Commission Regulation (EU) No 582/2011 of 25 May 2011 implementing and amending Regulation (EC) No 595/2009 of the European Parliament and of the Council with respect to emissions from heavy duty vehicles (Euro VI) and amending Annexes I and III to Directive 2007/46/EC of the European Parliament and of the Council (Text with EEA relevance)

ANNEX II

CONFORMITY OF IN-SERVICE ENGINES OR VEHICLES

1. INTRODUCTION

1.1. This Annex sets out requirements for checking and demonstrating the conformity of in-service engines and vehicles.

2. PROCEDURE FOR IN-SERVICE CONFORMITY

2.1. The conformity of in-service vehicles or engines of an engine family shall be demonstrated by testing vehicles on the road operated over their normal driving patterns, conditions and payloads. The in-service conformity test shall be representative for vehicles operated on their real driving routes, with their normal load and with the usual professional driver of the vehicle. When the vehicle is operated by a driver other than the usual professional driver of the particular vehicle, this alternative driver shall be skilled and trained to operate vehicles of the category subject to be tested.

2.2. If the normal in-service conditions of a particular vehicle are considered to be incompatible with the proper execution of the tests, the manufacturer or the approval authority may request that alternative driving routes and payloads are used.

2.3. The manufacturer shall demonstrate to the approval authority that the chosen vehicle, driving patterns, conditions and payloads are representative for the engine family. The requirements as specified in points 4.1 and 4.5 shall be used to determine whether the driving patterns and payloads are acceptable for in-service conformity testing.

2.4. The manufacturer shall report the schedule and the sampling plan for conformity testing at the time of the initial type-approval of a new engine family.

2.5. Vehicles without a communication interface which permits the collection of the necessary ECU data as specified in points 5.2.1 and 5.2.2 of Annex I, with missing data or with a non-standard data protocol shall be considered as non-compliant.

2.6. Vehicles where the collection of ECU data influences the vehicle emissions or performance shall be considered as non-compliant.

3. ENGINE OR VEHICLE SELECTION

3.1. After the granting of type-approval for an engine family the manufacturer shall perform in-service testing on this engine family within 18 months from first registration of a vehicle fitted with an engine from that family. In case of multistage type-approval first registration means first registration of a completed vehicle.

The testing shall be repeated at least every 2 years for each engine family periodically on vehicles over their useful life period as specified in Article 4 of Regulation (EC) No 595/2009.

At the request of the manufacturer the testing may stop 5 years after the end of production.

3.1.1. With a minimum sample size of three engines the sampling procedure shall be set so that the probability of a lot passing a test with 20 % of the vehicles or engines defective is 0,90 (producer's risk = 10 %) while the probability of a lot being accepted with 60 % of the vehicles or engines defective is 0,10 (consumer's risk = 10 %).

3.1.2. The test statistic quantifying the cumulative number of non-conforming tests at the n-th test shall be determined for the sample.

3.1.3. The pass or fail decision of the lot shall be made according to the following requirements:

(a) if the test statistic is less than or equal to the pass decision number for the sample size given in Table 1, a pass decision is reached for the lot;

(b) if the test statistic is greater than or equal to the fail decision number for the sample size given in Table 1, a fail decision is reached for the lot;

(c) otherwise, an additional engine is tested according to this Annex and the calculation procedure is applied to the sample increased by one more unit.

In Table 1 the pass and fail decision numbers are calculated by means of the International Standard ISO 8422/1991.

TABLE 1

Pass and fail decision numbers of the sampling plan Minimum sample size: 3

Cumulative number of engines tested(sample size)	**Pass decision number**	**Fail decision number**
3	—	3
4	0	4
5	0	4
6	1	4
7	1	4
8	2	4
9	2	4
10	3	4

The approval authority shall approve the selected engines and vehicle configurations before the launch of the testing procedures. The selection shall be performed by presenting to the approval authority the criteria used for the selection of the particular vehicles.

3.2. The engines and vehicles selected shall be used and registered in the Union. The vehicle shall have been in service for at least 25 000 km.

