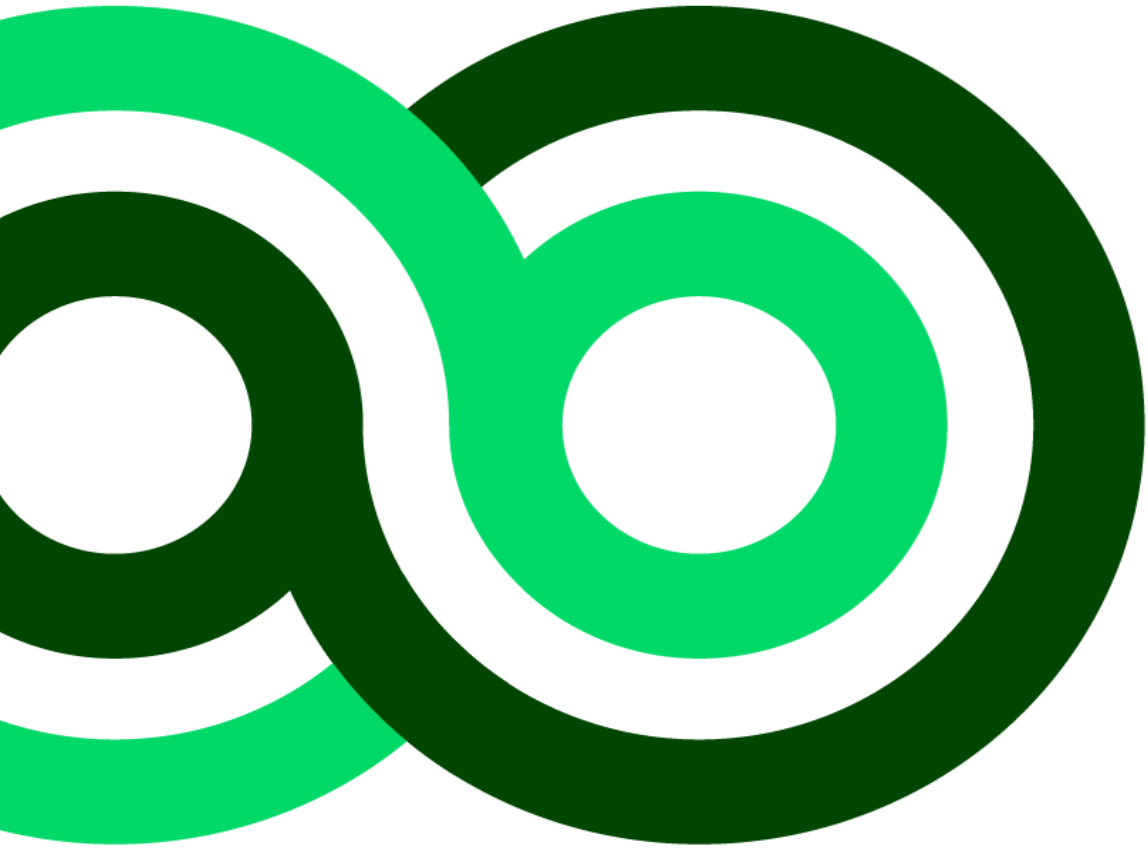
TEST PROCEDURE

Emission Robustness

Version 1.0.1 November 2020



Disclaimer: Currently this test procedure is not applicable to Plug-In Hybrid (PHEV) Electric Vehicles.

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1. INTRODUCTION

Vehicle emission robustness tests are part of the future GreenNCAP test procedure and consists of a set of tests complementary to the general type-approval based tests and will be carried out on a chassis dynamometer and on the road.

