipment and Calibrations.

3.3. Measurement Units and Presentation of results

Accuracy of measurement units and presentation results shall be as follows:

Parameter	Units	Communication of test results
AER	km	Rounded to nearest whole number
AERcity	km	Rounded to nearest whole number
EAER	km	Rounded to nearest whole number
R_{cda}	km	Rounded to nearest whole number
R_{CDC}	km	Rounded to nearest whole number
Distance	km	For calculation purposes: 0.1km , For reporting purposes : whole number
Electric energy consumption	Wh/km	Rounded to nearest whole number
NEC	Wh	Rounded to the first decimal place
NEC ratio	%	Rounded to the first decimal place
Eac recharged E	Wh	Rounded to nearest whole number
FC correction factor	l/100km/Ah	Rounded to 4 significant figures (e.g. 0.xxxx or xx.xx)
CO_2 correction factor	g/km/Ah	Rounded to 4 significant figures (e.g. 0.xxxx or xx.xx)
Utility Factor		Rounded to 3 decimal places

4. REESS Preparation

4.1. For all OVC-HEVs, NOVC-HEVs, PEVs, [FCV-HEVs, and FCVs] with and without driver-selectable operating modes, the following shall apply:

(a) the vehicles must have been driven at least 300 km with those batteries installed in the test vehicle,

(b) if the batteries are operated above the ambient temperature, the operator shall follow the procedure recommended by the car manufacturer in order to keep the temperature of the REESS in its normal operating range. The manufacturer's agent shall be in a position to attest that the thermal management system of the REESS is neither disabled nor reduced.

4.2. In addition to fulfilling §4.1., all energy storage systems available for purposes other than providing traction (electric, hydraulic, pneumatic, etc.) for all OVC-HEVs with and without driver-selectable operating modes, and PEVs with and without driver-selectable operating modes shall be charged to the maximum level specified by the manufacturer.

5. Test Procedure

5.1. General requirements

5.1.1. For all OVC-HEVs, NOVC-HEVs, and PEVs with and without driver-selectable operating modes, the following shall apply where applicable:

(a) vehicles shall be conditioned, soaked and tested according to the test procedures applicable to vehicles powered solely by a combustion engine described in Annex 6 of this Regulation unless modified by this Annex,

(b) gear selection and the gear shift points shall be determined according to Annex 2 of this Regulation,

(c) the vehicle shall be started by the means provided for normal use to the driver,

(d) exhaust emission sampling and electricity measuring shall begin for each test cycle before or at the initiation of the vehicle start up procedure and end on conclusion of the final vehicle standstill of each test cycle,

(f) emissions species shall be sampled and analysed for each individual WLTC phase when the combustion engine starts consuming fuel,

(g) breaks for the driver and/or operator shall be permitted only between WLTC cycles as described in the table below:

Distance driven, km	Maximum total break time, min
Up to 100	10
Up to 150	20
Up to 200	30
Up to 300	60
More than 300	Shall be based on the manufacturer's recommendation

During a break, the switch for the propulsion system shall be in the "OFF" position to guarantee continuity of the control system of the vehicle.

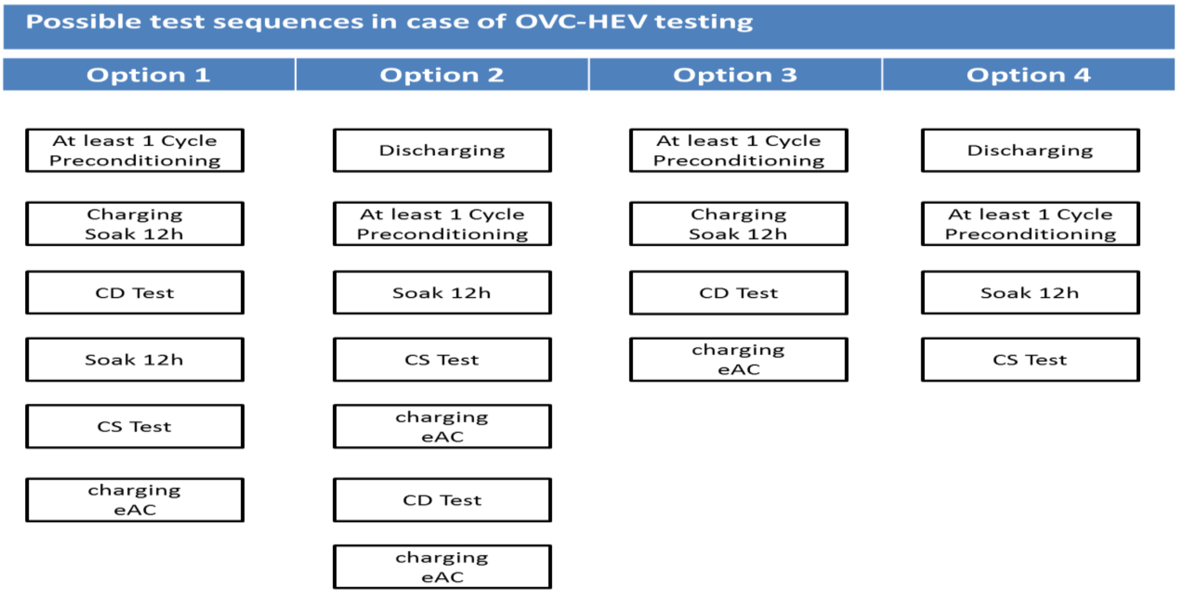
5.1.2. All OVC-HEV and PEV vehicles shall be tested using the WLTC and WLTC city cycles.

5.1.3. Forced cooling as per Annex 6, §1.2.7.3. shall apply only for the charge-sustaining test and for the testing of NOVC-HEVs.

5.2. OVC-HEV, with and without driver-selectable operating modes

5.2.1. Vehicles shall be tested under either charge-depleting (CD) and charge-sustaining (CS) conditions, or in a combination of CD and CS conditions.

5.2.2. Vehicles may be tested according to four possible test sequences:
5.2.2.1. Option 1: charge-depleting test with a subsequent charge-sustaining test (CD + CS test),
5.2.2.2. Option 2: charge-sustaining test with a subsequent charge-depleting test (CS + CD test),
5.2.2.3. Option 3:charge-depleting test with no subsequent charge-sustaining test (CD test),
5.2.2.4. Option 4: charge-sustaining test with no subsequent charge-depleting test (CS test).



5.2.3. A change of driver-selectable operating mode shall be permitted during a CD or a CS test.

5.2.4. Charge-depleting (CD) test with no subsequent charge-sustaining (CS) test
5.2.4.1. Preconditioning
The vehicle shall be prepared according to the procedures in Appendix IV, §2.2. of this Annex.

5.2.4.2. Test conditions
5.2.4.2.1. The test shall be carried out with a fully charged electrical energy storage device according the charging requirements as described in 2.2.5. of Appendix IV of this Annex.

5.2.4.2.2. Operation mode selection

5.2.4.2.2.1. The charge depletion test shall be performed by using the most electric energy consuming mode that best matches the driving cycle. If the vehicle cannot follow the trace, other installed propulsion systems shall be used to allow the vehicle to best follow the cycle.

5.2.4.2.2.2. Dedicated driver-selectable modes such as “mountain mode” or “maintenance mode” which are not intended for normal daily operation but only for special limited purposes shall not be considered for charge-depleting condition testing.

5.2.4.3. Type I test procedure

5.2.4.3.1. The charge-depleting test procedure shall consist of a number of consecutive cycles, each followed by a maximum [20] minute soak period until charge-sustaining operation is achieved.

5.2.4.3.2. During soaking between individual WLTC cycles, the key switch shall be in the “off” position, and the REESS shall not be recharged from an external electric energy source. The RCB instrumentation shall not be turned off between test cycle phases. In the case of ampere-hour meter measurement, the integration shall remain active throughout the entire test until the test is concluded.
Restarting after soak, the vehicle shall be operated in the required driver-selectable operation mode in case it is not already in the default mode.

5.2.4.3.3. Bags may be analysed after each phase. Optionally, analysers may be spanned and zero checked before and after each complete cycle, and the bags analysed.

5.2.4.4. End of the charge-depleting test
The end of the charge-depleting test is considered to have been reached at the end of the WLTC cycle n (defined as the transient cycle) when the break-off criteria during cycle n + 1 is reached for the first time.

5.2.4.4.1. For vehicles without charge-sustaining capability on the complete WLTC, end of test is reached by indication on standard on-board instrument panel to stop the vehicle, or when the vehicle deviates from the prescribed driving tolerance for 4 seconds or more. The acceleration controller shall be deactivated. The vehicle shall be braked to a standstill within 60 seconds.

