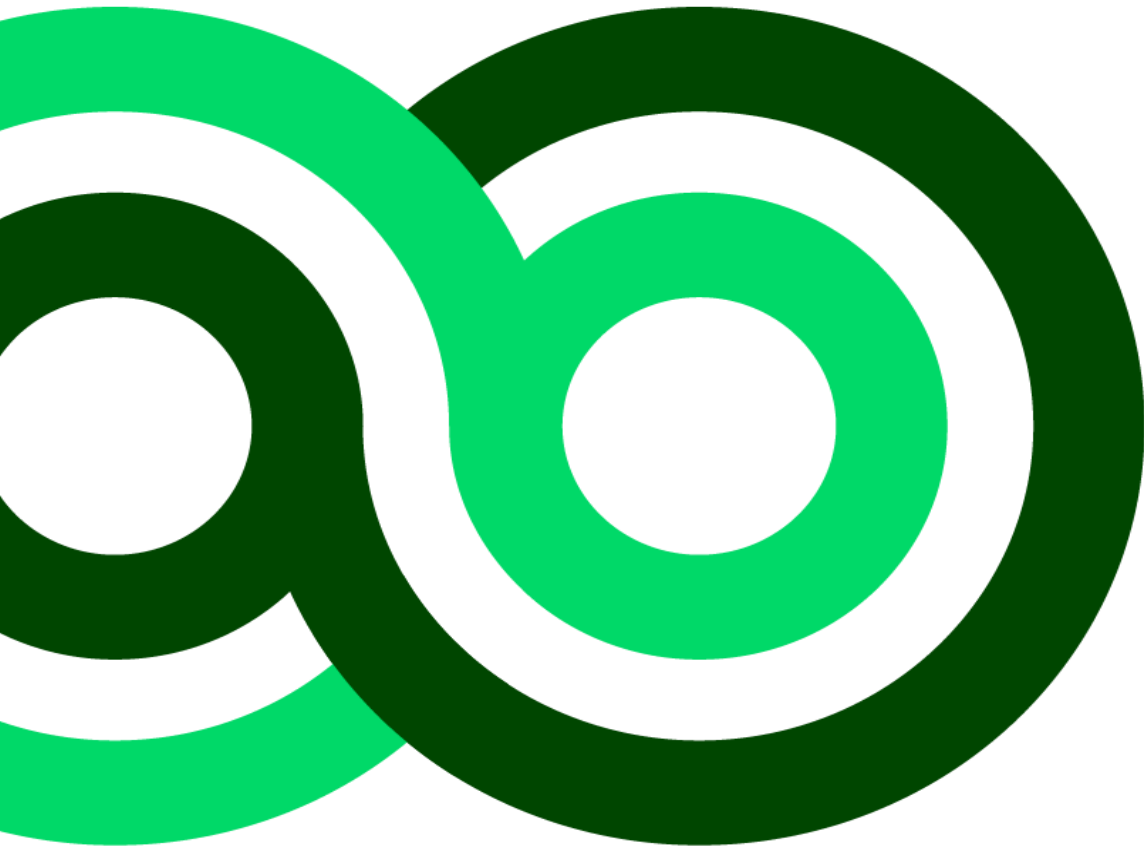


TEST PROCEDURE

Emission Robustness





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Emission Robustness

Introduction

Vehicle emission robustness tests are part of the future Green NCAP 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 tests which are performed in the laboratory, i.e. various WLTC's and the BAB130, are described in the documents related to laboratory testing:

- *GNT_Overview_Laboratory_Test_Sequence_v1.0.0*
- *GNT_BAB_Motorway_v1.0.0*
- *GNT_WLTC+_v1.0.0*

The on-road robustness test program includes and is built around the regular GNCAP PEMS+ tests which described in the document “*GNT_PEMS+_v1.0.0*”. This document describe certain aspects in the robustness procedure which overrule the regular PEMS+ procedure as they are tailored for the on-road robustness tests. 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).

Future 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 connection recognition of the vehicle by execution of a test with and a test without CAN-bus connection. By comparing the environmental performance under a wide range of conditions, the robustness of the vehicle's emission control and fuel consumption can be established.