This document describes a test protocol for the robustness tests carried out on the road with a Portable Emission Measurement System (PEMS). The robustness test which is performed in the laboratory, i.e., the BAB130, is described in the documents related to laboratory testing:

- *GNT_BAB_Motorway_WG_vx*

The on-road robustness test program includes and is built around the regular GNCAP PEMS+ tests which are described in the document "*GNT_PEMS+_WG_vx.*". This document describes certain aspects in the robustness procedure, which overrule the regular PEMS+ procedure as they are tailored for the on-road robustness tests and supplement the WLTC+ emission laboratory test. The complementary on-road tests investigate the environmental performance of the vehicle in specific corners of the PEMS+ test window or even beyond (in particular higher and lower load conditions and driving styles). The supplemental robustness laboratory tests allow a wider operation range of the propulsion unit in terms of engine/vehicle speed versus engine load as well.

Future robustness tests might also include well-known specific situations like a holiday trip (high speed motorway driving, a fully packed car and a roof box). Moreover, trips can be added to detect potential CAN-bus or remote connection recognition of the vehicle by execution of a test with and a test without CAN-bus connection or with and without remote connectivity. By comparing the environmental performance under a wide range of conditions, the robustness of the vehicle's emission control, fuel / energy consumption, driving range and other environmental performance characteristics can be established.
The on-road robustness tests are for the time being planned after the laboratory testing in the overall GNT test procedure. In practice a flexible timeline can be followed if the regular PEMS+ test is performed with a cold engine after an overnight soak. The robustness tests conducted in the emission laboratory follow the sequence as set out in this document and in the overall GNT test procedure.

2. AIM AND APPROACH OF THE ON-ROAD ROBUSTNESS TESTS

Robustness tests are meant to characterise the emission performance of a vehicle in a wide range of ambient and driving conditions, both in the laboratory and on the road. The on-road conditions are not necessarily limited to the conditions covered in the official RDE procedure and the lab tests are not limited to UN GTR No 15 on WLTP. However, the applied conditions shall be realistic. Any deviations on the legal boundary conditions are described below in Table 3. Abbreviations, acronyms, and definitions used in this robustness test procedure shall be retrieved from file "GNT_Definitions_Accronyms_Symbols_WG".

On-road robustness priorities

In table 1 the robustness priorities are described based on an assessment of test feasibility and readiness and impact on the environmental performance. Due to technical developments and new insights this table can be extended over time.

Table 1: Robustness priorities

Driving style
High payload
Cold-warm start
High speed & load
Urban trips
Short trips
Wide open throttle
Congestion
Low engine load
Sportive shifting

3. ON-ROAD PEMS TEST PROGRAMME

3.1. On-road PEMS test set-up

The vehicle preparations shall consist of the next items (building on regular PEMS test set up):

1. Installation of the PEMS.
2. Debugging and commissioning of the test set up.
3. Vehicle preparation and conditioning.
4. Preparation of different payloads with load packages of 10-25 kg.

3.2. Test programme

In order to cover the maximum range of the engine map, tests will be performed under light, regular and heavy conditions. The test under regular conditions is part of the general PEMS+ procedure where the tests under **light** and **heavy** conditions are part of the on-road robustness procedure.

Part of the robustness test is to simulate low engine load with possible repercussions on light-off and efficiencies of the emission abatement system. Low engine load is especially related to low after treatment temperatures. These circumstances are created in the light test. Moreover, a separate robustness test is included where **congestion** is simulated.

3.3. Vehicle preparation

The vehicle shall be refuelled at the maximum level with reference fuel as per laboratory test. Liquids, brake pads, tyres conditions shall be checked in order to guarantee the safety conditions and the representativeness of the tests. In general, the same prerequisites for the test vehicles and preparations shall apply as set out in the corresponding points of the WLTC+, PEMS+ and GNT Overall test procedures. The schedule of table 2 contains the specific preparations for the robustness tests.