3.3. Each vehicle tested shall have a maintenance record to show that the vehicle has been properly maintained and serviced in accordance with the manufacturer's recommendations.

3.4. The OBD system shall be checked for proper functioning of the engine. Any malfunction indications and the readiness code in the OBD memory shall be recorded and any required repairs shall be carried out.

Engines presenting a Class C malfunction shall not be forced to be repaired before testing. The Diagnostic Trouble Code (DTC) shall not be cleared.

Engines having one of the counters required by provisions of Annex XIII not at '0' may not be tested. This shall be reported to the approval authority.

3.5. The engine or vehicle shall exhibit no indications of abuse (such as overloading, misfuelling, or other misuse), or other factors (such as tampering) that could affect emission performance. OBD system fault code and engine running hours information stored in the computer shall be taken into account.

3.6. All emission control system components on the vehicle shall be in conformity with those stated in the applicable type-approval documents.

3.7. In agreement with the approval authority, the manufacturer may run in-service conformity testing comprising fewer engines or vehicles than the number given in point 3.1, if the number of engines manufactured within an engine family is less than 500 units per year.

4. TEST CONDITIONS

4.1. **Vehicle payload**

For the purpose of in-service conformity testing the payload may be reproduced and an artificial load may be used.

In the absence of statistics to demonstrate that the payload is representative for the vehicle, the vehicle payload shall be 50 to 60 % of the maximum vehicle payload.

The maximum payload is the difference between technically permissible maximum laden mass of the vehicle and the mass of the vehicle in running order as specified in accordance to Annex I to Directive 2007/46/EC.

4.2. **Ambient conditions**

The test shall be conducted under ambient conditions meeting the following conditions:

Atmospheric pressure greater than or equal to 82,5 kPa,

Temperature greater than or equal to 266 K (– 7 °C) and less than or equal to the temperature determined by the following equation at the specified atmospheric pressure:

$T = – 0{,}4514 \times (101{,}3 – pb) + 311$

where:

— T is the ambient air temperature, K

— pb is the atmospheric pressure, kPa

4.3. **Engine coolant temperature**

The engine coolant temperature shall be in accordance with point 2.6.1 of Appendix 1.

4.4. The lubricating oil, fuel and reagent shall be within the specifications issued by the manufacturer.

4.4.1. *Lubricating oil*

Oil samples shall be taken.

4.4.2. *Fuel*

The test fuel shall be market fuel covered by Directive 98/70/EC and relevant CEN standards or reference fuel as specified in Annex IX to this Regulation. Fuel samples shall be taken.

4.4.2.1. If the manufacturer in accordance with Section 1 of Annex I to this Regulation has declared the capability to meet the requirements of this Regulation on market fuels declared in point 3.2.2.2.1 of Appendix 4 to Annex I to this Regulation, tests shall be conducted on at least one of the declared market fuels or blend between the declared market fuels and the market fuels included in Directive 98/70/EC and the relevant CEN standards.

4.4.3. *Reagent*

For exhaust after-treatment systems that use a reagent to reduce emissions, a sample of the reagent shall be taken. The reagent shall not be frozen.

4.5. **Trip requirements**

The shares of operation shall be expressed as a percentage of the total trip duration.

The trip shall consist of urban driving followed by rural and motorway driving according to the shares specified in points 4.5.1 to 4.5.4 In the case another testing order is justified for practical reasons and after the agreement of the approval authority another order of urban, rural and motorway operation may be used.

For the purpose of this Section, 'approximately' shall mean the target value ± 5 %.

Urban operation is characterised by vehicle speeds between 0 and 50 km/h,

Rural operation is characterised by vehicle speeds between 50 and 75 km/h,

Motorway operation is characterised by vehicle speeds above 75 km/h.

4.5.1. For M_1 and N_1 vehicles the trip shall consist of approximately 45 % urban, 25 % rural and 30 % motorway operation.

4.5.2. For M_2 and M_3 vehicles the trip shall consist of approximately 45 % urban, 25 % rural and 30 % motorway operation. M_2 and M_3 vehicles of Class I, II or Class A as defined in Annex I to Directive 2001/85/EC of the European Parliament and of the Council[(1)] shall be tested in approximately 70 % urban and 30 % rural operation.

