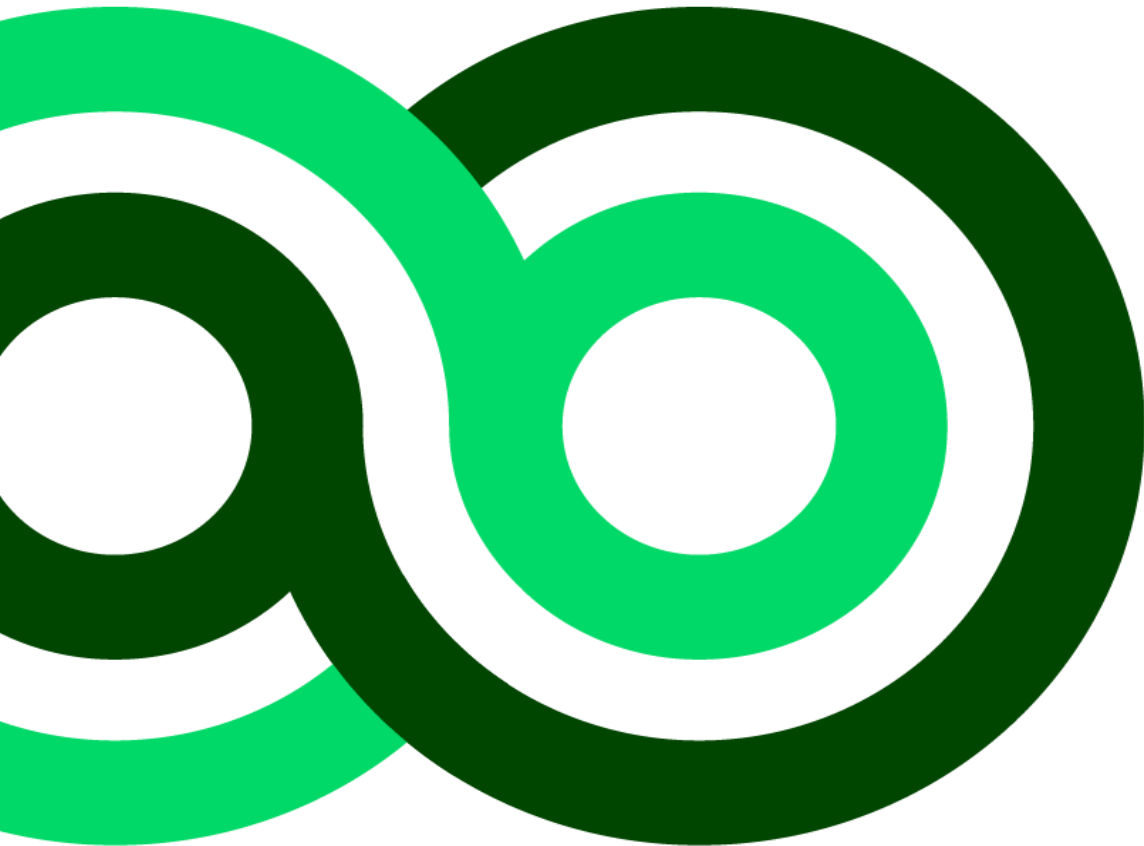


TEST PROCEDURE

Propulsion Unit Performance – Maximum Engine Load





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Version 1.0.0 February 2019

Green NCAP Environmental test procedure

- Determination of engine load regimes

Preface

This procedure is composed of parts A) and B). Green NCAP decided initially not to conduct the maximum propulsion unit performance test to determine the maximum power and torque curves over engine speed. Therefore part A) as complete procedure is void and frozen for the moment until Green NCAP would decide to reactivate part A) again. However, some provisions of part A) were referenced in part B) and remained valid.

In order to measure and determine the maximum engine load curve, needed to supplement engine load - engine speed plots to characterise and distinguish between test sampling and non-sampling part B) was compiled and is to be conducted. Part B) also provides guidance how to plot engine load - engine speed scatter points obtained in the various GNCAP tests.

A) GNT test procedure to measure maximum Propulsion Unit Performance (PUP = max power and torque) curves at the test vehicle's driven wheels