The on-road robustness tests are for the time being planned after the laboratory testing of the overall GNT test procedure. In practice a flexible timeline can be followed as long as the regular PEMS+ test is performed with a cold engine after an overnight soak.

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 conditions, both on the laboratory as on the road. The on-road conditions are not necessarily limited to the conditions covered in the official RDE procedure. However, the applied conditions are realistic. Any deviations on the legal boundary conditions are described below in Table 3.

Fuel and vehicle preparation

Vehicle shall be refuelled at 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.

On-road robustness priorities

In table 1 the robustness priorities are proposed based on an assessment of test feasibility and readiness and impact on emissions. Due to technical developments and new insights this table can be extended in time. The priorities in the first column are included in the current test protocol.

Table 1: Proposal robustness priorities

Priority	
First	Second
Driving style	Air drag impact (e.g. roof box)
High payload	Additional load (caravan)
Cold-hot start	Wide open throttle
High speed & load	Fuel quality
Urban trips	Cold testing
Short trips	Congestion
	Low payload
	Extreme shifting

On-road PEMS test set up

The vehicle preparations consists 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.

Note: preparations necessary to fit the PEMS to the exhaust system and, if appropriate, external power supply or CAN-bus connection are considered to have started on day 1 of the overall test programme.

On-road PEMS test programme

The test schedule of table 2 contains the minimum number of on-road PEMS emission tests, including the regular PEMS+ test, to span the relevant driving conditions. 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. The deviating conditions of the light and heavy test overrule the regular PEMS+ procedure. In table 3 the three different conditions are specified. Over time the test schedule of table 2 can be extended with additional tests for testing specific items with regard to robustness.

Table 2: Test schedule

Day-Test	Name	Test	Duration [hr]	Comment	Payload	Driving Style	Typical distance [km]
DAY1	Final lab test Installation PEMS						
1-0	Conditioning	Free urban trip	0.5	Commissioning Check PEMS Cold or warm start	Regular	Regular	10
DAY2	Soak		Overnight	Soak outside ¹	-	-	-
2-1	PEMS cold start Full PEMS+ route	Cold Regular	1.5 to 2.0	Regular conditions	Regular	Regular	up to 90
	Soak		-	Soak outside		-	-
	Warm-up	Free urban trip	0.33	Warm the engine up to coolant temp of 80°C			
2-2	PEMS warm start Full PEMS+ route	Warm Light	Up to 2.5 ²	Light conditions	Regular	Economy	up to 90
2-3	Conditioning		Up to 1	Change payload	High	-	-
DAY3	Soak		Overnight	Soak outside		-	-
	Warm-up	Free urban trip	0.33	Warm the engine up to coolant temp of 80°C			
3-1	PEMS warm start Full PEMS+ route	Warm Heavy	Up to 2.5 (excl. 0.5hr for Post- calibration)	Heavy conditions	High	Sportive	up to 90
	Total test duration		±10.5				Up to 280

¹ Minimum temperature should be 0 degrees Celsius, otherwise the soaking should be performed inside at a maximum temperature of 10 degrees Celsius.

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.

Table 3: Light, regular and heavy driving conditions

	Light	Regular	Heavy
General driving and vehicle conditions	According to general PEMS+ procedure		
Driving style	Economy	Regular	Sportive
Max speed [km/h]	100 – 110	110-130	120 – 130
Payload, according to PEMS+ definitions	Regular (PEMS and driver only)	Regular (PEMS and driver only)	90%
Up gear shift speed [rpm]	Follow GSI ³	Follow GSI ⁴	3500 for diesel 4000 for gasoline
Down shift speed [rpm]	Follow GSI ³	Follow GSI ⁴	Follow GSI ⁵
Coasting in gear	As much as possible	Regular	As little as possible
Braking system usage	Moderate	Regular	Aggressive
Start-stop system active	Yes	Yes	No
Vehicle stops of 120-180 s in PEMS test	2	0	0
Maximum position speed pedal [%]	75	85	100
Speed pedal activation speed	Slow	Regular	Fast (avoid spinning wheels)
Airconditioning	Off	On at 22°C	Max. As of start test
Other auxiliary devices (like lights, radio, seat heating)	Only lights on	Only lights on	On
Gear shifting mode (aut)	Economy	Default	Sportive/Power /Performance
PHEVs	Start with charged battery	Start with charged battery	Start with empty battery