5.2.4.5. Break-off criteria
5.2.4.5.1. The break-off criteria for the charge-depleting test is reached when the relative net energy change, NEC, as shown in the equation below is less than 4 per cent.

$$\text{Net energy change (per cent)} = \frac{\text{RCB} * \text{nominal REESS voltage}}{\text{cycle energy demand of the test vehicle}} * 100$$

5.2.4.6. REESS charging and measuring electric energy consumption
The vehicle shall be connected to the mains within 120 minutes after the conclusion of the charge-sustaining Type I test. The energy measurement equipment, placed before the vehicle charger, shall measure the charge energy, E, delivered from the mains, as well as its duration. Charging stops when a fully charged REESS is detected. The responsible authority shall confirm that the REESS is fully charged.

5.2.4.7. Each individual full WLTC within the charge-depleting test shall fulfil the applicable exhaust emission limits.

5.2.5. CS test with no subsequent CD test

5.2.5.1. Preconditioning
The vehicle shall be prepared according to the procedures in Appendix IV, §2.1. of this Annex.

5.2.5.2. Test conditions
5.2.5.2.1. The test shall be carried out with the electrical energy storage device in a neutral charging balance state.

5.2.5.2.2. Tests shall be carried out with the vehicle operated in charge-sustaining operation condition in which the energy stored in the REESS may fluctuate but, on average, is maintained at a charging neutral balance level while the vehicle is driven.

5.2.5.2.3. For vehicles equipped with a driver-selectable operating mode, the charge-sustaining test shall be performed in the charging balance neutral hybrid mode that best matches the target curve.

5.2.5.2.4. In case the requirements of the charging balance window are not fulfilled, the CS test CO_2 and fuel consumption values shall be corrected according to Appendix II, RCB compensation.

5.2.5.2.5. The profile of the state of charge of the electrical energy storage device during different stages of the Type I test is given in Appendices Ia and Ib.

5.2.5.2.6. Upon request of the manufacturer and with approval of the responsible authority, the manufacturer may set the start SOC for the charge-sustaining test.

5.2.5.3. Type I test procedure

5.2.5.3.1. If required by paragraph 6.2.1., CO_2, emissions and fuel consumption results shall be corrected according to the RCB correction as described in Appendix II.

5.2.5.3.2. The charge-sustaining test shall fulfil the applicable exhaust emission limits.

5.2.5.4. REESS charging and measuring electric energy consumption
The vehicle shall be connected to the mains within 120 minutes after the conclusion of the charge-sustaining Type I test. The energy measurement equipment, placed between the mains socket and the vehicle charger, shall measure the charge energy, E, delivered from the mains, as well as its duration. Electric energy measurement can be stopped when the state of charge after the CD/CS test is at least equal to the state of charge measured before the CD test. The state of charge shall be determined by on board or external instruments

5.2.6. CD test with a subsequent CS test
5.2.6.1. The procedures for the CD test from §5.2.4.1. to §5.2.4.5. in this Annex shall be followed.
5.2.6.2. Subsequently, the procedures for the CS test from §5.2.5.1. to §5.2.5.4. in this Annex shall be followed.

5.2.7. CS test with a subsequent CD test
5.2.7.1. The procedures for the CS test from §5.2.5.1. to §5.2.5.4. in this Annex shall be followed.

5.2.7.2. Subsequently, the procedures for the CD test from §5.2.4.3. to §5.2.4.6. in this Annex shall be followed.

5.2.8. Cycle energy demand

5.2.8.1. Cycle energy demand of the test vehicle shall be determined by one of the two options defined in Appendix VII of this Annex.

5.2.9. Electric Range Determination

5.2.9.1. The charge-depleting test procedure as described in paragraph 5.2.4. shall apply to electric range measurements.

5.2.9.2. All-electric range (AER, AERcity)
5.2.9.2.1. The total distance travelled over the WLTC cycles from the beginning of the charge-depleting test to the point in time during the test when the combustion engine starts to consume fuel shall be measured.

5.2.9.3. Equivalent all-electric range (EAER, EAERcity)
5.2.9.3.1. The range shall be calculated according to §6.4.1.2.

5.2.9.5. Charge-depleting cycle range (RCDC, RCDCcity)
5.2.9.5.1. The distance from the beginning of the charge-depleting test to the end of the last cycle prior to the cycle or cycles satisfying the break-off criteria shall be measured. This shall include the distance travelled during the transient cycle where the vehicle operates in both depleting and sustaining modes. If the charge-depleting test possesses a transient range, the R_{cdc} shall include those transient cycles or cycles.

5.2.9.6. Actual charge-depleting range (RCDA, RCDAcity)
5.2.9.6.1. The range shall be calculated according to §6.4.1.5 (and possibly an additional equation).

5.3. NOVC-HEV, with and without driver-selectable operating modes

5.3.1. Vehicle and REESS Conditioning

5.3.1.1. For preconditioning, at least 1 complete WLTC cycle shall be driven using the gear shifting procedure described in Annex 2.

5.3.1.1.1. Alternatively, at the request of the manufacturer, the SOC level of the REESS for charge-sustaining test can be set according to manufacturer's recommendation in order to achieve a charge balance neutral charge-sustaining test.

5.3.2. Type I Test
5.3.2.1. These vehicles shall be tested according to Annex 6, unless modified by this Annex.

5.3.2.2. If required by paragraph 6.2.2., CO_2 emissions and fuel consumption results shall be corrected according to the RCB correction described in appendix II.

5.4. PEV, with and without driver-selectable operating mode
5.4.1. General

5.4.1.1. The test sequence for all-electric range AER determination as described in §5.2.9.2. for OVC-HEVs shall apply unless modified by this Annex.

5.4.1.2. The test sequence for all-electric range city AERcity determination described in §5.2.9.2. for OVC-HEVs shall apply unless modified by this Annex.

5.4.2. Testing
5.4.2.1. If the vehicle is equipped with a driver-selectable operating mode, the charge-depletion test shall be performed in the highest electric energy consumption mode that best matches the target curve.

5.4.2.2. The gear shift prescription defined in Annex 2 shall be used.

5.4.2.3. The measurement of all-electric range, AER, and electric energy consumption shall be performed during the same test.

5.4.2.4. All-electric range test
5.4.2.4.1. The test method shall include the following steps:

(a) initial charging of the REESS;

(b) driving consecutive WLTC cycles until the break-off criteria is reached and measuring AER;

(c) recharging the REESS and measuring electric energy consumption

5.4.2.4.1.1. The initial charging procedure of the REESS starts with a normal overnight charge. The end of charge criteria shall correspond to a charging time of 12 hours except if a clear indication is given to the driver by the standard instrumentation that the REESS is not yet fully charged. In this case,

$$\text{maximum time} = 3 * \frac{\text{claimed REESS capacity, Wh}}{\text{mains power supply, W}}$$

5.4.2.4.1.2. WLTC cycles shall be driven and the all-electric range (AER) distance shall be measured.

5.4.2.4.1.3. The end of the test occurs when the break-off criteria is reached.

The break-off criteria shall have been reached when the vehicle deviates from the prescribed driving tolerance for 4 seconds or more. The acceleration controller shall be deactivated. The vehicle shall be braked to a standstill within 60 seconds.
[For vehicles with a maximum speed lower than the maximum speed on the WLTC, the vehicle shall be operated at maximum available power when the vehicle cannot achieve the driving trace within the speed and time tolerances specified in Annex 2 of this regulation].

5.4.2.4.1.4. The vehicle shall be connected to the mains within 120 minutes after the conclusion of the all-electric range AER determination. The energy measurement equipment, placed between the mains socket and the vehicle charger, shall measure the charge energy E delivered from the mains, as well as its duration. Charging stops when a fully charged REESS is detected. The responsible authority shall confirm that the REESS is fully charged.

5.4.2.5. All-electric range city (AERcity) test

5.4.2.5.1. The test method includes the following steps:

(a) initial charging of the REESS;
(b) driving the WLTCcity cycle to measure the AERcity;
(c) measuring electric range, AERcity, until the break-off criteria is reached

5.4.2.5.1.1. The initial charging procedure of the REESS shall start with a normal overnight charging and the end of charge criteria shall be defined as in §5.4.2.4.1.1

5.4.2.5.1.2. City cycles shall be driven and the all-electric range (AER) distance shall be measured.

5.4.2.5.1.3. The end of the test occurs when the break-off criteria is reached according to §5.4.2.4.1.3.

6. Calculations
6.1. Emission species calculations
Exhaust gases shall be analysed according to Annex 6.
All equations shall apply to WLTC cycle and WLTC city cycle tests

6.1.1. OVC-HEV with and without operating mode switch
6.1.1.1. Charge-depleting mode emissions

The level of the emission species at charge-depleting shall be calculated as follows:

$$M_{i,CD} = \frac{\sum_{j=1}^{k}(UF_j * M_{i,CD,j})}{\sum_{j=1}^{k} UF_j}$$

where:
$M_{i,CD,j}$ is the mass of the emissions species measured during the j^{th} phase, mg/km
i is the emissions species
UF_j is the fractional utility factor of the j^{th} phase
j is the index number of the phases up to the end of the transient cycle n
k is the number of phases driven until the end of transient cycle n

6.1.1.2. Charge-sustaining mode emissions

Exhaust emissions from a cold start charge-sustaining test shall be calculated according the requirements for conventional vehicles as described in Annex 6.

$$Emission_{CS} = Emission_{CS,cold}$$

where
$Emission_{CS}$ are the charge-sustaining test emissions, g/km
$Emission_{CS,cold}$ are the emissions measured from the cold start charge-sustaining test, g/km

The calculations specified in Annex 7 of this regulations shall be used in conjunction with the above equation in measuring each regulated emissions species.