1. Objectives, subject matter and priorities

- 1.1. In regulatory approval testing UN Regulation No 85 sets out engine dynamometer test requirements to measure the maximum power and torque at the crank shaft of an internal combustion engine (ICE) or the net power and 30 minutes power of an electric motor output shaft of e.g. a pure electric vehicle (PEV). Due to losses in the powertrain (e.g. friction), maximum power at the crank shaft and at the wheels are not the same.
- 1.2. Therefore, this procedure sets out test requirements to measure the maximum propulsion unit performance (power, torque) of light-duty vehicles equipped with an ICE, BEVs and HEVs at the wheels on a chassis dynamometer.
- 1.3. Modern propulsion units produce high output torque at the wheels. Hence, it may be difficult if not impossible to prevent (too high) slip between driven axle wheels and chassis dynamometer rolls. In this case:
 - 1.3.1. The maximum propulsion unit performance (power and torque) at the wheels cannot be measured and shall be determined by plotting the full-load curves of engine power and engine torque as provided by the manufacturer and by subtracting 20% of these maximum values to assume average drivetrain¹ efficiency losses. The resulting calculated maximum propulsion unit curves at the wheels shall be plotted as final result.
 - 1.3.2. Alternative quantities indicating the maximum engine load variable(s) curve(s) shall be measured following part B) of this test procedure.
- 1.4. The test results shall be plotted as curves of maximum power and maximum torque at the wheels as well as the maximum engine load variable(s) curve(s), all as function of engine or electric motor rotation speeds. Owing to efficiency losses in the drivetrain the test results when applying this procedure will be 10 to 20% lower than the engine curves reported by the vehicle manufacturer.

¹ Drivetrain is grouping the transmission, clutch, power axles, differential, end gear and wheels and is part of the vehicle's powertrain

2. Scope

- 2.1. Vehicle categories² M1 and N1 equipped with the propulsion unit types listed below.
- 2.2. Internal combustion engines of the following categories:
- reciprocating piston engines (positive-ignition or compression-ignition), but excluding free piston engines;
 - rotary piston engines (positive-ignition or compression ignition);
 - naturally aspirated or supercharged engines;
 - variable compression ratio engine;
 - HCCI engine;
 - internal combustion engine as partial mode and/or total propulsion mode of the powertrain (combustion engine as part of HEV, plug-in HEV, range extender of HEV).
- 2.3. The *electric* part of the powertrain³ is composed of controllers and electric motors that are used for a vehicle's propulsion:
- as partial mode and/or total mode of propulsion (electric motor in HEV or in plug-in HEV)
 - as the sole mode of propulsion (BEV or FCV).

3. Definitions

See separate file (Definitions_Accronyms_Symbols_v1.0.0.xlsx)

4. Vehicle preparation

- 4.1. The test vehicle shall comply with the requirements lined out in GNT_WLTC+_v1.0.0.
Additionally it shall also be ensured that there are no relevant, pending or confirmed diagnostic trouble codes were stored in memory.
- 4.2. **Caution:** the test vehicle's engine / motor compartment, the clutch and automatic transmission, the exhaust manifold, down- and tailpipes, tyres and test equipment may become extremely hot when the Propulsion Unit Performance (PUP) tests will be conducted if no special precautions will be taken prior to start of the test. The vehicle shall be operated at its maximum propulsion unit performance for an extended period to stabilise the engine and/or motor under steady state conditions and this full-load test is conducted in a confined space on a chassis dynamometer without cooling other than from the chassis dynamometer cooling fan. It may be necessary to install additional cooling fans directed on the tyres and exhaust system. In any case, all precautions necessary to be able to extinguish fire shall be taken prior to start of the test.
- 4.3. The test driver and/or lab operator shall be able to continuously monitor coolant and engine oil temperatures during the full-load tests, preferably also lubrication oil temperature of an automatic transmission or CVT. It may be required to install data acquisition thermocouples for that purpose. If the combustion engine's coolant temperature rises over 110 °C or engine oil

² As defined in the UN Consolidated Resolution on the Construction of Vehicles (R.E.3.)

³ A vehicle is equipped with only one powertrain, in accordance with the definitions in UNECE Mutual Resolution No 3 and consists of fuel / energy storage, propulsion unit(s) and the drivetrain

temperature over 120 °C, the test sample point shall be aborted to cool down the engine and other hot vehicle parts.

5. Chassis dynamometer types and associated testing methodology

5.1. General procedure

The procedure is based on multiple engine speed-based sweep tests, covering the range of engine speed from approximately 1000 min⁻¹ up to red line engine speed.

The time required for the whole sweep test shall be minimised as much as possible to prevent measurement drift owing to excessive heat development of the propulsion unit(s), transmission exhaust system or other affected vehicle parts.

5.1.1. The general test setup shall comply to the requirements defined in GNT_WLTC+_v1.0.0, especially ambient conditions, setup of the vehicle and the chassis dynamometer and exhaust gas sampling system.

5.1.2. The vehicle shall be fixed on the chassis dynamometer to comply with GNT_WLTC+_v1.0.0. If a high-powered vehicle is tested, special precautions (e.g. extra fixation of the vehicle) shall be taken if necessary, to avoid damage to the vehicle of the chassis dynamometer. Reporting is mandatory, if any of these measures are applied.