Table 2: Preparations and instructions for the robustness tests

Test	Name	Test	Duration	Comment	Payload
Preparation for light test					
	Warm-up	Free (random) urban trip		ICE: ca. 5 min AND coolant > 80ºC (P)HEV: until SOC adjusted[1] AND coolant > 80ºC BEV/FCEV: ca. 5 min	As light as possible
PEMS+ **light**	PEMS **warm** start Full PEMS+ route	Warm Light	Up to 2.5[2]	Light conditions	
Preparation for heavy test					
	Warm-up	Free (random) urban trip		ICE: ca. 5 min AND coolant > 80ºC (P)HEV: until SOC adjusted[1] AND coolant > 80ºC BEV/FCEV: ca. 5 min	90%
		Idling	15 minutes (start stop deactivated)	N/A for BEV/FCEV. For (P)HEV it means that in most cases the ICE is off.	
PEMS+ **heavy**	PEMS **warm** start Full PEMS+ route	Warm Heavy	Up to 2.25[1] (excl. 0.5hr for Post-calibration)	Heavy conditions	
Preparation for congestion test	Warm-up	Free (random) urban trip		ICE: ca. 5 min AND coolant > 80ºC (P)HEV: Until SOC is as low as possible AND coolant > 80ºC BEV/FCEV: ca. 5 min	As light as possible
PEMS+ **congestion**	Congestion simulation		- 15 minutes idling - 5 minutes stop and go	<u>In all cases the start/stop system should be deactivated (both during idling and stop and go)</u> Except for the start/stop system, the same vehicle settings as during the PEMS+ Light test shall be applied. I.e. economy mode and A/C off (see table 3). <u>Note:</u> For (P)HEV it can be that the ICE is turned off during 'idling' and 'stopping'. Both idling and stop and go need to be included in the test results.	

[1] As defined nominal during the chassis dynamometer tests.

[2] PEMS light and PEMS heavy must be driven on the same route as the regular PEMS+ test, however, the duration may be shorter or longer than the provided thresholds for the PEMS+ regular test.

3.4. Driving conditions

The tests under regular conditions are part of the general PEMS+ procedure. The light and heavy test have some deviating driving conditions. The deviating conditions of the light and heavy test shall overrule the regular PEMS+ procedure. In table 3 the different conditions for the three tests are specified.

Safety for the driver and other road users are by far the most important aspect and prevail at all times before start and during the tests. Therefore, the instructions provided in Table 3 should only be performed if it is safe.

Table 3: Light, regular and heavy driving conditions

Instructions		**PEMS+ Light**	**PEMS+ Regular**	**PEMS+ Heavy**
General driving and vehicle conditions		According to general PEMS+ procedure		
Settings before start	Gear shifting mode (automatic gearbox)	Economy	Default	Sportive/Power /Performance
	Start-stop system active	Yes (deactivated at the 15 min idling phase)	Yes	No
	Airconditioning (temperature set in climate system)	Off (blower at medium level)[3]	On at 21 to 23°C (blower at medium level)	Tamb <20°C → A/C set at 21 to 23°C Tamb >=20°C → A/C set at 18 to 19°C (blower at medium level)
	Auxiliary devices	Only lights on at selected position 'automatic' + radio on	Lights + radio on	Lights + radio on + seat heating on (passenger seat only) + rear window heating on (reactivate once after 30 minutes)
Driving style instruction	General	Economy	Regular	Sportive
	Maximum vehicle speed [km/h]	100 (measured via GPS, use cruise control, if possible)[4]	110-120 (measured via GPS, cruise control and speed limiter deactivated)	Maximum permissible vehicle speed (120 or 130, measured via GPS). Use, if possible, the speed limiter
Driving style instruction – *gear shifting with manual transmission*	Up gear shift rotation speed [rpm]	Follow GSI[5]	Follow GSI[6]	Diesel: *Gear 1-3: 3500* *Gear 4-5: 3000* Petrol: *Gear 1-3: 4500* *Gear 4-5: 4000* *Shift to highest gear when the vehicle speed limit is reached.*
	Down shift roatation speed [rpm]	Follow GSI[4]	Follow GSI[5]	Diesel: 2250 rpm Petrol: 2500 rpm

[3] Comfort and safety of the driver are very important. Therefore, the window may be slightly opened in the urban and rural part (not allowed in motorway part).