6.1.1.3. Weighted emissions species
The weighted emissions species from the charge-depleting and charge-sustaining test results shall be calculated using the equation below:

$$M_{i,weighted} = \sum_{j=1}^{k}(UF_j * M_{i,CD,j}) + (1 - \sum_{j=1}^{k} UF_j) * M_{i,CS}$$

where:

$M_{i,weighted}$	is the utility factor-weighted exhaust emissions of each measured emission species, mg/km
i	is the emissions species
UFj	is the fractional utility factor of the jth phase
$M_{i,CD,j}$	are the species mass emissions measured during the jth charge-depleting phase, mg/km
$M_{i,CS}$	are the species mass emissions for the charge-sustaining test according to 6.1.1.3., mg/km
j	is the index number of the phases up to the end of the transient cycle n
k	is the number of phases driven until the end of transient cycle n

6.1.2. NOVC-HEV with and without driver-selectable operating modes
6.1.2.1. Exhaust emissions shall be calculated as required for conventional vehicles according to Annex 7.
6.1.2.2. The charging balance correction (RCB) calculation is not required for the determination of emissions species.

6.2. CO_2 and Fuel Consumption Calculations
Exhaust gases shall be analysed according to Annex 6.

6.2.1. OVC-HEV with and without an operating mode switch
All equations shall apply to the WLTC cycle and WLTC city cycle tests.

6.2.1.1. Charge-depleting CO_2 Emissions

The CO_2 values at charge-depleting shall be calculated as follows:

$$CO_{2,CD} = \sum_{j=1}^{k}(UF_j * CO_{2,CD,j}) / \sum_{j=1}^{k} UF_j$$

where:

$CO_{2,CD}$ is the utility factor-adjusted mass of CO_2 emissions during charge-depleting mode, (g/km)

$CO_{2,CD,j}$ are the CO_2 emissions measured during the jth charge-depleting phase, g/km

UF_j the driving cycle and phase-specific utility factor according to Appendix VII of this Annex

j is the index number of each phase up to the end of the transient cycle n
k is the number of phases driven up to the end of transient cycle n

6.2.1.2. Charge-depleting fuel consumption

The fuel consumption values at charge depleting shall be calculated as follows:

$$FC_{CD} = \sum_{j=1}^{k} (UF_j * FC_{CD,j}) / \sum_{j=1}^{k} UF_j$$

where:
FC_{CD} is the utility factor-adjusted fuel consumption charge-depleting mode, l/100 km
$FC_{CD,j}$ is the fuel consumption measured during the j^{th} charge-depletion phase, l/100 km
UF_j is the driving cycle and phase-specific utility factor according to Appendix II of this Annex
j is the index number of each phase up to the end of the transient cycle n
k is the number of phases driven up to the end of transient cycle n

6.2.1.3. Charge-sustaining fuel consumption and CO2 emissions

6.2.1.3.1. Test result correction as a function of REESS charging balance

The corrected values $CO_{2,CS,corrected}$ and $FC_{CS,FC,corrected}$ shall correspond to a zero energy balance (RCB = 0), and shall be determined according to Appendix II of this Annex.

6.2.1.3.2. The electricity balance, Q, measured using the procedure specified in Appendix III to this Annex, is used as a measure of the difference in the vehicle REESS's energy content at the end of the cycle compared to the beginning of the cycle. The electricity balance is to be determined for the WLTC cycle driven.

6.2.1.3.3. The test results shall be the uncorrected measured values of $CO_{2,CS}$ and FC_{CS} in case any of the following applies:
(a) the manufacturer can prove that there is no relation between the energy balance and fuel consumption,
(b) ΔE_{REESS} as calculated from the test result corresponds to REESS charging,
(c) ΔE_{REESS} as calculated from the test result corresponds to REESS discharging and ΔE_{REESS}, as expressed as a percentage of the energy content of the fuel consumed over the cycle, as calculated in the equation below, is less than the RCB correction criteria, according to the following table:

$$\Delta E_{REESS} = \frac{0.0036 * RCB[Ah] * V_{REESS}}{E_{Fuel}} * 100[\%] \leq \text{RCB correction criteria}$$

Cycle	WLTC City (L+Med)	WLTC (L+Med+High+eHigh)	WLTC (L+Med+High)
RCB correction criteria [%]	1,5 [ACEA proposal]	0,5 (Agreed)	1 [ACEA proposal]

where:

ΔE_{REESS}	is the change in the electrical REESS energy content, MJ;
V_{REESS}	is the nominal REESS voltage, V;
RCB	is REESS charging balance over the whole cycle, Ah;
E_{Fuel}	is the energy content of the consumed fuel, MJ

Where the RCB correction of CO_2 and fuel consumption measurement values are required, the procedure described in Appendix II of this Annex shall be used.

6.2.1.4. Weighted CO_2 Emissions

The weighted CO_2 emissions from the charge-depleting and charge-sustaining test results shall be calculated using the equation below:

$$CO_{2,weighted} = \sum_{j=1}^{k}(UF_j * CO_{2,CD,j}) + (1 - \sum_{j=1}^{k} UF_j) * CO_{2,CS}$$

where:

$CO_{2,weighted}$	are the utility factor-weighted CO_2 emissions, g/km;
UF_j	is the fractional utility factor of the j^{th} phase;
$CO_{2,CD,j}$	are the CO_2 emissions measured during the j^{th} charge-depleting phase, g/km;
$CO_{2,CS}$	are the CO_2 emissions for the charge-sustaining test according to 6.1.1.3., g/km;
j	is the index number of each phase up to the end of the transient cycle n;
k	is the number of phases driven up to the end of transient cycle n.

6.2.1.5. Weighted FC Emissions

The weighted fuel consumption from the charge-depleting and charge-sustaining test results shall be calculated using the equation below:

$$FC_{weighted} = \sum_{j=1}^{k}(UF_j * FC_{CD,j}) + (1 - \sum_{j=1}^{k} UF_j) * FC_{CS}$$

where:

$FC_{weighted}$	is the utility factor-weighted fuel consumption, l/100 km;
UF_j	is the fractional utility factor of the j^{th} phase;
$FC_{CD,j}$	is the fuel consumption measured during the j^{th} charge-depleting phase, l/100 km;
FC_{CS}	is the fuel consumption measured during the charge-sustaining test according to 6.1.1.3., l/100 km;
j	is the index number of each phase up to the end of the transient cycle n;
k	is the number of phases driven up to the end of transient cycle n.

6.2.2. NOVC-HEV with and without driver-selectable operating modes

6.2.2.1. Exhaust gases shall be analysed according to Annex 6.

6.2.2.2. Charge-sustaining fuel consumption and CO_2 emissions shall be calculated according to §6.2.1.3. of this Annex.

6.2.2.3. Test result correction as a function of REESS charging balance

The corrected values $CO_{2,CS,corrected}$ and $FC_{CS,FC,corrected}$ shall correspond to a zero energy balance (RCB = 0), and shall be determined according to Appendix II of this Annex.

6.2.2.3.1 The electricity balance, Q, measured using the procedure specified in Appendix III to this Annex, is used as a measure of the difference in the vehicle REESS's energy content at the end of the cycle compared to the beginning of the cycle. The electricity balance is to be determined for the WLTC cycle driven.

6.2.2.3.2. The test results shall be the uncorrected measured values of $CO_{2,CS}$ and FC_{CS} in case any of the following applies:
(a) the manufacturer can prove that there is no relation between the energy balance and fuel consumption,
(b) ΔE_{REESS} as calculated from the test result corresponds to REESS charging,
(c) ΔE_{REESS} as calculated from the test result corresponds to REESS discharging and ΔE_{REESS}, as expressed as a percentage of the energy content of the fuel consumed over the cycle, as calculated in the equation below, is smaller than the RCB correction criteria, according to the following table:

$$\Delta E_{REESS} = \frac{0.0036 * RCB[Ah] * V_{REESS}}{E_{Fuel}} * 100[\%] \leq \text{RCB correction criteria}[\%]$$

Cycle	WLTC City (L+Med)	WLTC (L+Med+High+eHigh)	WLTC (L+Med+High)
RCB correction criteria [%]	1,5 [ACEA proposal]	0,5 (Agreed)	1 [ACEA proposal]

where:
ΔE_{REESS} is the change in the electrical REESS energy content, MJ;
V_{REESS} is the nominal REESS voltage, V
RCB is REESS charging balance over the whole cycle, Ah
E_{Fuel} is the Energy content of the consumed fuel, MJ

6.2.2.3.3 Where the RCB correction of CO_2 and fuel consumption measurement values are required, the procedure described in appendix II of this Annex shall be used.