5.1.3. If necessary, precautions (e.g. extra cooling of the exhaust system and/or gases) shall be taken, to avoid damage to the exhaust sampling system and especially the analysers. Reporting is mandatory, if any of these measures are applied.

5.1.4. Select a high constant volume flow for the CVS system, to give a higher dilution of the exhaust gases (for cooling reasons).

Data of the exhaust gas sampling system shall be measured and recorded as modal values (no bag measurement).

The cooling fan setting can be adapted (set to a higher speed), to prevent overheating of the engine.

Reporting is mandatory, if any of these measures are applied.

5.1.5. If possible, switch-off the air-conditioning and all auxiliaries that consume power before start of the sweep tests.

5.1.6. Prior to the start of the test, the test vehicle and chassis dynamometer rolls shall be warmed up for 15 minutes at 50 km/h (in 3rd gear, if applicable), followed by 10 minutes at 120 km/h (in the highest gear), to ensure that coolant and engine oil temperatures of the test vehicle both are higher than 80 °C (warm engine) and stabilized.

5.1.7. Measurements shall be taken to cover the whole engine speed range starting at 1000 min⁻¹-up to maximum design engine speed (red line) with steps of 500 min⁻¹ to define correctly the curves of maximum power and torque at the wheels as well as the maximum engine load variable(s) curve(s) at full load operation. Engine load variables specified in point 5 of part B) shall be logged. Additional load variables can be logged to be able to correlate these with the chassis dynamometer logged data at the wheels, if available. This range of engine speeds shall also include the speeds of revolution at which the engine produces its maximum power, maximum torque and its maximum engine load variable(s) values.

The test procedure depends on the type of chassis dynamometer used for the evaluation of maximum PUP and engine load variable.

5.1.7.1. Chassis dynamometer, designed for vehicle power testing

This kind of chassis dynamometer is especially designed for evaluation of full load performance of a vehicle. A target engine speed (or vehicle speed, respectively) can be selected and maintained stable during vehicle full load operation.

The initial target vehicle speed shall be set to a value, resulting in an engine speed of 1000 min^{-1} in 3rd gear. If an engine speed of 1000 min^{-1} cannot be maintained (e.g. due to engine stuttering), the lowest possible engine speed shall be used instead.

- 5.1.7.1.1. For manual transmission: If engine speed is stabilized, depress the accelerator pedal to a full load position and keep this position for 20 seconds.

For automatic transmission: If engine speed is stabilized, depress the accelerator pedal to a position close to kick-down to avoid a gear change. Keep this position for 20 seconds.

- 5.1.7.1.2. Lift off the accelerator pedal. If necessary, repeat the tests, until stable results are achieved.

- 5.1.7.1.3. The target engine speed shall then be increased by 500 min^{-1} . After the first test at or close to 1000 min^{-1} , target engine speed shall be set to 1500 min^{-1} . Paragraphs 5.1.6.1.1. and 5.1.6.1.2 of this part shall be repeated.

- 5.1.7.1.4. Paragraphs 5.1.6.1.1. to 5.1.6.1.3 of this part shall be repeated, until target engine speed is larger than red-line engine speed for the first time. The test conducted with this target engine speed shall be the last one.

- 5.1.7.2. Chassis dynamometer, designed for emissions testing

This kind of chassis dynamometer is designed for emissions testing and therefore not capable to set and maintain a target engine speed under full load operation like the one in paragraph 5.1.7.1. of this part. Therefore, other measures have to be taken, to ensure a slow rise of engine speed.

- 5.1.7.2.1. Apply a high inertia class and adapt the F_2 factor of the road load curve to a higher value.

- 5.1.7.2.2. Accelerate the vehicle to a speed corresponding to an engine speed of 1000 min^{-1} in 3rd gear. If an engine speed of 1000 min^{-1} cannot be maintained (e.g. due to engine stuttering), the lowest possible engine speed shall be used instead.

- 5.1.7.2.3. For manual transmission: If vehicle speed is stabilized, depress the accelerator pedal to a full load position and keep this position until red-line engine speed is reached.

For automatic transmission: If engine speed is stabilized, depress the accelerator pedal to a position close to kick-down to a gear change. Keep this position until red-line engine speed is reached.

- 5.1.7.2.4. Lift off the accelerator pedal.

- 5.1.7.2.5. Repeat the tests as lined out in paragraphs 5.1.7.2.2 to 5.1.7.2.4 of this part, until stable results are observed.

- 5.1.7.3. Chassis dynamometer, designed for emissions testing but capable of performance or steady-state testing

This kind of chassis dynamometer is designed for emissions testing but also capable of performance and steady state testing. As the electric machine of the chassis dynamometer has a limited power, this method may be used for low-powered vehicles only.