4.5.3. For N_2 vehicles the trip shall consist of approximately 45 % urban, 25 % rural and followed by 30 % motorway operation.

4.5.4. For N_3 vehicles the trip shall consist of approximately 20 % urban, 25 % rural and followed by 55 % motorway operation.

4.5.5 The following distribution of the characteristic trip values from the WHDC database may serve as additional guidance for the evaluation of the trip:

(a) accelerating: 26,9 % of the time;

(b) decelerating: 22,6 % of the time;

(c) cruising: 38,1 % of the time;

(d) stop (vehicle speed = 0): 12,4 % of the time.

4.6. **Operational requirements**

4.6.1. The trip shall be selected in such a way that the testing is uninterrupted and the data continuously sampled to reach the minimum test duration defined in point 4.6.5.

4.6.2. Emissions and other data sampling shall start prior to starting the engine. Any cold start emissions may be removed from the emissions evaluation, in accordance with point 2.6 of Appendix 1.

4.6.3. It shall not be permitted to combine data of different trips or to modify or remove data from a trip.

4.6.4. If the engine stalls, it may be restarted, but the sampling shall not be interrupted.

4.6.5. The minimum test duration shall be long enough to complete five times the work performed during the WHTC or produce five times the CO_2 reference mass in kg/cycle from the WHTC as applicable.

4.6.6. The electrical power to the PEMS system shall be supplied by an external power supply unit, and not from a source that draws its energy either directly or indirectly from the engine under test.

4.6.7. The installation of the PEMS equipment shall not influence the vehicle emissions and/or performance.

4.6.8. It is recommended to operate the vehicles under normal daytime traffic conditions.

4.6.9. If the approval authority is not satisfied with the data consistency check results according to Sections 3.2 of Appendix 1 to this Annex, the approval authority may consider the test to be void.

4.6.10. The same route shall be used for the tests of vehicles within the sample described in points 3.1.1 to 3.1.3.

5. ECU DATA STREAM

5.1. Verification of the availability and conformity of the ECU data stream information required for in-service testing.

5.1.1. The availability of the data stream information according to the requirements of point 5.2 of Annex I shall be demonstrated prior to the in-service test.

5.1.1.1. If that information cannot be retrieved by the PEMS system in a proper manner, the availability of the information shall be demonstrated by using an external OBD scan-tool as described in Annex X.

5.1.1.1.1. In the case where this information can be retrieved by the scan-tool in a proper manner, the PEMS system is considered as failing and the test is void.

5.1.1.1.2. In the case where that information cannot be retrieved in a proper manner from two vehicles with engines from the same engine family, while the scan-tool is working properly, the engine is considered as non-compliant.

5.1.2. The conformity of the torque signal calculated by the PEMS equipment from the ECU data stream information required in point 5.2.1 of Annex I shall be verified at full load.

5.1.2.1. The method used to check this conformity is described in Appendix 4.

5.1.2.2. The conformity of the ECU torque signal is considered to be sufficient if the calculated torque remains within the full load torque tolerance specified in point 5.

5.1.2.3. If the calculated torque does not remain within the full load torque tolerance specified in point 5.2.5 of Annex I, the engine is considered to have failed the test.

6. EMISSIONS EVALUATION

6.1. The test shall be conducted and the test results shall be calculated in accordance with the provisions of Appendix 1 to this Annex.

6.2. The conformity factors shall be calculated and presented for both the CO_2 mass based method and the Work based method. The pass/fail decision shall be made on the basis of the results of the Work based method.

6.3. The 90 % cumulative percentile of the exhaust emission conformity factors from each engine system tested, determined in accordance with the measurement and calculation procedures specified in Appendix 1, shall not exceed any of the values set out in Table 2.

TABLE 2

Maximum allowed conformity factors for in-service conformity emission testing

Pollutant	Maximum allowed conformity factor
CO	1,5
THC[a]	1,5
NMHC[b]	1,5
CH_4[b]	1,5
NO_x	1,5
PM mass	—
PM number	—

a For compression-ignition engines.

b For positive-ignition engines.