6.3. Electric Energy Consumption Calculations

6.3.1. OVC-HEV

6.3.1.1. Utility factor-weighted total AC electric energy consumption including charging losses shall be calculated using the following equations:

$$C_{weighted} = \sum_{j=1}^{k} (UF_j * C_{CD,j})$$

$$C_{CD,j} = \frac{RCB_j}{D_j * \sum_{j=1}^{k} RCB_j} * C_{AC}$$

where

$C_{weighted}$	is the utility factor-weighted total energy consumption, Wh/km,
UF_j	is the driving cycle and phase-specific utility factor according to Appendix VII of this Annex;
$C_{CD,j}$	is the calculated fraction of E_{AC} used in the j^{th} phase during the charge-depleting test, Wh;
RCB_j	is the measured charge balance of the j^{th} phase during the charge-depleting test, Ah;
D_j	is the distance driven in the j^{th} phase during the charge-depleting test, km;
E_{AC}	is the measured recharged electric energy from the grid, Wh;
j	is the index number of each phase up to the end of transient cycle n
k	is the number of phases driven up to the end of transient cycle n.

6.3.1.2. Electric energy consumption of the electric powertrain including charging losses.

6.3.1.2.1. Recharged electric energy E in Wh and charging time measurements shall be recorded in the test report.

6.3.1.2.2. Electric energy consumption C is defined by the equation:

$$C = E_{AC} / EAER$$

where:

C	is the electric energy consumption, Wh/km
E_{AC}	is the recharged electric energy from the grid, Wh
EAER	is the equivalent all-electric range according to §6.4.1.3., km

6.3.1.3. Charge-depleting AC electric energy consumption including charging losses

$$C_{CD} = \frac{E_{weighted}}{\sum_{j=1}^{k} UF_j}$$

6.3.2. Pure electric vehicle (PEV)

6.3.2.1. Recharged electric energy E in Wh and charging time measurements shall be recorded in the test report.

6.3.2.2. The electric energy consumption C including charging losses is defined by the equation:

$$C = E_{AC} / AER$$

where:

C	is the electric energy consumption, Wh/km;
E_{AC}	is the recharged electric energy from the grid, Wh;

AER is the all-electric range as defined in B.3. Definitions of this GTR.

6.4. Electric Range

6.4.1. OVC-HEV
All equations apply to the WLTC cycle and WLTC city cycle tests.

6.4.1.1. All-electric range, AER
The distance driven over a number of WLTC cycles using only the REESS until the combustion engine starts consuming fuel for the first time shall be measured and shall be rounded to the nearest whole number.

6.4.1.2. Equivalent all-electric range, EAER

6.4.1.2.1. EAER shall be calculated as follows:

$$EAER = \left(\frac{CO_{2,CS} - CO_{2,CDavg}}{CO_{2,CS}}\right) * R_{cdc}$$

where:

$$CO_{2,CD,avg} = \frac{\sum_{j=1}^{k} CO_{2,CD,}}{\sum_{j=1}^{k} D_j}$$

and:

EAER	is the equivalent all-electric range EAER, km
$CO_{2,CS}$	are the CO_2 emissions during the charge-sustaining test, g/km
$CO_{2,CD,j}$	are the CO_2 emissions in the j^{th} phase during the charge-depletion test, g
D_j	is the distance driven in the j^{th} phase during the charge-depletion test, km
R_{cdc}	is the charge-depleting cycle range, km
j	is the index number of each phase up to the end of the transient cycle n
k	is the number of phases driven up to the end of the transient cycle n

6.4.1.3. Charge-depleting Cycle Range R_{cdc}
The distance from the beginning of the charge-depleting test to the end of the last cycle prior to the cycle or cycles satisfying the break-off criteria shall be measured. This shall include the distance travelled during the transient cycle where the vehicle operates in both depleting and sustaining modes. If the charge-depleting test possesses a transient range, the R_{cdc} shall include those transient cycles or cycles.

<u>NOTE: §6.4.1.4. below currently under review.</u>

[6.4.1.4. Actual charge-depleting cycle range R_{cda}

Option 1: Based on CO_2 value

$$R_{cda} = \sum_{j=1}^{n-1} D_{j,cycle} + \left(\frac{CO_{2,CS} - CO_{2,n,cycle}}{CO_{2,CS} - CO_{2,CD,average,n-1}}\right) * D_n$$

where:

R_{cda}	is the actual charge-depleting range, km
$CO_{2,CS}$	are the CO_2 emissions during the charge-sustaining test, g/km
$CO_{2,n,cycle}$	are the CO_2 emissions over the n^{th} drive cycle in charge-depleting operating condition, g/km
$CO_{2,CD,average,n-1}$	are the average CO_2 emissions in charge-depleting operating condition until the $n-1^{th}$ drive cycle, g/km
$D_{j,cycle}$	is the test distance travelled during j^{th} drive cycle, km
D_n	is the test distance travelled during the n^{th} drive cycle in charge-depleting operating condition, km
j	is the index number of each whole cycle up to the end of transient cycle n
n	is the number of whole cycles driven including transient cycle n

Option 2: Based on SOC value

$$R_{cda} = \sum_{j=1}^{n-1} D_{j,cycle} + \left(\frac{\Delta SOC_n}{\Delta SOC_{n-1}}\right) * D_n$$

where:

R_{cda}	is the actual charge-depleting range, km;
ΔSOC_n	is the change of state of charge during the nth drive cycle under charge-depleting conditions, per cent;
ΔSOC_{n-1}	is the change of state of charge during the $n-1^{th}$ drive cycle under charge-depleting conditions, per cent;
$D_{j,cycle}$	is the test distance travelled during the j^{th} drive cycle, km;
D_n	is the test distance travelled during the nth drive cycle in charge-depleting operating condition, km;
n	is the last charge-depleting cycle during the charge depletion test (transient cycle).

6.4.2. PEV

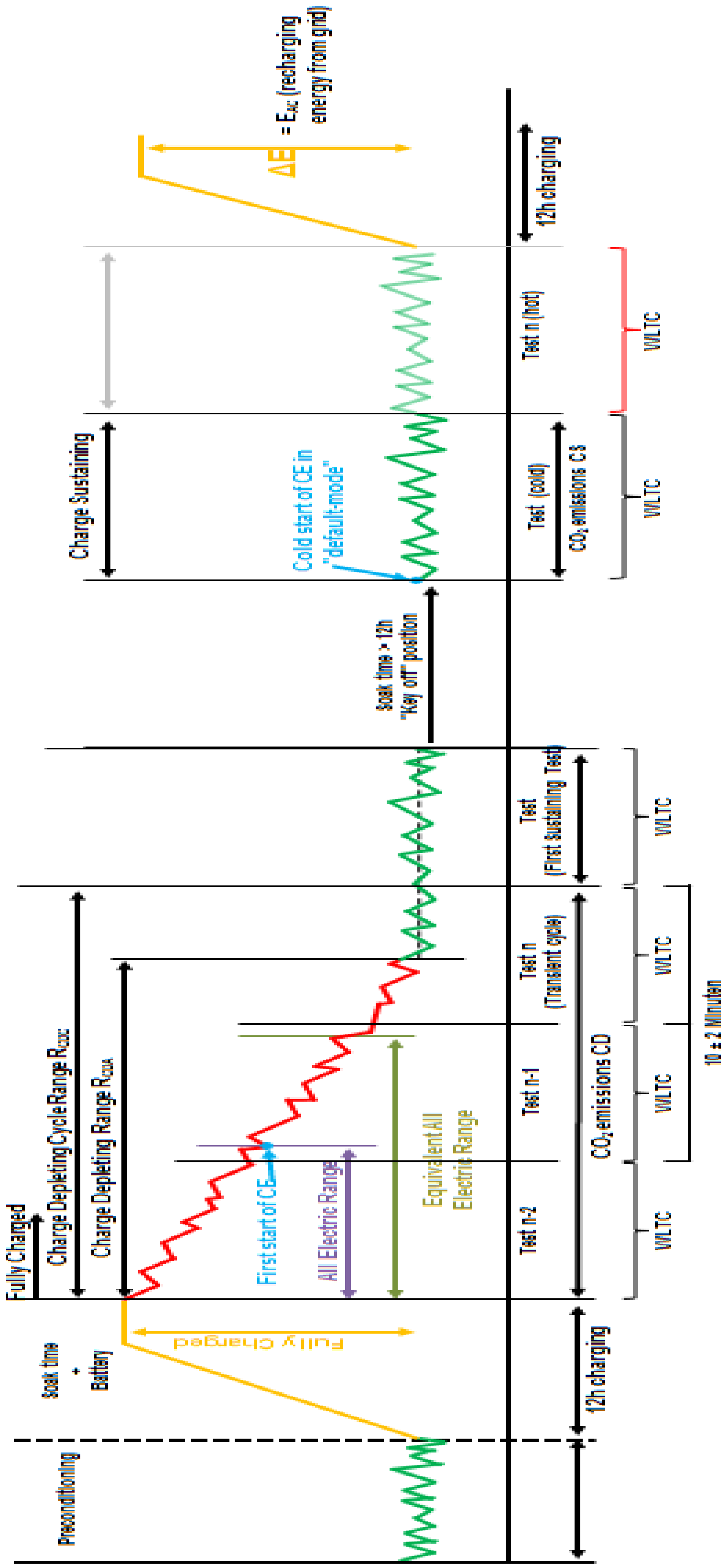
6.4.2.1. All-electric range, AER

The distance driven over complete WLTC cycles until the break-off criteria is reached shall be measured and shall be rounded to the nearest whole number.