The method can be applied, as long as a steady state engine speed can be maintained for the whole range of tested engine speed. Therefore, the maximum power of the electric machine of the chassis dynamometer needs to be at least as high or higher than the produced power of the vehicle. The controls of the chassis dynamometer need to be able to perform the described testing method as well.

The testing method is identical to the one described in point 5.1.7.1 of this part, limited by the maximum power of the electric machine of the chassis dynamometer.

6. Test results

- 6.1. The test report shall contain the curves of maximum power (in kW) and torque (Nm) at the wheels as function of engine / electric motor speed build from the measurements at the breakpoints, the curve of maximum engine load variable(s) values, the lambda or air/fuel ratio curve as well as the test equipment specifications and all information necessary to be able to repeat the test, if needed.
- 6.2. If available, manufacturer plots of the type-approved maximum engine power and engine torque curves shall be included in the report.

B) Determination of Engine Load Regimes including the full load curve at maximum depressed pedal

1. Purpose

This procedure aims to provide measurement methods to determine the engine operation – by now – of:

- vehicles equipped with internal combustion engines and
- pure electric vehicles (PEV), as defined in 1151/2017: Article 2 Definitions (34).

The results shall depict the operation regime by engine speed or vehicle speed (admissible for pure electric vehicles only) and a load representing parameter, including the maximum engine load curve mapped in a full engine load (full depressed pedal) sweep test.

For the time being, modal energy consumption of the propulsion generating unit (internal combustion engine, electric engine) is selected as a proxy for the load representing parameter.

The results shall allow to visualize the operation of the vehicle's energy converter during chassis-dynamometer- and on-road vehicle operation, by depicting a characteristic curve for full-load operation and the operation (scatter) points for the executed test.

2. Scope

2.1. This procedure applies to vehicles solely equipped with an internal combustion engine as well as PEVs.

2.2. Vehicles equipped with internal combustion engines

2.2.1. The method allows to depict the engine speed in its physical size (e.g. radians per second or rounds per minute).

2.2.2. The method allows to depict the engine load represented by:

(a) available OBD-signals (primary OBD calculated load value – PID \$04) and

(b) the measured gas mass flow rate of gaseous exhaust components (CO₂, CO, THC), using either:

I. a portable emission measurement system (PEMS), fulfilling the requirements of GNT_PEMS+_v1.0.0, Appendix 2 and Appendix 3.

II. an exhaust gas sampling system which allows a direct, undiluted and time aligned exhaust gas concentration and mass flow measurement at the tailpipe, fulfilling the requirements of GNT_WLTC+_v1.0.0, Sub-Annex 5.

III. a constant volume sampling (CVS)-exhaust gas sampling system which verifiably allows a compensation of the exhaust gas transport dynamics from tailpipe- to analyser-out for accurate instantaneous emission measurements, effectively providing results comparable to (a) and (b) and fulfilling the requirements of GNT_WLTC+_v1.0.0, Sub-Annex 5. Verification data shall be presented for this case.

(c) Wheel torque to correlate with points (a) and (b) above, if vehicles are measured on the chassis dynamometer.

2.3. Pure electric vehicles

2.3.1. The method allows to depict the engine speed in its physical size (e.g. radians per second or rounds per minute). Vehicle speed in its physical size (e.g. kilometres per hour) may be used, if engine speed is not available.

2.3.2. The method allows to depict engine load represented by:

- (a) available OBD-signals (primary OBD calculated load value – PID \$04) and
- (b) electric energy at the rechargeable electric energy storage system (REESS) calculated according to point 7.2.1. of part B), as an indirect indicator / proxy for engine load.
- (c) Wheel torque to correlate with points (a) and (b) above, if vehicles are measured on the chassis dynamometer.

2.4. This procedure does not apply to vehicles equipped with more than one energy converter or vehicles equipped with any other energy converter than referenced in paragraph 2.1 of part B) (particularly plug-in hybrids). Nevertheless, the described methods can be applied to determine the sole operation regime of a vehicle equipped with an internal combustion engine, if present in a vehicle with multiple energy converters. In this case the vehicle's propulsion power and energy demand are not fully reflected.

3. General requirements

3.1. Vehicle preparation

For tests on the chassis dynamometer, the test vehicle shall comply with the requirements lined out in GNT_WLTC+_v1.0.0.

For tests on road, the vehicle shall comply with the requirements lined out in GNT_PEMS+_v1.0.0.

Additionally, it shall also be ensured that there are no relevant, pending or confirmed diagnostic trouble codes were stored in memory.

3.2. Vehicles equipped with internal combustion engines

3.2.1. Exhaust gas sampling system

All exhaust gas emission sampling systems used shall be in a fault-free operating condition and shall be maintained as specified by the manufacturer. Portable Emission Measurement Systems (PEMS) shall meet the requirements of GNT_PEMS+_v1.0.0, Appendix 2 and Appendix 3.