7. EVALUATION OF IN-SERVICE CONFORMITY RESULTS

7.1. On the basis of the in-service conformity report referred to in Section 10, the approval authority shall either:

(a) decide that the in-service conformity testing of an engine system family is satisfactory and not take any further action;

(b) decide that the data provided is insufficient to reach a decision and request additional information and test data from the manufacturer;

(c) decide that the in-service conformity of an engine system family is unsatisfactory and proceed to the measures referred to in Article 13 and in Section 9 of this Annex.

8. CONFIRMATORY VEHICLE TESTING

8.1. Confirmatory testing is done for the purpose of confirmation of the in-service emission functionality of an engine family.

8.2. Approval authorities may conduct confirmatory testing.

8.3. The confirmatory test shall be performed as vehicle testing as specified in points 2.1 and 2.2. Representative vehicles shall be selected and used under normal conditions and be tested according to the procedures defined in this Annex.

8.4. A test result may be regarded as non-satisfactory when, from tests of two or more vehicles representing the same engine family, for any regulated pollutant component, the limit value as determined according to Section 6 is exceeded significantly.

9. PLAN OF REMEDIAL MEASURES

9.1. The manufacturer shall submit a report to the approval authority of the Member State where the engines or vehicles subject to remedial action are registered or used when planning to conduct remedial action, and shall submit this report when deciding to take action. The report shall specify the details of the remedial action and describe the engine families to be included in the action. The manufacturer shall report regularly to the approval authority after the start of the remedial action.

9.2. The manufacturer shall provide a copy of all communications related to the plan of remedial measures, and shall maintain a record of the recall campaign, and supply regular status reports to the approval authority.

9.3. The manufacturer shall assign a unique identifying name or number to the plan of remedial measures.

9.4. The manufacturer shall present a plan of remedial measures which shall consist of the information specified in points 9.4.1 to 9.4.11.

9.4.1. A description of each engine system type included in the plan of remedial measures.

9.4.2. A description of the specific modifications, alterations, repairs, corrections, adjustments, or other changes to be made to bring the engines into conformity including a brief summary of the data and technical studies which support the manufacturer’s decision as to the particular measures to be taken to correct the non-conformity.

9.4.3. A description of the method by which the manufacturer informs the engine or vehicle owners about the remedial measures.

9.4.4. A description of the proper maintenance or use, if any, which the manufacturer stipulates as a condition of eligibility for repair under the plan of remedial measures, and an explanation of the manufacturer’s reasons for imposing any such condition. No maintenance or use conditions may be imposed unless it is demonstrably related to the non-conformity and the remedial measures.

9.4.5. A description of the procedure to be followed by engine or vehicle owners to obtain correction of the non-conformity. This description shall include a date after which the remedial measures may be taken, the estimated time for the workshop to perform the repairs and where they can be done. The repair shall be done expediently, within a reasonable time after delivery of the vehicle.

9.4.6. A copy of the information transmitted to the engine or vehicle owner.

9.4.7. A brief description of the system which the manufacturer uses to assure an adequate supply of components or systems for fulfilling the remedial action. It shall be indicated when there will be an adequate supply of components or systems to initiate the campaign.

9.4.8. A copy of all instructions to be sent to those persons who are to perform the repair.

9.4.9. A description of the impact of the proposed remedial measures on the emissions, fuel consumption, driveability, and safety of each engine or vehicle type, covered by the plan of remedial measures with data, technical studies, etc., which support these conclusions.

9.4.10. Any other information, reports or data the approval authority may reasonably determine is necessary to evaluate the plan of remedial measures.

9.4.11. Where the plan of remedial measures includes a recall, a description of the method for recording the repair shall be submitted to the approval authority. If a label is used, an example of it shall be submitted.

9.5. The manufacturer may be required to conduct reasonably designed and necessary tests on components and engines incorporating a proposed change, repair, or modification to demonstrate the effectiveness of the change, repair, or modification.

