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Proposal for test description for cars and LCV for chassis dyno tests and RDE tests as basis for emission factors

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CONTENT

1 INTRODUCTION

This text describes the procedure for the measurement of fuel consumption and emissions of a light-duty vehicle in different test cycles.

The procedure consists of a physical test with the entire vehicle on a chassis dynamometer in an emission laboratory.

Test mass and driving resistance values are assumed to be available from weighting and coast down tests or from other sources. Default values for driving resistances based on the vehicle weight are provided in the text as option.

2 DEFINITIONS

“CVS” means Constant Volume Sampling (dilution system for emission measurements).

“DPF” means Diesel Particle Filter.

“FC” means Fuel Consumption.

“SOC” means State Of Charge of the battery

“NEDC” means New European Driving Cycle

“RDE” means Real Driving Emissions

“RWC” means Real World Cycle

“WLTC WC” means Worldwide Light duty Test Cycle with Worst Case settings

“WLTP” means Worldwide Light duty Test Procedure

“CADC” means Common Artemis Driving Cycle

“ERMES” means European Research on Mobile Emission Sources

“IUFC” means Inrets – urbain fluide court

“RDE” means Real Driving Emissions

“PEMS” means Portable Emission Measurement System

“LCV” means Light Commercial Vehicles

Others to be added on demand

3 GENERAL REQUIREMENTS

The test procedure shall be executed according to WLTP with exception of items defined differently in the text below.

The test procedure shall apply to vehicles of categories M1 and N1.

4 TECHNICAL REQUIREMENTS

4.1 Test set-up

4.1.1 Test cell

4.1.1.1 Characteristics

The test bed and test cell shall fulfil the definitions given in Annex 5 of WLTP as well as the specific requirements and definitions in this Annex.

4.1.1.2 Cooling fan in front of the vehicle.

The fan and it's positioning shall meet the requirements as given in Annex 5 of WLTP. To provide sufficient air to the condenser of the MAC system and the radiator of the engine the cooling fan shall be positioned at a distance of approximately 50cm from front of the vehicle.

4.1.1.3 Target values for temperature and humidity of the test cell.

If not specified in the chapter "test cycles" differently, humidity and temperature in the test cell shall fulfil the WLTP regulations:

"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 outlet at a minimum of 1 Hz. For temperature at the start of the test, see paragraph 1.2.8.1. in Annex 6.

1.2.2.2.1.2. The absolute humidity (Ha) of either the air in the test cell or the intake air of the engine shall be such that: $5.5 \leq H_a \leq 12.2$ (g H_2O/kg dry air)"

4.1.2 Vehicle

The test vehicle shall meet the requirements set out in paragraph 5.2 of WLTP. Furthermore the vehicle shall be measured with the default settings (as received) without any optimizations or repairs based on error memory checks. Exceptions are if the driver is informed by warning light in the instrument cluster or if the safety of humans and the environment could not be ensured before, during or after the test. Any changes against the default settings shall be reported for each vehicle.

4.1.2.1 Auxiliaries

If not specified in the chapter "test cycles" differently, all auxiliaries not necessary to run the vehicle shall be deactivated (i.e. no air conditioning, heating, light, etc. on). The information on active auxiliaries shall be put into the data collection sheet (ERMES_LDV_BagDB_Input_DataSheet_"date".xlsx in sheet "EmissionData" in column "Comment_Test").

4.1.3 Additional requirements

4.1.3.1 Battery SOC (electric imbalance)

If not specified in the chapter "test cycles" differently, the battery shall not be charged externally before and during a test. The test shall always be started at SOC which is given by the preconditioning procedure. Before the first preconditioning cycle of the vehicle on the chassis dyno it is suggested to load the battery to 100% to have common start conditions.

In case of low temperature cold start tests charging of the battery during soaking may be necessary. In this case specify in the data collection sheet (ERMES_LDV_BagDB_Input_DataSheet_"date".xlsx in sheet "EmissionData" in column "Comment_Test": "battery fully charged at test start")

The test result can later be corrected for differences in electric energy stored in the battery according to WLTP regulations. Uncorrected results shall be provided in any case, ideally also the Current flow from and to the battery shall be recorded during each test as described in WLTP.