Undiluted tailpipe exhaust gas sampling systems and/or CVS exhaust gas sampling systems used shall meet the requirements of GNT_WLTC+_v1.0.0, Sub-Annex 5 and allow transiently measured gaseous exhaust emission results comparable to the system lined out in paragraph (b) I. (PEMS) of part B).

Therefore, the time delays between:

- (a) the exhaust gas mass flow meter and the gas analyser(s), as well as
- (b) the so calculated exhaust gas emission mass flows and the simultaneously recorded engine parameter (e.g. engine speed)

need to be verifiably compensated.

To facilitate time alignment of exhaust emission- and engine-specific data (e.g. CO₂-exhaust mass flow and engine speed), it is recommended to record the parameters that are subject to time alignment and relevant to determine the engine load solely by a PEMS measurement system.

3.3. Pure electric vehicles

3.3.1. Determination of REESS current and REESS voltage

The method and required instrumentation to determine the REESS current and the REESS voltage is described in GNT_WLTC+_v1.0.0, Sub-Annex 8, Appendix 3.

4. Measurement equipment

4.1. Vehicles equipped with internal combustion engines

At least one of the gaseous emission measurement systems listed in paragraphs (b) I. to III. of part B) shall be present and operational during any test performed. During laboratory correlation testing both I. and III. shall be present and operational to correlate the proxy engine load variables with wheel torque. The requirements in paragraph 3.2.1. of this part shall be met.

4.2. Pure electric vehicles

Appropriate measurement equipment meeting the requirements in paragraph 3.3.1. of this part shall be used during any test performed.

5. Test parameter

5.1. Vehicles equipped with internal combustion engines

Measuring and recording of the following test parameter:

- (a) Engine speed (OBD PID \$0C or directly measured)
- (b) OBD Engine Load (PID \$04)
- (c) CO₂ concentration in the exhaust gas
- (d) CO concentration in the exhaust gas
- (e) HC concentration in the exhaust gas
- (f) Exhaust gas mass flow rate
- (g) OBD Accelerator Pedal Position D (PID \$49)
- (h) OBD Driver's demand engine - percent torque (PID \$61)
- (i) OBD Actual engine – percent torque (PID \$62)
- (j) OBD Engine fuel rate (PID \$5E)
- (k) Any other engine load relevant OBD variable accessible (calculated torque, IMEP, injector base pulse width, etc.)

at a sample rate of at least 1 Hz is mandatory, as far as applicable for the test vehicle. For vehicles supporting PID \$63 the

- (l) OBD Engine reference torque (PID \$63)

shall at least be recorded once, if reducing permanent sampled OBD data is required. Not available OBD channels shall be reported as well as any significant deviations of the engine load proxy variables compared to the reference engine load variable.

5.2. Pure electric vehicles

Measuring and recording of the following test parameter:

- (a) Vehicle Speed (OBD PID\$0D or directly measured)
- (b) Engine speed (OBD PID \$0C or directly measured)
- (c) OBD Engine Load (PID \$04)
- (d) REESS current

- (e) REESS voltage
- (f) OBD Accelerator Pedal Position D (PID \$49)
- (g) OBD Driver's demand engine - percent torque (PID \$61)
- (h) OBD Actual engine – percent torque (PID \$62)
- (i) Any other engine load relevant OBD variable accessible (calculated torque, propulsion unit current, etc.)

at a sample rate of at least 1 Hz is mandatory, as far as applicable for the test vehicle. For vehicles supporting PID \$63 the

- (j) OBD Engine reference torque (PID \$63)

shall at least be recorded once, if reducing permanent sampled OBD data is required. Not available OBD channels shall be reported as well as any significant deviations of the engine load proxy variables compared to the reference engine load variable.

6. Measurement procedure

6.1. General Settings

If the vehicle is equipped with a driver selectable mode as described in GNT_WTLC+_v1.0.0, the most energy consuming mode in terms of fuel consumption for vehicles equipped with internal combustion engines or in terms of electric energy for PEVs shall be selected.

6.2. Vehicles equipped with internal combustion engines

6.2.1. Test sequence for evaluation of characteristic full load (full depressed pedal) operation curve

The characteristic full load (full depressed pedal) operation curve shall be evaluated on the chassis dynamometer or on-road, respectively

6.2.1.1 Evaluation on the chassis dynamometer

The method is based on multiple measurements at full-load (fully depressed pedal) accelerations. The procedure is lined out in point 5 of part A).

6.2.1.2 Evaluation on-road using PEMS

If none of the measuring methods referred to in point 5 of part A) can be performed, the engine load variables at full load shall be determined by performing multiple PEMS On-road measurements at fully pressed accelerator pedal.