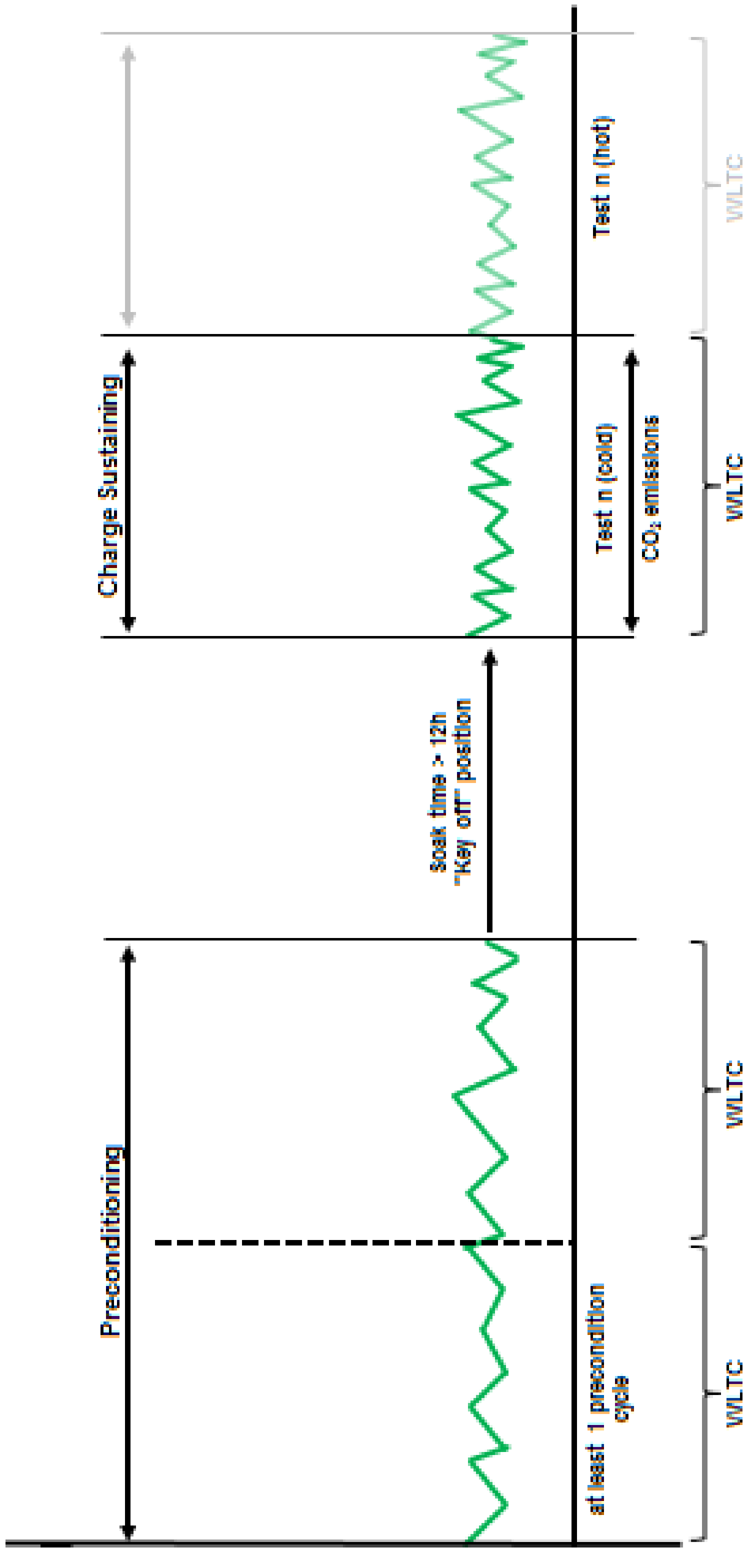
6.4.2.2. All-electric city range, AERcity

The distance driven over complete low and medium WLTC cycles until the break-off criteria is reached shall be measured and shall be rounded to the nearest whole number.

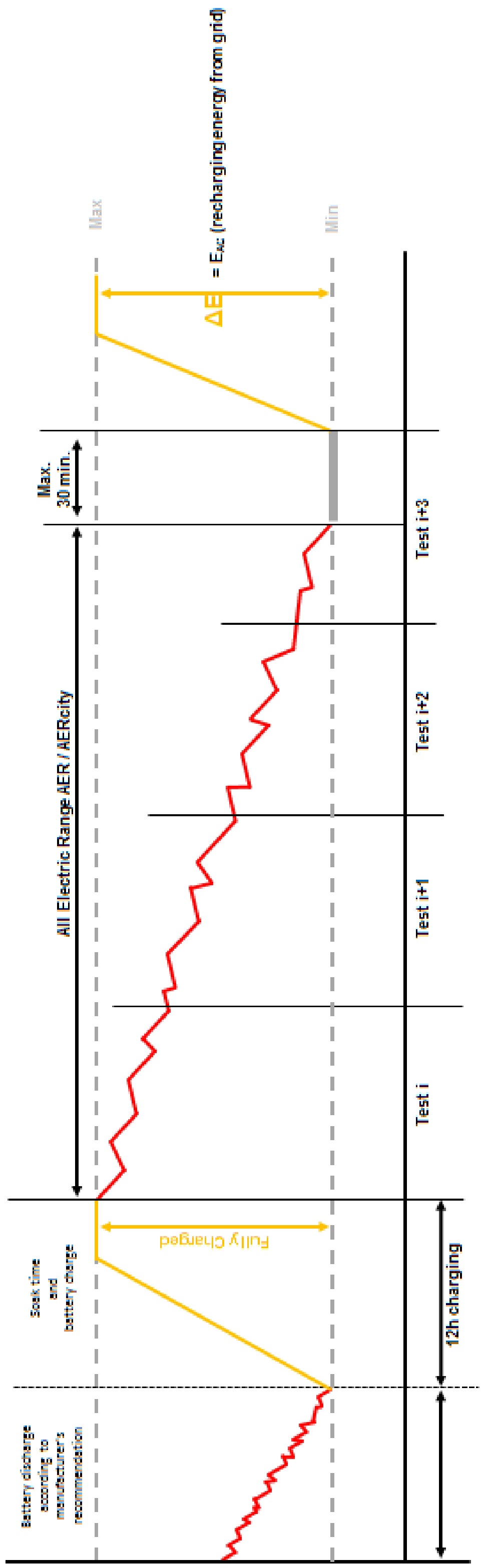
APPENDIX Ia: RCB PROFILE OVC-HEV, CHARGE-DEPLETING FOLLOWED BY CHARGE-SUSTAINING TEST



APPENDIX Ib: RCB PROFILE, OVC-HEV, CHARGE-SUSTAINING TEST



APPENDIX Ic: RCB PROFILE, PEV, ELECTRIC RANGE AND ELECTRIC ENERGY CONSUMPTION TEST



APPENDIX II: REESS CHARGE BALANCE (RCB) COMPENSATION

1. This Appendix describes the test procedure for RCB compensation of CO_2 and fuel consumption measurement results when testing NOVC-HEV and OVC-HEV vehicles.

2. Fuel consumption correction coefficient (K_{fuel}) defined by the manufacturer

2.1. The fuel consumption correction coefficient (K_{fuel}) shall be determined from a set of n measurements performed by the manufacturer. This set shall contain at least one measurement with $Q_i < 0$ and at least one with $Q_j > 0$. If the latter condition cannot be realised on the driving cycle (each part of cycle) used in this test, the responsible authority shall evaluate the statistical significance of the extrapolation necessary to determine the fuel consumption value at $\Delta E_{batt} = 0$.