4.1.3.2 Start/Stop systems

For vehicle types equipped with a system that automatically stalls the combustion engine when the vehicle is in standstill condition, generally known as Start/Stop systems, these systems shall be disabled during at least one entire real world test cycle to produce useful idling emission and fuel consumption values.

4.1.4 Test fuel

The test fuel shall be conform to the specifications in XII of 692/2008/EC (latest amended by 195/2013/EC).

If such test fuel is not available, local reference fuel may be used or fuel from local refuelling stations. In both cases fuel quality shall be analysed if possible. Main relevant parameters are fuel density [kg/litre] and energy density [MJ/kg] which is represented by the lower heating value (LHV).

4.2 Quantities to be measured

4.2.1 Mandatory quantities

Following quantities shall be measured and recorded at 1 Hz over the entire test cycle.

(i) Test cell temperature and test cell humidity [g/kg].

(ii) Battery current and voltage: Energy flow into the battery shall be measured as positive current, energy from the battery as negative value. The accuracy as well as the application of the current clamp for the measurement of the battery current shall be conform Annex 6 - Appendix 2 of WLTP.

(iii) The speed on the chassis dynamometer shall be recorded according to Annex 5 of WLTP.

(iv) Road load (power to the wheel) [kW] as calculated from the chassis dynamometer force and speed, see paragraph **Fehler! Verweisquelle konnte nicht gefunden werden.**.

(v) For measurement of the FC and emissions test phase following options are allowed:
(vii-1) The average FC [kg/h] per test phase by bag measurement, using the

carbon balance method and the emissions based on the evaluation method described in WLTP (or for EURO 6 tests with NEDC).

(vi) Following exhaust gas components shall be measured as minimum requirement: CO_2, CO, HC, NO_x, NO, PM. Optional PN, CH_4, NH_3, N_2O are very useful if available. Any other components are useful too but usually available only with very special analyser equipment (if single components are not available, the data still will be useful).

4.2.2 Analysers

During the test cycles, the exhaust gas analysers shall have the same calibration (span, zero) during one test. Before each test cycle one calibration shall be done.

The analysers specifications and all other requirements with regard to the checking and handling of the emission measurement system shall be conform Annex 5 of WLTP.

5 Test procedure

5.1 Vehicle preparation, dynamometer calibration procedure and soak phase

The ERMES test cycles are preceded by a soak phase if cold start tests shall be included. The preconditioning phase is established within the test cycles for bringing all the relevant vehicle parts to a defined status.

The following soak and preconditioning procedure shall be applied before a cold start test starts.

(i) Set the road load and the inertia of the roller test bed according to Annex 4 of WLTP. Mass and road load to be set as defined in chapter “test cycles”.

(ii) Set the tyre pressure according to Annex 4 of WLTP.

(iii) Soak phase. The temperature of the vehicle before test start shall be the stabilised temperature which would be reached by soaking the vehicle indoors at the target test temperature as defined in chapter “test cycles” +/- 5°C. The vehicle shall be put at the test bed in the cell at given temperatures for at least 8 hours. The temperature of the soak area in which the vehicle is soaked shall be measured and recorded according Annex 6 of WLTP. In case of forced cooling at lower temperatures, the engine oil temperature level shall be used as trigger. If engine oil temperature has reached the target value for the ambient temperature, set the test cell temperature back to target ambient temperature and stabilize the room for approximately one hour before test start.

5.2 Test cycles for emission factor production

Following test cycles are typically used in tests for emission factors from passenger cars and LCV in the ERMES group:

5.2.1 *NEDC cycle to measure type approval emission level.*

The cycle has to be pre-conditioned as described above for cold starts. Additionally before the soak phase a NEDC shall be driven. Tests and settings for mass and driving resistances shall follow the EURO 6 type approval procedure. Default values for driving resistances are provided in 5.3, if no type approval data is available. If different mass and road load settings are used – e.g. real world values – this shall be reported in the corresponding columns in the “EmissionData” sheet. Please indicate also the data source in the “RLM_source” column in the file ERMES_LDV_BagDB_Input_DataSheet_”date”.xlsx.