6.2.1.2.1. The ambient conditions shall comply with those defined in GNT_PEMS+_v1.0.0 for PEMS testing.

6.2.1.2.2. In general, a high road load (payload, steep road slope) shall be selected for the described tests, to ensure a slow rise of engine speed.

6.2.1.2.3. Measurements shall be taken to cover the whole engine speed range, starting at 1000 min⁻¹ up to maximum design engine speed (red line) to correctly define the curves of maximum engine load variable(s) curve(s) at full load operation.

6.2.1.2.4. Manual transmission

6.2.1.2.4.1. The highest possible gear shall be selected, to ensure a slow rise of engine speed. The initial vehicle speed is thereby defined by the lowest driveable engine speed in the selected gear.

6.2.1.2.4.2. Starting from the initial vehicle speed at a constant level, the accelerator pedal shall be fully pressed until the maximum engine speed (red line) in the selected gear is reached.

- 6.2.1.2.4.3. If vehicle speeds exceed given speed limits before the maximum engine (red line) speed is reached, a lower gear shall be selected and the test shall be repeated in this gear.
- 6.2.1.2.5. Automatic transmission
 - 6.2.1.2.5.1. If the vehicle is equipped with a gear-selectable gearbox, the highest possible gear shall be selected. If vehicle speeds exceed given speed limits before the maximum engine speed (red line) is reached, a lower gear shall be selected and the test shall be repeated in this gear.
In any other case, the vehicle shall be driven in a high gear at an engine speed close to the shift down engine speed.
The initial vehicle speed is defined by the lowest driveable engine speed in the selected gear.
 - 6.2.1.2.5.2. Starting from the initial vehicle speed at a constant level, the accelerator pedal shall be depressed as close as possible to the kick-down-point and kept at that level until the maximum engine speed (red line) in the selected gear is reached.
 - 6.2.1.2.6. The test shall be repeated until reproducible results for the maximum engine load variables are generated. These may be combined results from different measurements in multiple gears.
 - 6.2.1.2.7. Special precautions need to be taken to avoid thermal damage of emission sampling equipment, if this test method is chosen.
- 6.2.2. Test sequence for engine operation points evaluation
The tests shall be carried out as specified in the respective section for laboratory emission testing (GNT_WLTC+_v1.0.0, GNT_BAB_Motorway_v1.0.0) or for PEMS testing (GNT_PEMS+_v1.0.0, GNT_Emission_Robustness_v1.0.0), depending on the test performed.
- 6.2.3. Sampling, measurement and recording of parameters shall begin prior to the start of the engine. Before as well as directly after engine start, it shall be confirmed that all necessary parameters are recorded by the data logger.
- 6.2.4. Sampling, measurement and recording of parameters shall continue throughout the test performed. The engine may be stopped and started, but emissions sampling and parameter recording shall continue. Any warning signals, suggesting malfunctioning of the emission measurement system, shall be documented and verified.
- 6.2.5. Test end
Data recording shall continue until the response time of the sampling systems has elapsed.
- 6.3. Pure electric vehicles
 - 6.3.1. Test sequence for evaluation of characteristic full load (full depressed pedal) operation curve
The full load (full depressed pedal) operation curve shall be evaluated on the chassis dynamometer or on-road, respectively.
 - 6.3.1.1. Evaluation on the chassis dynamometer
The method is based on multiple measurements at full-load (fully depressed pedal) accelerations. The procedure is lined out in point 5 of part A).
 - 6.3.1.2. Evaluation on-road
If none of the measuring methods referred to in point 5 of part A) can be performed, the engine load variables at full load shall be determined by performing multiple on-road measurements at fully pressed accelerator pedal.
 - 6.3.1.2.1. The ambient conditions shall comply with those defined in GNT_PEMS+_v1.0.0 for PEMS testing.
 - 6.3.1.2.2. In general, a high road load (payload, steep road slope) shall be selected for the described tests, to ensure a slow rise of engine speed.

6.3.1.2.3. Measurements shall be taken to cover the whole engine speed range, starting at $< 100 \text{ min}^{-1}$ up to the engine speed, which correlates to a vehicle speed of 140 km/h, to define correctly the curves of maximum engine load variable(s) curve(s) at full load operation.

If engine speed cannot be measured, vehicle speed can be used instead. Measurements shall then be taken to cover the whole vehicle speed range, starting at $< 5 \text{ km/h}$ up to 140 km/h to define correctly the curves of maximum engine load variable(s) curve(s) at full load operation.

6.3.1.2.4. Single speed transmission

6.3.1.2.4.1. Starting from an initial $< 100 \text{ min}^{-1}$ or an engine speed vehicle speed $< 5 \text{ km/h}$ (both at a constant level), respectively, the accelerator pedal shall be fully pressed until the engine speed reaches the value, which correlates to a vehicle speed of 140 km/h, or the vehicle speed reaches 140 km/h or the applicable legal limit, whatever is lower.