[4] For vehicles without cruise control: keep speed pedal as constant as possible and maintain 100 km/h as precise as possible.

[5] Gear shifting guidance for vehicles without GSI for the light test: up shift: 2000 rpm, down shift: 1500 rpm.

[6] Gear shifting guidance for vehicles without GSI for the regular test: up shift: 2500 rpm, down shift: 1750 rpm.

Driving style instruction – **If safe only** *Coasting*	Coasting in gear	As much as possible	Regular	As little as possible
	Coasting in gear towards target (e.g. traffic light) - delay time speed pedal to brake pedal [s]: *Indicative target*	±10-20	±3-5	0-2
Driving style instruction – *Braking / decelerations*	Braking system usage	Moderate	Regular	Aggressive
	Distance to target at start of decelerating [m]: *Indicative target*	±90	±60	±30
Driving style instruction – *Accelerations*	Speed pedal activation speed	Slow	Regular	Fast (avoid spinning wheels)
	Maximum position speed pedal during accelerations [%] *Indicative target*	±50	±70	PMR <90: ±100 PMR >90: ±90 (PMR based on actual mass)
	Average position speed pedal during accelerations that are >1 m/s^2 [%] *Indicative target*	10 - 20	20 - 30	>30
Specific test instructions	Extra idling periods	15 minutes idling after 8 -12 km accumulated distance in urban part (start stop deactivated at idling)	n.a.	15 minutes idling before start of the test (not applicable for BEV/FCEV) (start stop deactivated)
	Wide open throttle acceleration during rural driving (20 to 80 km/h)	n.a.	n.a.	4 times: MT: 2th and 3rd gear -Diesel: Shift at 3500 rpm -Petrol: Shift at 4500 rpm AT: full sport mode, apply kick down
	Wide open throttle acceleration up to maximum permissible speed on the motorway (when entering the motorway)	n.a.	n.a.	MT Diesel: Shift at 4000 rpm MT Petrol: Shift at 5000 rpm. AT: full sport mode, apply kick down *Shift to highest gear when the speed limit is reached.*
	Wide open throttle acceleration during motorway driving (80 - 120 km/h)	n.a.	n.a	4 times: MT: apply 4th gear AT: in full sport mode, apply kick down

Additional data analysis after on-road test *Indicative target*	Trip dynamics	RPA not applicable $v*a_{pos}$ applicable	Within PEMS+ boundaries (RPA and $v*a_{pos}$)	RPA applicable $v*a_{pos}$ not applicable Number of seconds at a $v*a_{pos}$ value >40% of the PMR (based on test mass): - Urban: 50 – 80s - Rural: 40 – 70s - Motorway: 45 – 70s *<u>Alternative approach</u>:* *95^{th} $v*a_{pos}$ value:* *X% of the PMR (based on test mass)* *Urban: X = 35 -55%* *Rural: X = 45 -65% Motorway: X = 55 -70%*
	Short urban trip with cold start	-	Select first accumulated 8 kilometres after cold start of the urban part → check performance criteria for evaluation	-

Deviations in the boundary conditions compared to the PEMS+ test

- <u>Ambient temperature, ambient pressure and road conditions</u>: no change
- <u>Trip composition</u>:
  - The length of trip does not change as all tests should be driven on the same route, to be able to compare results;
  - The trip duration may be exceeded with a testing of up to 2.5 hours;
  - In the light test, the maximum number of vehicle stops as specified in the PEMS+ test may be exceeded.
- <u>Driving behaviour:</u>
  - Vehicle speed range of motorway driving (light) will be lower
  - The $v*a_{pos}$ limits may be exceeded.
    - A heavy test is meant to reflect driving a vehicle according to its full capabilities, instead of driving it to a standard – vehicle independent - speed profile. A heavy test should contain enough demanding events, reflected against the power-to-mass ratio of the vehicle. Preferably also the dynamics should be higher than the demand in the 'regular' and 'light' test. As a guidance there should be several seconds driven at relatively high $v*a_{pos}$ values in all road segments (urban, rural and motorway).
      - The $v*a_{pos}$ target values are based on the power-mass-ratio (PMR), based on the mass as it is in the heavy test. More specific; the $v*a_{pos}$ value is equal to 40% of the PMR. A certain number of seconds