2.1.1. The fuel consumption correction coefficient (K_{fuel}) is defined as:

$$K_{fuel} = (n \cdot \Sigma Q_i FC_i - \Sigma Q_i \cdot \Sigma FC_i) / (n \cdot \Sigma Q_i^2 - (\Sigma Q_i)^2)$$

where:

K_{fuel} is the fuel consumption correction coefficient, l/100 km/Ah

FC_i is the fuel consumption measured during i^{th} manufacturer's test, l/100 km

Q_i is the electricity balance measured during i^{th} manufacturer's test, Ah

n is number of data

The fuel consumption correction coefficient shall be rounded to four significant figures. The statistical significance of the fuel consumption correction coefficient is to be evaluated by the responsible authority.

2.2. Separate fuel consumption correction coefficients shall be determined for the fuel consumption values measured over [each phase of the WLTC cycle].

2.3. Fuel consumption at zero REESS energy balance (C_0)

2.3.1. The fuel consumption FC_0 at $\Delta E_{batt} = 0$ is determined by the following equation:

$$FC_0 = FC - K_{fuel} \cdot Q$$

where:

FC_0 is the fuel consumption at $\Delta E_{batt} = 0$, l/100 km

FC is the fuel consumption measured during the test, l/100 km

Q is the electricity balance measured during test, Ah

or:

$$FC' = 100/FC_0$$

where:

FC' is the fuel consumption C_0 in units of km/l

2.3.2. Fuel consumption at zero REESS energy balance shall be determined separately for the fuel consumption values measured over the [Part One] cycle and the [Part Two] cycle respectively.

3. CO_2 emission correction coefficient (K_{CO2}) defined by the manufacturer

3.1. The CO_2 emission correction coefficient (K_{CO2}) shall be determined as follows from a set of n measurements performed by the manufacturer. This set shall contain at least one measurement with $Q_i < 0$ and at least one with $Q_j > 0$. If the latter condition cannot be realised on the driving cycle (Part One or Part Two) used in this test, the responsible authority will be asked to approve the statistical significance of the extrapolation necessary to determine the CO_2 emission value at $\Delta E_{batt} = 0$.

3.1.1. The CO_2 emission correction coefficient (K_{CO2}) is defined as:

$$K_{CO2} = (n \cdot \Sigma Q_i M_i - \Sigma Q_i \cdot \Sigma M_i) / (n \cdot \Sigma Q_i^2 - (\Sigma Q_i)^2)$$

where:
K_{CO2} are the CO_2 emissions correction coefficient, g/km/Ah
M_i are the CO_2 emissions measured during i^{th} manufacturer's test, g/km
Q_i is the electricity balance during i^{th} manufacturer's test, Ah
n is the number of measurements

3.1.2. The CO_2 emission correction coefficient shall be rounded to four significant figures. The statistical significance of the CO_2 emission correction coefficient is to be judged by the responsible authority.

[3.1.3. Separate CO_2 emission correction coefficients shall be determined for the fuel consumption values measured over WLTC].

3.2. CO_2 emission at zero REESS energy balance (M_0)

3.2.1. The CO_2 emission M_0 at $\Delta E_{batt} = 0$ is determined by the following equation:

$$M_0 = M - K_{CO2} \cdot Q$$

where:
M_0 are the C_{O2} emissions at zero REESS energy balance, g/km
C is the fuel consumption measured during test, l/100 km
Q is the electricity balance measured during test, Ah

3.2.2. CO_2 emissions at zero REESS energy balance shall be determined separately for the CO_2 emission values measured over each WLTC cycle phase.

APPENDIX III: METHOD FOR MEASURING THE ELECTRICITY BALANCE OF TRACTION BATTERIES OF NOVC-HEVS AND OVC-HEVS

1. Introduction

1.1. This Appendix defines the method and required instrumentation to measure the electricity balance of OVC-HEVs and NOVC-HEVs.

Measurement of the electricity balance is necessary to determine when the minimum state of charge of the REESS has been reached during the test procedures defined in [§5.2.4. (CD test) and §5.2.5. (CS test)] of this Annex; and to correct the measured fuel consumption and CO_2 emissions for the change in REESS energy content occurring during the test.

1.2. The method described in this Annex shall be used by the manufacturer for the measurements that are performed to determine the correction factors K_{fuel} and K_{CO2}, as defined in Appendix II of this Annex.
The responsible authority shall check whether these measurements have been performed in accordance with the procedure described in this Annex.

1.3. The method described in this Annex shall be used by the responsible authority for the measurement of the electricity balance Q, as defined in [Paragraphs x.x.x.x.x.] of this Annex.

2. Measurement equipment and instrumentation

2.1. During the tests described in [Paragraphs 3., 4., 5. and 6. of this Annex], the REESS current shall be measured using a current transducer of the clamp-on or closed type. The current transducer (i.e. a current sensor without data acquisition equipment) shall have a minimum accuracy of 0.5 per cent of the measured value (in A) or 0.1 per cent of the maximum value of the scale. OEM diagnostic testers shall not be used for the purpose of this test.

2.1.1. The current transducer shall be fitted on one of the wires directly connected to the REESS. In order to easily measure REESS current using external measuring equipment, manufacturers should preferably integrate appropriate, safe and accessible connection points in the vehicle. If that is not feasible, the manufacturer is obliged to support the responsible authority by providing the means to connect a current transducer to the wires connected to the REESS in the above described manner.

2.1.2. Output of the current transducer shall be sampled with a minimum sample frequency of [5] Hz. The measured current shall be integrated over time, yielding the measured value of Q, expressed in ampere-hours (Ah).

2.1.3. The temperature at the location of the sensor shall be measured and sampled with the same sample frequency as the current, so that this value can be used for possible compensation of the drift of current transducers and, if applicable, the voltage transducer used to convert the output of the current transducer.

2.2. A list of the instrumentation (manufacturer, model no., serial no.) used by the manufacturer to determine

(a) when the minimum state of charge of the REESS has been reached during the test procedure defined in [Paragraphs 3. and 4. of this Annex]; and

(b) the correction factors K_{fuel} and KCO_2 (as defined in Appendix II of this Annex)
(c) the last calibration dates of the instruments (where applicable)

shall be provided to the responsible technical authority.

3. MEASUREMENT PROCEDURE

3.1. Measurement of the REESS current shall start at the same time as the test starts and shall end immediately after the vehicle has driven the complete driving cycle.

3.2. Separate values of Q shall be logged over the cycles required to be driven for that class of vehicle.

APPENDIX IV: CONDITIONING FOR PEV AND OVC-HEV TESTING

1. This appendix describes the test procedure for REESS and ~~IC~~ combustion engine conditioning in preparation for (a) electric range, charge-depleting and charge-sustaining measurements when testing OVC-HEV and (b) electric range measurements when testing PEV vehicles.

2. OVC-HEV combustion engine and REESS conditioning
When testing in charge-sustaining mode is followed by testing in charge-depleting mode, the charge-sustaining mode test and the charge-depleting test may be repeated independent of one another. In that case, the vehicle shall be prepared as prescribed 2.1.1. before the charge-depleting test or the charge-sustaining test starts.

2.1. OVC-HEV combustion engine and REESS condition when the test procedure starts with a charge-sustaining test

2.1.1. The soak area shall have a temperature set point of 296 K and the tolerance of the actual value shall be within ± 3 K. The temperature shall be measured continuously at a minimum of 1 Hz. This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant, if any, are within ± 2 K of the temperature of the room.

2.1.2. For preconditioning of the combustion engine, the OVC-HEV shall be driven over two consecutive WLTC cycles required for that class of vehicle. The manufacturer shall guarantee that the vehicle operates in a charge-sustaining operation. The preconditioning cycle shall be performed in a cold condition after a soak period according to §2.1.1.

2.1.3. When testing an OVC-HEV with driver-selectable operation mode, the preconditioning cycles shall be performed in the same operation mode as the charge-sustaining test as described in §5.2.5. of this Annex.

2.1.4. During the preconditioning cycle according to §2.1.2., the charging balance of the traction REESS must be recorded and shall be within the permissible charging balance deviation in §5.1.3.3.1. of this Annex.

2.1.5. If the charging balance deviation during the preconditioning cycle is higher than in [§5.1.3.3.1.] of this Annex, the preconditioning cycle according to §2.1.2. must be repeated until the charging balance deviation complies with the limit in [§5.1.3.3.1.] of this Annex.

2.1.6. Alternatively, at the request of the manufacturer, the SOC level of the REESS for the charge-sustaining test can be set according to the manufacturer's recommendation in order to achieve a charge balance neutral charge-sustaining test.
In that case an additional ICE preconditioning procedure according to the conventional vehicles can be applied.[to be validated during VP2]

2.2. OVC-HEV combustion engine and REESS condition when the test procedure starts with a charge-depleting test

2.2.1. Before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant around 298 K (25°C) within 293 K and 303 K (20 °C and 30 °C). This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant, if any, are within ± 2 K of the temperature of the room.

2.2.2. For preconditioning the combustion engine, the OVC HEV shall be driven in two consecutive WLTC. The manufacturer guarantees that the vehicle operates in a charge-depleting operation.