6.3.1.2.5. Manual transmission

Has to be defined, as vehicles are market-available.

6.3.1.2.6. Automatic transmission

Has to be defined, as vehicles are market-available.

6.3.2. Test sequence for engine operation points evaluation

The tests shall be carried out as specified in the respective section for laboratory emission testing (GNT_WLTC+_v1.0.0, GNT_BAB_Motorway_v1.0.0) or for PEMS testing (GNT_PEMS+_v1.0.0, GNT_Emission_Robustness_v1.0.0), depending on the test performed.

6.3.3. Measurement and recording of parameters shall begin prior to the start of the engine. Before as well as directly after vehicle start, it shall be confirmed that all necessary parameters are recorded by the data logger.

6.3.4. Measurement and recording of parameters shall continue throughout the test performed. The vehicle may be stopped and started, but parameter recording shall continue. Any warning signals, suggesting malfunctioning of the vehicle, shall be documented and verified.

6.3.5. Test end

Data recording shall continue until the response time of the data logging systems has elapsed.

7. Engine Load calculation and visualization

7.1. Vehicles equipped with internal combustion engines

7.1.1. Data post-processing

The following paragraphs describe post-processing of 1 Hz data for full load operation plots, especially time alignment to account for time shifts (response time, time delay due to measurement position, etc.) within the data. If data for full load operation are part of a log file, time alignment for each part with full load operation is recommended.

7.1.1.1 Evaluation of modal exhaust gas mass flow rates for CO₂, CO and HC

7.1.1.1.1. On-road data

7.1.1.1.1.1. PEMS data processing shall be carried out in accordance with GNT_PEMS+_v1.0.0, Appendix 4, to ensure time alignment of measured exhaust gas mass flow rate and concentrations of measured exhaust components (especially CO₂, CO and HC) for full load operation phases.

Post processing tools provided by the PEMS manufacturer may directly be used for an alignment of determined signals as long as time alignment of recorded signals is granted, respectively the provisions of the first part of this paragraph are met.

- 7.1.1.1.1.2. The modal exhaust gas mass flow rates for CO₂, CO and HC shall be determined in accordance with GNT_PEMS+_v1.0.0, Appendix 4.

Post processing tools provided by the PEMS manufacturer may directly be used for the calculation of modal CO₂, CO and THC exhaust gas mass flow rate as long as time alignment of recorded signals is granted, respectively the provisions of paragraph 7.1.1.1.1.1. of this part are met.

- 7.1.1.1.2. Chassis dynamometer data

- 7.1.1.1.2.1. Data recorded by exhaust gas sampling systems as listed in paragraphs (b) II. and III. of part B) shall by any means necessary be processed to ensure time alignment of measured exhaust gas mass flow rate and concentrations of measured exhaust components (especially CO₂, CO and HC) for full load operation phases. Verification data shall be presented.

- 7.1.1.1.2.2. The modal CO₂ exhaust gas mass flow rate shall be determined by multiplying the measured exhaust gas mass flow rate with the CO₂-concentrations, both corrected and aligned for the transformation time, to ensure provisions of paragraph 7.1.1.1.2.1. of this part are met.

The modal CO exhaust gas mass flow rate shall be determined by multiplying the measured exhaust gas mass flow rate with the CO-concentrations, both corrected and aligned for the transformation time, to ensure provisions of paragraph 7.1.1.1.2.1. of this part are met.

The modal HC exhaust gas mass flow rate shall be determined by multiplying the measured exhaust gas mass flow rate with the HC-concentrations, both corrected and aligned for the transformation time, to ensure provisions of paragraph 7.1.1.1.2.1. of this part are met.

- 7.1.1.1.2.3. The time alignment between measured engine speed and the calculated, modal CO₂ exhaust gas mass flow rate shall be conducted by cross-correlation of both signals following the equation below in this paragraph. The calculated, modal CO₂ exhaust gas mass flow signal shall be shifted in time by k in a way that the absolute value of $1 - K$ reaches a minimum.

$$K(k) = \frac{\sum_{i=1}^N x[i] * y[i + k]}{\sqrt{\sum_{i=1}^N (x[i])^2 * \sum_{i=1}^N (y[i + k])^2}}$$

Where:

- x is the calculated CO₂ exhaust gas mass flow rate signal
- y is the recorded engine speed signal

The same value for k shall be used for the time shift of modal CO- and HC-exhaust gas mass flow.

- 7.1.1.2 Evaluation of modal energy consumption

Both for on-road test data as well as chassis dynamometer data, the evaluation of the modal energy consumption is based on a conversion factor, converting modal fuel consumption values to modal energy consumption (conversion of l/s to Wh/s). The conversion factor accounts for the fuel density as well as for the heating value of the fuel.