5.2.2 *WLTC cycle to measure emissions for the coming type approval test.*

The cycle has to be pre-conditioned as described above for cold starts.

Tests and settings for mass and driving resistances shall follow the procedure described in the WLTP draft. Default values for driving resistances are provided in 5.3, if no data are available from the manufacturer or from a coast down.

5.2.3 *IUFC cycle to measure cold start extra emissions.*

The cycle has to be pre-conditioned as described above for cold starts.

Test mass and driving resistance settings shall reflect real world driving conditions and shall be the same as in all other real world cycles (ERMES, CADC). It is recommended to use the settings of real world default data if no other information is provided. The settings have to be recorded and reported for each cycle.

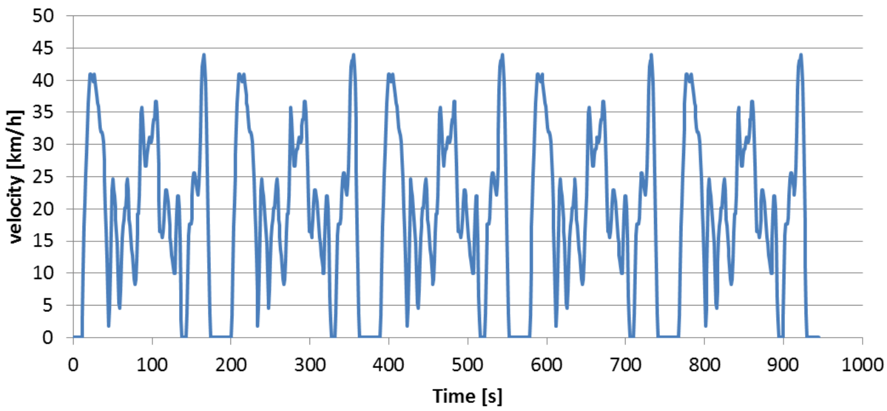

Figure 1: IUFC cycle consisting of 5 repetitions of an urban speed profile

5.2.4 *ERMES cycle to measure real world emissions and to provide test data to fill the engine emission for PHEM.*

The cycle usually is driven as hot start cycle and has to be pre-conditioned with at least 5 minutes driving at 100 km/h (with engine coolant > 70°C before start of preconditioning)[1].

The cycle can be tested additionally as cold start with defined preconditioning temperatures (recommended following temperatures: -7°C, 0°C, 10°C, 23°C, where 10°C and 23°C are seen as the most important test points).

[1] Alternative preconditioning can be based on oil temperature (80°C target). Since oil temperature is not recorded in all labs/all tests, the defined time&speed combination is preferred to have a common procedure.

Test mass and driving resistance settings shall be the same as in all other real world cycles (IUFC, CADC). It is recommended to use the settings of real world default data if no other information is provided. The settings have to be recorded and reported for each cycle.

The full load ramps in ERMES cycle shall provide high load test data. In these phases the driver shall perform full load acceleration in the gear defined (i.e. full throttle operation, for automatic transmission kick-down, until the target speed is met again, then follow the cycle as usual).