2.2.3. In case of testing a OVC-HEV with driver-selectable operation mode, the preconditioning cycles shall be performed in the same operation mode as the charge-depleting test as described 5.2.4. of this Annex.

2.2.4. During soak, the electrical energy storage device shall be charged, using the normal overnight charging procedure as defined in paragraph 2.2.5. below.

2.2.5. Application of a normal overnight charge

2.2.5.1. The electrical energy storage device shall be charged:

(a) with the on board charger if fitted, or

(b) with an external charger recommended by the manufacturer using the charging pattern prescribed for normal charging;

(c) in an ambient temperature comprised between 20 ºC and 30 ºC. This procedure excludes all types of special charges that could be automatically or manually initiated like, for instance, the equalisation charges or the servicing charges. The manufacturer shall declare that during the test, a special charge procedure has not occurred.

2.2.5.2. End of charge criteria

The end of charge criteria corresponds to a charging time of 12 hours, unless a clear indication is given to the driver by the standard instrumentation that the electrical energy storage device is not yet fully charged. In this case:[JP will consider later]

$$\text{Maximum time} = 3 * \frac{\text{claimed REESS capacity (Wh)}}{\text{mains power supply (W)}}$$

3. PEV REESS conditioning

3.1. Initial charging of the REESS

Charging the REESS consists of discharging the REESS and applying a normal overnight charge

3.1.1. Discharging the REESS

Discharge test procedure shall be performed according to the manufacturer's recommendation. The manufacturer will guarantee that the REESS is as fully depleted as is possible by the discharge test procedure.

3.1.2. Application of a normal overnight charge

The REESS shall be charged:

(a) with the on-board charger if fitted,

(b) with an external charger recommended by the manufacturer, using the charging pattern prescribed for normal charging,

(c) at an ambient temperature between between 20 °C and 30 °C.

The procedure shall exclude any special charges that could be automatically or manually initiated equalisation charges or servicing charges. The car manufacturer shall declare that no special charge procedure took place during the test.

3.1.3. End of charge criteria
The end of charge criteria shall correspond to a charging time of 12 hours except if a clear indication is given to the driver by the standard instrumentation that the REESS is not yet fully charged. In this case,[JP will consider later]

$$\text{Maximum time} = 3 * \frac{\text{claimed REESS capacity (Wh)}}{\text{mains power supply (W)}}$$

3.1.4. Fully charged REESS
A fully charged REESS is one which has been charged according to the overnight charge procedure fulfilling the end of charge criteria.

NOTE: Utility factors to be discussed outside of the GTR working groups.

APPENDIX V: [STANDARDIZED METHODOLOGY FOR DETERMINATION OF A GLOBAL HARMONIZED UTILITY FACTOR (UF) FOR OVC-HEVs]

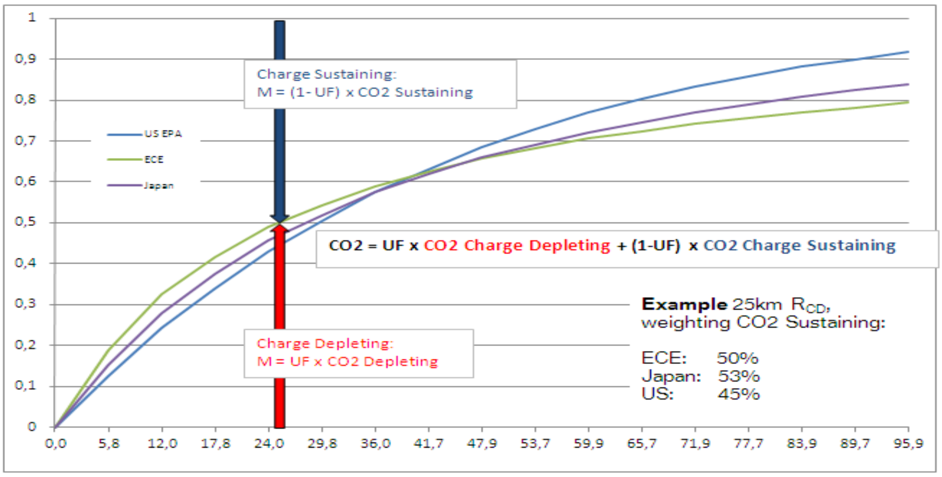
The Utility Factor UF indicates the limited utility of a particular initial operating mode (e.g. CD mode of an OVC-HEV). An operating mode with a very long range, for example, will have a very high utility and, thus, a UF that approaches 1.0. The UF result is for a distance RCD based upon a set of in-use data collected of daily miles travelled per day of a large sample group. The UF is defined by using the assumptions that (1) the vehicle starts the day from a routinely achieved, fully charged state and (2) the vehicle is charged to said state before every day of personal travel. The UF weighting for a given RCD is applied to the CD results, and the term (1-UF) is applied the CS mode results. (Source: SAE J2841, modified by TB).

It is proposed by the ACEA DTP e-Lab group to apply a Utility Factor (UF) to generate weighted combined values from a charge-depleting test condition and a charge-sustaining test condition for externally chargeable HEV (OVC HEV). For OVC HEV these weighted combined test results (e.g. for CO_2 and emission species) shall be considered to be the equivalent to the test results determined for conventional vehicles and electric vehicles as determined according to the applicable test procedures (Annex 6).

The Utility Factor is determined by statistical methods and is based on real driving behaviour data analyses. An example of how an UF can be determined is given by SAE J2841.

The UF is applied to the CD test results, and (1-UF) is applied to the CS test results.

Most OVC-HEV regulations already include utility factors to merge CD and CS values. (Remark: even the equations in Regulation No. 101 can be transformed in a way that they represent a utility factor) → see figure below (from initial OICA presentation):



The WLTP DTP e-Lab group does currently not focus on the determination of the UF. However, there is a need to further elaborate on the determination on a global harmonized utilization factor. To determine the UF, a set of statistical data needs to be generated and methodologies need to be developed how to generate the UFs from the statistical data. SAE J2841could act as an sample for such a methodology.

It is therefore recommended that the WLTP process starts with global harmonized activities to determine the methodology and gather the relevant statistical data.
The WLTP e-Lab group could support this activity, especially regards the development of a global methodology and by providing a list of data that need to be collected. The data gathering itself is beyond the capabilities of the DTP e-Lab group.

For the purpose of CO_2 and fuel consumption determination there is the need to develop equations to calculate the fractional utility factors.
Also the adoption of this known equation from the EPA legislation is possible.]

APPENDIX VIa: OVC-HEV CO_2 CALCULATION EXAMPLE

Example of a WLTP CO2 emissions calculation

PHEV carbon dioxide (CO2) emissions

The fractional UFj is the driving cycle and phase-specific UF

CD Mode	Bag No	RCB WLTC	CO_2 g/km	Ah	Wh	km	Fractional Ufj	Wh/km	YmCD [g/km]	YmCS =CS*(1-ΣUF)	Em [Wh/km]	Combined CO_2 [g/km]
1.CD	1	6,68	0,00	0,60	259,44	3,102	0,125	83,64	0,000		10,454	
	2		0,00	1,13	487,78	4,742	0,118	102,86	0,000		12,138	
	3		11,85	1,92	829,44	7,141	0,096	116,15	1,138		11,151	
	4		52,63	3,03	1308,24	8,24	0,091	158,77	4,789		14,448	
2.CD	1	6,84	0,00	0,59	256,67	3,098	0,074	82,85	0,000		6,131	
	2		0,00	1,16	498,84	4,735	0,07	105,35	0,000		7,375	
	3		7,36	2,03	875,38	7,161	0,057	122,24	0,420		6,968	
	4		36,54	3,07	1323,78	8,239	0,054	160,67	1,973		8,676	
Trans	1	2,19	0,00	0,62	266,69	3,103	0,044	85,95	0,000		3,782	
	2		0,00	1,22	527,51	4,742	0,041	111,24	0,000		4,561	
	3		92,73	0,33	143,36	7,141	0,033	20,08	3,060		0,663	
	4		150,15	0,00	0,00	8,23	0,031	0,00	4,655		0,000	
1.CS	1	-0,02	[illegible]7,95	0,54	0	3,103	0,025	0			0,000	
	2		[illegible]14,07	0,03	0	4,746	0,023	0				
	3		[illegible]08,07	0,00	0	7,161	0,018	0				
	4		[illegible]50,28	[illegible]	0	8,237	0,017	0			0,000	
								SUM	16,03	9,81	86,35	25,84