The value is set to

- 8,67 for petrol vehicles and

9,86 for diesel vehicles.

The evaluation of the modal fuel consumption is based on the carbon-balance of gaseous exhaust emissions, especially CO₂, CO and HC.

If HC emissions cannot be measured (especially at PEMS-testing due to missing measurement equipment), the values for HC shall be set to 0.

For all equations in subparagraph 7.1.1.2

$\dot{E}C(t)$	is the modal energy consumption, Wh/s
ρ_{fuel}	is the test fuel density, kg/l
$\dot{H}C(t)$	is the calculated, modal HC exhaust gas mass flow rate signal, g/s
$\dot{C}O(t)$	is the calculated, modal CO exhaust gas mass flow rate signal, g/s
$\dot{C}O_2(t)$	is the calculated, modal CO ₂ exhaust gas mass flow rate signal, g/s

7.1.1.2.1. For a vehicle with a positive ignition engine fuelled with petrol (E10):

$$\dot{E}C(t) = \left(\frac{1,206}{\rho_{fuel}} \right) \times [(0,829 \times \dot{H}C(t)) + (0,429 \times \dot{C}O(t)) + (0,273 \times \dot{C}O_2(t))] \times 8,67$$

7.1.1.2.2. For a vehicle with a compression engine fuelled with diesel (B7):

$$\dot{E}C(t) = \left(\frac{1,165}{\rho_{fuel}} \right) \times [(0,858 \times \dot{H}C(t)) + (0,429 \times \dot{C}O(t)) + (0,273 \times \dot{C}O_2(t))] \times 9,86$$

7.1.2. Visualization of the characteristic full load (maximum depressed pedal) curve

7.1.2.1 The characteristic full-load curve shall be visualized using the processed signals of engine speed and energy consumption for the time-shares with full load operation by plotting the sample data x over y, where x specifies the engine speed and y specifies the energy consumption. In case of variations within the result, the envelope shall be used.

7.1.3. Visualization of the engine operation regime

7.1.3.1 The engine operation regime shall be visualized using the processed signals of engine speed and modal energy consumption by plotting the sample data x over y, where x specifies the engine speed and y specifies the modal energy consumption.

7.1.3.2 The maximum modal energy consumption at any given engine speed as defined in paragraph 7.1.2.1. of this part shall be additionally plotted in the engine operation regime plot.

7.2. Pure electric vehicles

7.2.1. Data post-processing

The following paragraphs describe post-processing of 1Hz data for full load operation plots, especially time alignment to account for time shifts within the data. If data for full load operation are part of a log file, time alignment for each part with full load operation is recommended.

7.2.2. The time alignment between measured engine speed (or vehicle speed, if engine speed is not available) and the measured REESS current shall be conducted by cross-correlation of both signals following the equation below in this paragraph. The calculated, modal CO₂ exhaust gas mass flow signal shall be shifted in time by k in a way that the absolute value of $1 - K$ reaches a minimum.

$$K(k) = \frac{\sum_{i=1}^N x[i] * y[i + k]}{\sqrt{\sum_{i=1}^N (x[i])^2 * \sum_{i=1}^N (y[i + k])^2}}$$

Where:

x is the measured REESS current
 y is the recorded engine speed (or vehicle speed, if engine speed is not available) signal

The same value for k shall be used for the time shift of the measured REESS voltage.

7.2.2.1 Evaluation of modal energy consumption of the REESS:

$$\dot{E}C(t) = \frac{1}{3600} \times U_{REESS}(t) \times I_{REESS}(t)$$

Where:

$\dot{E}C(t)$ is the modal energy consumption, Wh/s
 $U_{REESS}(t)$ is the modal REESS voltage, V
 $I_{REESS}(t)$ is the modal REESS current, A

7.2.3. Visualization of the characteristic full load curve

7.2.3.1 The characteristic full load curve shall be visualized using the signals of engine speed (or vehicle speed, if engine speed is not available) and modal energy consumption of the REESS for the time-shares with full load operation by plotting the sample data x over y , where x specifies the engine speed (or vehicle speed, if engine speed is not available) and y specifies the modal energy consumption of the REESS. In case of variations within the result, the envelope shall be used.

7.2.4. Visualization of the engine operation regime

7.2.4.1 The engine operation regime shall be visualized using the signals of engine speed (or vehicle speed, if engine speed is not available) and modal energy consumption of the REESS by plotting the sample data x over y , where x specifies the vehicle speed and y modal energy consumption of the REESS.

7.2.4.2 The maximum electric power of the REESS at any given engine speed (or vehicle speed, if engine speed is not available) as defined in paragraph 7.2.3.1. of this part shall be additionally plotted in the engine operation regime plot.