Deviations in the boundary conditions compared to the PEMS+ test

- Ambient temperature and road conditions: no change
- Trip composition:
 - 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 vehicle stops are exceeded.
- Driving behaviour:
 - Speed range of motorway driving (light) will be lower
 - A heavy test is meant to reflect driving a vehicle according to its capabilities, instead of driving it to a standard – vehicle independent - speed profile. A heavy test should contain a sufficient amount of demanding events, reflected against the power-to-

³ Gear shifting guidance for vehicles without GSI for the light test: up shift: 2000 rpm, down shift: 1500 rpm.

⁴ Gear shifting guidance for vehicles without GSI for the regular test: up shift: 2500 rpm, down shift: 1750 rpm.

⁵ Gear shifting guidance for vehicles without GSI for the heavy test: down shift diesel: 2250 rpm, down shift gasoline: 2500 rpm.

mass ratio of the vehicle. Preferably also the average demand should be higher than the demand in the ‘regular’ and ‘light’ test. As a guidance and as a first step the heavy test should indicatively contain 50s of $v \cdot a_{pos}$ above 50% of the power-to-mass ratio of the vehicle⁶. From the 2020-tests onwards and as a second step, the guidance will be translated into a requirement and will be supplemented with a requirement, still to be developed, on an average $v \cdot a_{pos}$ target related to the power-to-mass ratio in a heavy test.

- Vehicle conditions: no change

PEMS operation

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

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 would be to make the gear shift point dependent of the engine speed at maximum engine power, e.g. 2000 rpm below this point⁷.*

The selected gear shift speeds shall be reported.

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.

Braking system usage

The braking system usage is described as ‘moderate’, ‘regular’ or ‘aggressive’. In all these driving styles the principle of ‘safety first’ should be maintained. A safe distance with respect to other traffic would be at minimum two seconds.

Overnight soak

In the full programme conditioning will be according to the PEMS+ test requirement: test conditions are in the range of 0 – 30 °C; the vehicle must be soaked outside in open air and the scheduled soak period is at least 6 hours. The maximum time between the end of a conditioning trip and the start of a test shall be not more than 5 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 2-2 shall start after a soak period of max 1.5 hours following a prior PEMS-test. Engine temperature at the start of a warm start test may vary depending on duration of the soak period and/or ambient temperature. The conditioning and soak periods allows for calibration of the PEMS system , if necessary change driver, etc.

⁶ In test data a relatively good correlation has been found between the power-to-mass ratio and the max $v \cdot a$ positive value, this is based on tests where the test mass was varied. An example for a vehicle of 1500kg/1.5 ton and 120 kW would give a power to mass ratio of 80. Half of the power-to-mass ratio would provide a $v \cdot a$ positive value of 40. The proposal of 50 seconds is based on the typical 2000 seconds of acceleration in an RDE trip. 2,5% of these 2000 seconds is 50 seconds for which the maximum $v \cdot a$ pos value of – in this example – 40 should be reached.

⁷ To be elaborated in more detail.

Data collection

Datafiles should contain all measured signals with a measuring frequency of 1 Hz or more, following the general PEMS+ requirements. The vehicle speed signal must be logged at least in two ways. The OBD-VSS and the GPS vehicle speed signal must be logged and a directly derived vehicle speed signal from an ABS wheel speed sensor is strongly recommended when this signal is available.

Data processing and robustness evaluation

For every trip the raw data and the calculated second-by-second data shall be delivered. 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' are⁴:

- RPA and $v \cdot a_{pos}$ checks;
- Indication for level of trip load (CO₂ as a function of velocity);
- More detailed analysis of pollutant emissions. For example, at which driving conditions high emissions occur?

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. Take care of an equal distribution of the payload over the vehicle, especially for Heavy PEMS+.