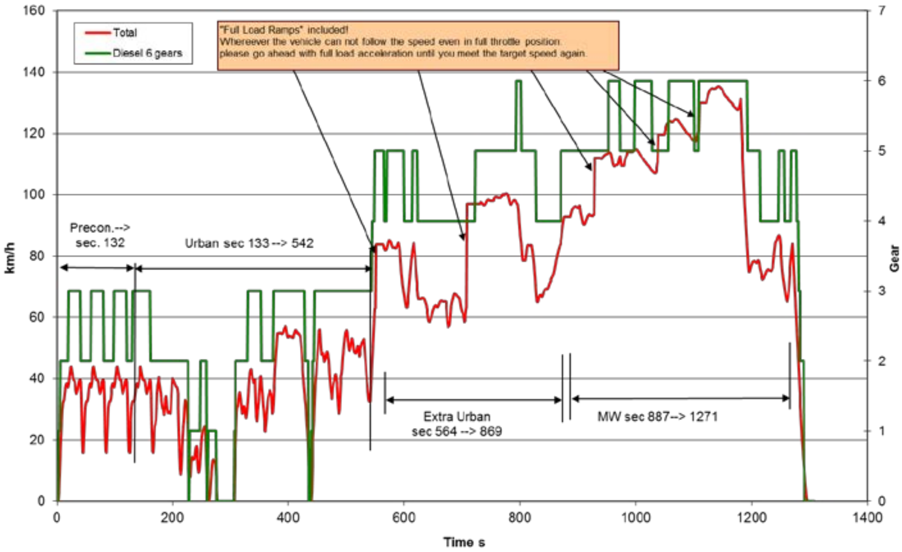

Figure 2: ERMES cycle consisting of preconditioning phase, 20 sub-cycles and 5 full load ramps

5.2.5 *CADC cycles to measure real world emissions and to provide test data to fill the engine emission for PHEM.*

The cycle usually is driven as 3 hot start cycles but also one test run consisting of urban, road and motorway is possible. The cycle(s) have to be pre-conditioned at least 5 minutes driving at 100 km/h (with engine coolant > 70°C before start of preconditioning).

The urban CADC cycle can be tested additionally as cold start with defined preconditioning temperatures (recommended following temperatures: (recommended following temperatures: -7°C, 0°C, 10°C, 23°C, where 10°C and 23°C are seen as the most important test points).

Test mass and driving resistance settings shall be the same as in all other real world cycles (IUFC, ERMES). It is recommended to use the settings of real world default data if no other information is provided. The settings have to be recorded and reported for each cycle.

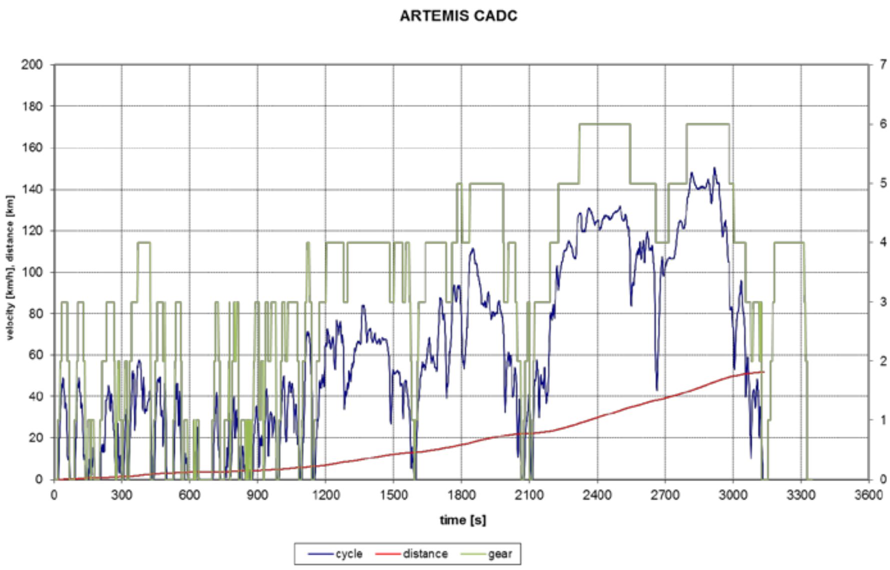

Figure 3: CADC cycles consisting of urban, road and motorway part each with different sub cycles. The urban, road and motorway part can be driven as separate cycles also.

5.2.6 Other cycles:

Any other cycles can be tested. If results are delivered to the ERMES group the cycles need to be registered in the ERMES data base (contact Infras) and in the test results settings and measured data has to be reported as defined for ERMES and CADC.

At least the NEDC and one RWC (ERMES, CADC) should be measured for each investigated vehicle.

5.3 Default road load resistances for the test cycles

General:

If vehicle specific data for NEDC and for real world road load (from own coast down tests) and vehicle mass are available, those values shall be used.