Break-off criteria is reached

UF-weighted CD CO2 Emission

CS Mode	Bag No	CO_2 g/km	Ah	Wh	km	Phase UF	Wh/km	CS [g/km]
2.CS	1	75,50	-	-	3,611	-	-	118,185
	2	112,67	-	-	5,389	-	-	
	3	107,35	-	-	5,134	-	-	
	4	151,29	-	-	7,235	-	-	
3.CS	1	70,62	-	-	3,377354	-	-	
	2	102,77	-	-	4,914853	-	-	
	3	104,51	-	-	4,998335	-	-	
	4	148,60	-	-	7,106807	-	-	

warm CS optional

APPENDIX VIb: OVC-HEV FUEL CONSUMPTION CALCULATION EXAMPLE

Example of a WLTP fuel consumption calculation

PHEV fuel consumption (FC) calculation

The fractional UFj is the driving cycle and phase-specific UF

CD Mode	Bag No	RCB WLTC	FC l/100km	Ah	Wh	km	Fractional UFj	Wh/km	YmCD [l/100km]	YmCS =CS*(1-ΣUF)	Em [Wh/km]	Combined KV [l/100km]
1.CD	1	6,68	0,00	0,60	259,44	3,102	0,125	83,64	0,000		10,454	
	2		0,00	1,13	487,78	4,742	0,118	102,86	0,000		12,138	
	3		0,52	1,92	829,44	7,141	0,096	116,15	0,049		11,151	
	4		2,29	3,03	1308,24	8,24	0,091	158,77	0,208		14,448	
2.CD	1	,84	0,00	0,59	256,67	3,098	0,074	82,85	0,000		6,131	
	2		0,00	1,16	498,84	4,735	0,07	105,35	0,000		7,375	
	3		0,32	2,03	875,38	7,161	0,057	122,24	0,018		6,968	
	4		1,59	3,07	1323,78	8,239	0,054	160,67	0,086		8,676	
Trans	1	2,19	0,00	0,62	266,69	3,103	0,044	85,95	0,000		3,782	
	2		0,00	1,22	527,51	4,742	0,041	111,24	0,000		4,561	
	3		4,03	0,33	143,36	7,141	0,033	20,08	0,133		0,663	
	4		6,28	0,00	0,00	8,23	0,031	0,00	0,195		0,000	
1.CS	1	-0,02	[illegible]	0,54	0	3,103	0,025	0			0,000	
	2		[illegible]	0,03	0	4,746	0,023	0			0	
	3		[illegible]	0,00	0	7,161	0,018	0				
	4		[illegible]	[illegible]	0	8,237	0,017	0				
								SUM	0,69	0,43	86,35	1,12

Break-off criteria is reached

UF-weighted fuel consumption

CS Mode	Bag No	FC l/100km	Ah	Wh	km	Phase UF	Wh/km	CS [l/100km]
2.CS	1	3,28	-	-	3,121	-	-	5,204978749
	2	4,90	-	-	4,733	-	-	
	3	4,67	-	-	7,154	-	-	
	4	6,58	-	-	8,23	-	-	
3.CS	1	3,07	-	-	3,111	-	-	
	2	4,47	-	-	4,75	-	-	
	3	4,54	-	-	7,152	-	-	
	4	6,46	-	-	8,244	-	-	

CS fuel consumption

warm CS optional

APPENDIX VII: DETERMINATION OF THE CYCLE ENERGY DEMAND OF THE VEHICLE

Option 1:
Calculation of Cycle Energy Demand :

$$E_{cycle} = \int_{t=0}^{t=t_{end}} \left\{ \left[F_{RL}\big(v(t)\big) + M_{test} * \frac{dv(t)}{dt} \right] . v(t). dt \right\}_{\left(\frac{dv(t)}{dt}\right)_{\geq 0}}$$

where :

E_{cycle}	is the cycle energy demand, W;
F_{RL}	is the road load force expressed as a second degree polynomial, N;
$v(t)$	cycle speed, m/sec;
M_{test}	vehicle test mass, kg;
$\left(\frac{dv(t)}{dt}\right)_{\geq 0}$	0 or 1 (only positive accelerations or steady state speeds are considered).

[Option 2:
Determination of Cycle Energy Demand by using the chassis dynamometer load table depending on the test mass of the vehicle:]

Reference mass of vehicle	Equivalent inertia	Power and load absorbed by the dynamometer at 80 km/h		Coefficients	
				a	b
Rm (kg)	kg	kW	N	N	N/(km/h)
Rm ≤ 480	455	3.8	171	3.8	0.0261
480 < Rm ≤ 540	510	4.1	185	4.2	0.0282
540 < Rm ≤ 595	570	4.3	194	4.4	0.0296
595 < Rm ≤ 650	625	4.5	203	4.6	0.0309
650 < Rm ≤ 710	680	4.7	212	4.8	0.0323
710 < Rm ≤ 765	740	4.9	221	5.0	0.0337
765 < Rm ≤ 850	800	5.1	230	5.2	0.0351
850 < Rm ≤ 965	910	5.6	252	5.7	0.0385
965 < Rm ≤ 1080	1020	6.0	270	6.1	0.0412
1080 < Rm ≤ 1190	1130	6.3	284	6.4	0.0433
1190 < Rm ≤ 1305	1250	6.7	302	6.8	0.0460
1305 < Rm ≤ 1420	1360	7.0	315	7.1	0.0481
1420 < Rm ≤ 1530	1470	7.3	329	7.4	0.0502
1530 < Rm ≤ 1640	1590	7.5	338	7.6	0.0515
1640 < Rm ≤ 1760	1700	7.8	351	7.9	0.0536
1760 < Rm ≤ 1870	1810	8.1	365	8.2	0.0557
1870 < Rm ≤ 1980	1930	8.4	378	8.5	0.0577
1980 < Rm ≤ 2100	2040	8.6	387	8.7	0.0591
2100 < Rm ≤ 2210	2150	8.8	396	8.9	0.0605
2210 < Rm ≤ 2380	2270	9.0	405	9.1	0.0619
2380 < Rm ≤ 2610	2270	9.4	423	9.5	0.0646
2610 < Rm	2270	9.8	441	9.9	0.0674

NOTE: The following Annex is under development

ANNEX 9: DETERMINATION OF SYSTEM EQUIVALENCE

Systems or analysers other than those described in this GTR may be approved by the responsible authority if it is found that they produce an output equivalent to that from reference systems or analysers.

The determination of system equivalency shall be based on a 7 sample pair (or larger) correlation study between the candidate system and one of the accepted reference systems of this GTR using the appropriate test cycle(s). The equivalency criteria to be applied shall be the F-test and the two-sided Student t-test.

Correlation testing is to be performed at the same laboratory, test cell, and on the same vehicle, and is to be run simultaneously. Should it not be possible to run the test simultaneously, it should at least be conducted concurrently. The equivalency of the sample pair averages shall be determined by F-test and t-test statistics as described below obtained under the laboratory test cell and the vehicle conditions described in this GTR. Outliers shall be determined in accordance with ISO 5725-2:1994 and excluded from the database. The systems to be used for correlation testing shall be subject to the approval by the responsible authority.

This statistical method examines the hypothesis that the sample standard deviation and sample mean value for an emission measured with the candidate system do not differ from the sample standard deviation and sample mean value for that emission measured with the reference system. The hypothesis shall be tested on the basis of a 10 per cent significance level of the F and t values. The critical F and t values for 7 to 10 sample pairs are given in Table 1. If the F and t values calculated according to the equation below are greater than the critical F and t values, the candidate system is not equivalent.

The following procedure shall be followed. The subscripts R and C refer to the reference and candidate system, respectively:

(a) conduct at least 7 tests with the candidate and reference systems operated simultaneously or, if not possible, concurrently. The number of tests is referred to as n_R and n_C.

(b) calculate the mean values $\overline{x_R}$ and $\overline{x_C}$ and the standard deviations s_R and s_C.

(c) calculate the F value, as follows:

$$F = \frac{S_{major}^2}{S_{minor}^2}$$

(the greater of the two standard deviations s_R or s_C must be in the numerator)

(d) calculate the *t* value, as follows:

$$t = \frac{|\overline{X_C} - \overline{X_R}|}{\sqrt{(n_C - 1) \times S_C^2 + (n_R - 1) \times S_R^2}} \times \sqrt{\frac{n_C \times n_R \times (n_C + n_R - 2)}{n_C + n_R}}$$

(e) compare the calculated F and t values with the critical F and t values corresponding to the respective number of tests indicated in Table 1. If larger sample sizes are selected, consult statistical tables for 10 per cent significance (90 per cent confidence) level.

(f) determine the degrees of freedom (df), as follows:

for the F-test: $df = n_R - 1 / n_C - 1$

for the t-test: $df = n_C + n_R - 2$

(g) determine the equivalency, as follows:

(i) if $F < F_{crit}$ and $t < t_{crit}$, then the candidate system is equivalent to the reference system of this GTR

(ii) if $F \geq F_{crit}$ or $t \geq t_{crit}$, then the candidate system is different from the reference system of this GTR

Table 1
t and F values for selected sample sizes

Sample Size	F-test		t-test	
	df	F_{crit}	df	t_{crit}
7	6/6	3.055	12	1.782
8	7/7	2.785	14	1.761
9	8/8	2.589	16	1.746
10	9/9	2.440	18	1.734