should be this value or higher. The number of seconds are prescribed in table 3.
    - An alternative approach is to keep the 95th percentile as a $v*a_{pos}$ target values, but make them PMR dependent. The 95th percentile should be X% of the PMR, as described in table 3.
- Vehicle conditions: no change

PEMS operation
Operation of the PEMS system shall be done according to the requirements of PEMS+ test procedure, including all requirements for audits, checks and calibrations.

Maximum vehicle speed
The maximum vehicle speed during the heavy test should be driven, whenever possible, at the maximum permissible speed (120 or 130 km/h). In contrast, the light test should be driven at a lower vehicle speed, i.e. at 100 km/h. The vehicle speed should be checked by using GPS. For the heavy test it is recommended to use the vehicle speed limiter.

Gear shifting
The light and regular tests will follow the GSI. The gear shift speeds for Heavy PEMS+ test in table 3 are meant to be general instructions. Vehicle's capabilities might require specific gear shift strategies. *An alternative approach may be to make the gear shift point dependent of the engine speed at maximum engine power, e.g. 2000 rpm below this point*[7].

The selected gear shift rotation speeds shall be reported.

Vehicle stops
To simulate low engine loads the following requirements are provided for the congestion simulation, the light test and the heavy test (in all idling cases the start/stop system should be deactivated):

- Congestion simulation:
    - 15 minutes idling | 5 minutes stop and go: 10 meter driving (first gear, max 10 km/h)→ 10 seconds stop → 10 meter driving etc. Both the idling as the stop and go need to be included in the test results.
- Light test:
    - 15 minutes idling after 8 -12 km in urban part
        - Included in the test result
- Heavy test: 15 minutes idling before start of the test
    - Excluded from the test results

Wide open throttle accelerations
To get sufficient trip dynamics during the heavy test, requirements are added in table 3 regarding wide open throttle accelerations in the rural and motorway part.

Coasting
During coasting the gearbox should be in the position of the last gear that was used before coasting. The clutch may be activated based on GSI Information for a downshift or for braking to standstill.

[7] To be elaborated in more detail.

Braking system usage
The braking system usage is described as 'moderate', 'regular' or 'aggressive'. In all these driving styles the princicple of 'safety first' shall be maintained. A safe distance with respect to other traffic shall be at minimum the distance covered within two seconds.

Overnight soak
After soaking the test shall be started within 10 minutes.

Cold start, warm start, conditioning,
The cold start test shall be performed directly after an overnight soak, without engine start prior to the test. The warm start test shall start after a warm trip which follows a soak period of max 1.5 hours following a prior PEMS-test. The conditioning and soak periods allow for calibration of the PEMS system, if necessary, change driver, etc. The maximum time between the end of a conditioning trip and the start of a test shall be not more than 5 minutes.

Data processing and robustness evaluation
For every trip the raw data and the calculated second-by-second data shall be carried over into the harmonised test result template. Standardization of data processing needs to be developed for the evaluation of the robustness test (in addition to the regular PEMS+ test). Useful graphs to indicate the level of 'heaviness' are[4]:
- RPA and $v*a\_{pos}$ checks;
- Indication for level of trip load (CO_2 as a function of velocity);

Moreover, for every robustness test a scatter plot should be generated where the engine load is displayed as a function of the engine speed, including the max engine load curve.

Other requirements
Take pictures of the vehicle and test set up with PEMS and payload in accordance with GNT_Footage_procedure_vx. Take care of an equal distribution of the payload over the vehicle, especially for Heavy PEMS+.