If road load values of the vehicle are not known, we suggest using different default values as described later for:

- NEDC
- WLTP
- Real World Cycles (RWC, such as CADC or ERMES)[2]

The default values suggested are based on tire specific RRC with different profile depth assumptions for NEDC and WLTP. For RWC the RRC will be calculated with a default factor based on the WLTP data. The exact RRC calculation for WLTP and RWC based on the NEDC data is described in the annex. Below a simplified version is proposed. The air drag coefficient is an average value from typical vehicles per segment. For each vehicle the cross-sectional area should be known. If no data are

[2] Different road loads can be used than suggested here. Road load setting shall be reported in the corresponding columns in the “EmissionData” sheet. Please indicate the source of the settings in the “RLM_source” column.

available, the cross-sectional area should be calculated based on the vehicle dimensions.

Basis for the default rolling resistance factors is a tire with label “E”. If for the tests tires with a higher efficiency will be used, the given rolling resistances f0 and f1 from label “E” shall be multiplied by the factor

- 0.73 for tire label “B”
- 0.86 for tire label “C”
- 1.15 for tire label “F”.

For NEDC: Segment	Example for Segment	f0 [-]	f1 [s/m]	RRC [kg/t]	Cd [-]
Segment A+B Diesel+Petrol	Fiat 500	0.0081	0.0000603	9.44	0.320
Segment C Diesel+Petrol	VW Golf				0.310
Segment D Diesel+Petrol	Audi A4				0.280
Segment E+F+J Diesel	5er BMW				0.280
Segment E+F+J Petrol	5er BMW				0.310
LCV N1-I Diesel+Petrol	Ford FiestaVan				0.320
LCV N1-II Diesel+Petrol	VW Caddy				0.335
LCV N1-III Diesel+Petrol	Mercedes Sprinter				0.350

For WLTC :Segment	Example for Segment	f0 [-]	f1 [s/m]	RRC [kg/t]	Cd [-]
Segment A+B Diesel+Petrol	Fiat 500	0.0099	0.0000570	11.19	0.340
Segment C Diesel+Petrol	VW Golf				0.332
Segment D Diesel+Petrol	Audi A4				0.300
Segment E+F+J Diesel	5er BMW				0.302
Segment E+F+J Petrol	5er BMW				0.335
LCV N1-I Diesel+Petrol	Ford ViestaVan				0.343
LCV N1-II Diesel+Petrol	VW Caddy				0.359
LCV N1-III Diesel+Petrol	Mercedes Sprinter				0.375

For Real World (= IUFC, CADC and ERMES):

For RWCs: Segment	Example for Segment	f0 [-]	f1 [s/m]	RRC [kg/t]	Cd [-]
Segment A+B Diesel+Petrol	Fiat 500	0.0108	0.0000620	12.16	Similar to WLTC
Segment C Diesel+Petrol	VW Golf				
Segment D Diesel+Petrol	Audi A4				
Segment E+F+J Diesel	5er BMW				

Segment E+F+J Petrol	5er BMW				
LCV N1-I Diesel+Petrol	Ford ViestaVan				
LCV N1-II Diesel+Petrol	VW Caddy				
LCV N1-III Diesel+Petrol	Mercedes Sprinter				

Example to calculate the road loads from the rolling resistance factors and drag coefficient/cross sectional area:

Test vehicle: Audi A3 (Segment C) with tire label “E”, kerb mass (DIN) = 1275kg, vehicle mass = 1310kg, gross vehicle mass = 1840kg, cross sectional area = 2.13m²

test_mass_NEDC = kerb mass (DIN) + 100kg = 1275kg + 100kg = 1375kg

The WLTC test mass is equal to the vehicle mass, including the existing additional equipment plus 75kg (should represent the weight of the driver).

test_mass_WLTC = vehicle mass + 75kg = 1310kg + 75kg = 1385kg

test_mass_RWC = kerb mass (DIN) + 140kg = 1275kg + 140 = 1415kg[3]

With the test mass the road loads could be determined for each cycle:

NEDC:

R0 = f0 * test_mass_NEDC * 9.81m/s² = 0.0081 * 1375kg * 9.81m/s² = 109.26 N

R1 = f1 * test_mass_NEDC * 9.81m/s² = 0.0000603s/m * 1375kg * 9.81m/s² = 0.81 Ns/m

R2 = ½ * density_air * cd * A = ½ * 1.189kg/m³ * 0.310 * 2.13m² = 0.3925 Ns²/m²

WLTC:

R0 = f0 * test_mass_WLTC * 9.81m/s² = 0.0099 * 1385kg * 9.81m/s² = 134.51 N

R1 = f1 * test_mass_WLTC * 9.81m/s² = 0.0000570s/m * 1385kg * 9.81m/s² = 0.77 Ns/m

R2 = ½ * density_air * cd * A = ½ * 1.189kg/m³ * 0.332 * 2.13m² = 0.4204 Ns²/m²

RWC:

R0 = f0 * test_mass_RWC * 9.81m/s² = 0.0108 * 1415kg * 9.81m/s² = 149.92 N

R1 = f1 * test_mass_RWC * 9.81m/s² = 0.0000620s/m * 1415kg * 9.81m/s² = 0.86 Ns/m

R2 = R2 WLTC = 0.4204 Ns²/m²

[3] Different mass settings can be used than suggested here. Mass setting shall be reported in the corresponding columns in the “EmissionData” sheet. Please indicate the source of the settings in the “RLM_source” column.

5.4 Test evaluation

5.4.1 Validity of the test

The test is regarded as valid if:

- The vehicle has not produced any error messages during the test
- The measurement equipment and data recording system had no malfunctions during the entire test.

5.4.2 Gaseous emissions sampling and analysis

The method used to measure the mass of emitted CO_2, THC, NOx, NO and CO with bags as well as the method to measure PM shall be the one prescribed in Annex 5 of WLTP. Measurements according to UN ECE regulation describing EURO 5 test procedure or later are accepted also.

5.4.3 Correction for electric energy imbalance

The eventual imbalance of electric energy produced by the alternator and/or stored in the battery shall be corrected by the difference of the average electric power measured as flow into the battery with a generic additional FC per kW engine power of called "$factor_{Willans}$" (seeTable 1) and with a generic efficiency of the alternator of 67% according to WLTP, Annex 6 -Appendix 2. The method follows the WLTP provisions. The resulting correction value shall be reported in the "SOCcorrection" column in the data collection sheet if available.

Table 1: Willans factors, transform l/kWh into kg/kWh.

			Naturally aspirated	*Supercharged*
Positive ignition	Gasoline (E0)	l/kWh	0.264	0.28
		gCO_2/kWh	630	668
	Gasoline (E5)	l/kWh	0.268	0.284
		gCO_2/kWh	628	666
	CNG (G20)	m^3/kWh	0.259	0.275
		gCO_2/kWh	465	493
	LPG	l/kWh	0.342	0.363
		gCO_2/kWh	557	591
	E85	l/kWh	0.367	0.389
		gCO_2/kWh	608	645
Compression ignition	Diesel (B0)	l/kWh	0.22	0.22
		gCO_2/kWh	581	581
	Diesel (B5)	l/kWh	0.22	0.22
		gCO_2/kWh	581	581

6 RDE-Measurements

In addition or as alternative to the tests on the chassis dyno, RDE tests with PEMS can be performed. Therefore some boundary conditions regarding the trip, the vehicle and the measured signals are suggested.

6.1 Trip parameter

Loading

The RDE measurements should be carried out with one driver, the measurement system and maximum one co-driver for passenger cars. For light commercial vehicles (LCV) an additional load of 25% from the maximal permissible payload should be added.

Trip composition

The trip shall follow the definitions in the RDE legislation for a valid trip in terms of kinematic parameters. The following table shows the statutory requirements for a valid RDE trip. *(Extract form Annex to the Commission Regulation amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (EURO6); March 2016).*

Different trip compositions can be used, as long as urban, road and motorway driving are covered and the overall test covers minimum of approx. 40 minutes. Please do not provide very special test conditions for the data base (e.g. only urban stop&go), since these cannot be aligned automatically in data evaluation yet. Such tests can be provided or reported separately.

RDE Road Category				
URBAN	vehicle speeds up to or equal to 60 km/h			
RURAL	vehicle speeds between 60 and 90 km/h			
MOTORWAY	vehicle speeds grater than 90 km/h			
RDE Requirment Checks/Boundary Conditions				
Value	***Unit***	***MIN***	***MAX***	***Describtion***
trip length	*s*	5400	7200	
trip distance	*km*	16		*For every road category (URBAN/RURAL/MW) the trip distance must be at least 16 km.*
share URBAN	*%*	29	44	*Distance based shares for the total trip distance.*
share RURAL	*%*	23	43	
share MW	*%*	23	43	
Stop periods % from urban	*%*	6	30	*Stop= v < 1 km/h. If a single stop has > 180s duration, the following 180s shall be eliminated from evaluation*
Stop period time	*s*		180	
avg. speed URBAN v_{kU}	*km/h*	15	40	*Stops included.*
avg. speed MW v_{kM}	*km/h*	90	110	*The vehicle speed shall be above 100 km/h for at least 5 min and shall cover 90 to 110km/h at minimum.*
Maximum speed	*km/h*	-	145	*The vehicle velocity for MW should not exceed 145 km/h. It may be exceede by a tolerance of 15 km/h for not more than 3% of the time duration of MW.*
RDE Dynamic Parameter				
95 Perzentil v*apos	m^2/s^3	if v_k<=74.6 km/h		*and 95 Perz* $v*a_{pos} > (0.136*v_k + 14.44)$ *the trip is invalid.*
	m^2/s^3	if v_k>74.6 km/h		*and 95 Perz* $v*a_{pos} > (0.0742*v_k + 18.966)$ *the trip is invalid.*
RPA	m/s^2	if v_k<=94.05 km/h		*and* $RPA_k < (-0.0016*v_{average} + 0.1755)$ *the trip is invalid.*
	m/s^2	v_k>94.05 km/h		*and* $RPA_k < 0.025$ *the trip is invalid.*
values a_{pos}	-	150		*values where ai> 0.1 m/s² have to count min. 150 entries for each category*
RDE Moderate/Extended Conditions				
Altitude	m	*if the ambient conditions are extended, the emissions are divided with 1.6 for this period*		*moderate altitude: altitude <= 700m above sea level extended altitude: 700m < altitude <= 1300 m*
Temperature	°C			*moderate temperature: 0°C <= temperature <= 30°C extended temperature: -7°C <= temperature < 0°C or 30°C < temperature <= 35°C*
Max. cum. pos. altitude	m/100 km		1200	The max. cum. positive height difference has to be lower than 1200 m/100 km.

Optionally at the end of a RDE test a “high load phase” where the vehicle is driven at full load uphill may be added. The idea behind this high load phase is to get a better coverage of the engine map at higher engine speeds and loads. During the RDE test these areas are normally not covered.

6.2 Measured Signals for RDE tests

The following table shows an overview for required and for optional additional signals for RDE tests.

Required signals										
Time	Engine speed	velocity	CO_2	NO_x	CO	Altitude	Cold Start *(yes/no)*	T_coolant	T_ambient	mass_trip
[s]	*[rpm]*	*[km/h]*	*[g/s]*	*[g/s]*	*[g/s]*	*[m]*		*[degC]*	*[degC]*	*[kg]*
Optinal additional signals										
T_before NSK	T_after NSK	λ before NSK	λ after NSK	T_before SCR	T_after SCR	exhaust mass flow	T_exhaust			
[degC]	*[degC]*	*[-]*	*[-]*	*[degC]*	*[degC]*	*[kg/h]*	*[degC]*			

The cold start according to the legislation is defined by a duration of the first 5 min of the RDE test or until the cooling water temperature reaches >70°C. To detect the cold start a parameter if the test was carried out under cold or warm conditions or the cooling water temperature have to be specified.

7 Annex

Detailed description for the RRC calculation based on the NEDC data is in progress.