10. REPORTING PROCEDURES

10.1. A technical report shall be submitted to the approval authority for each engine family tested. The report shall show the activities and results of the in-service conformity testing. The report shall include at least the following:

10.1.1. *General*

10.1.1.1. Name and address of the manufacturer.

10.1.1.2. Address(es) of assembly plant(s).

10.1.1.3. The name, address, telephone and fax numbers and e-mail address of the manufacturer's representative.

10.1.1.4. Type and commercial description (mention any variants).

10.1.1.5. Engine family.

10.1.1.6. Parent engine.

10.1.1.7. Engine family members.

10.1.1.8. The vehicle identification number (VIN) codes applicable to the vehicles equipped with an engine that is part of the in-service conformity check.

10.1.1.9. Means and location of identification of type, if marked on the vehicle.

10.1.1.10. Category of vehicle.

10.1.1.11. Type of engine: petrol, ethanol (E85), diesel/NG /LPG/ethanol (ED95) (Delete as appropriate).

10.1.1.12. The numbers of the type-approvals applicable to the engine types within the in-service family, including, where applicable, the numbers of all extensions and field fixes/ recalls (reworks).

10.1.1.13. Details of extensions, field fixes/recalls to those type-approvals for the engines covered within the manufacturer's information.

10.1.1.14. The engine build period covered within the manufacturer's information (e.g. 'vehicles or engines manufactured during the 2014 calendar year').

10.1.2. *Engine/vehicle selection*

10.1.2.1. Vehicle or engine location method.

10.1.2.2. Selection criteria for vehicles, engines, in-service families.

10.1.2.3. Geographical areas within which the manufacturer has collected vehicles.

10.1.3. *Equipment*

10.1.3.1. PEMS Equipment, brand and type.

10.1.3.2. PEMS calibration.

10.1.3.3. PEMS power supply.

10.1.3.4. Calculation software and version used (e.g. EMROAD 4.0).

10.1.4. *Test data*

10.1.4.1. Date and time of test.

10.1.4.2. Location of test including details information about the test route.

10.1.4.3. Weather/ambient conditions (e.g. temperature, humidity, altitude).

10.1.4.4. Distances covered per vehicle on the test route.

10.1.4.5. Test fuel specifications characteristics.

10.1.4.6. Reagent specification (if applicable).

10.1.4.7. Lubrication oil specification.

10.1.4.8. Emission test results according to Appendix 1 to this Annex.

10.1.5. *Engine information*

10.1.5.1. Engine fuel type (e.g. diesel, ethanol ED95, NG, LPG, petrol, E85).

10.1.5.2. Engine combustion system (e.g. compressed ignition or positive ignition).

10.1.5.3. Type-approval number.

10.1.5.4. Engine rebuilt.

10.1.5.5. Engine manufacturer.

10.1.5.6. Engine model.

10.1.5.7. Engine production year and month.

10.1.5.8. Engine identification number.

10.1.5.9. Engine displacement [litres].

10.1.5.10. Number of cylinders.

10.1.5.11. Engine rated power [kW @ rpm].

10.1.5.12. Engine peak torque [Nm @ rpm].

10.1.5.13. Idle speed [rpm].

10.1.5.14. Manufacturer supplied full-load torque curve available (yes/no).

10.1.5.15. Manufacturer supplied full-load torque curve reference number.

10.1.5.16. $DeNO_x$ system (e.g. EGR, SCR).

10.1.5.17. Type of catalytic converter.

10.1.5.18. Type of Particulate trap.

10.1.5.19. After-treatment modified with respect to type-approval? (yes/no)

10.1.5.20. Engine ECU information (Software calibration number).

10.1.6. *Vehicle information*

10.1.6.1. Vehicle owner.

10.1.6.2. Vehicle type (e.g. M_3, N_3) and application (e.g. rigid or articulated truck, city bus).

10.1.6.3. Vehicle manufacturer.

10.1.6.4. Vehicle Identification Number.

10.1.6.5. Vehicle registration number and country of registration.

10.1.6.6. Vehicle model.

10.1.6.7. Vehicle production year and month.

10.1.6.8. Transmission type (e.g. manual, automatic or other).

10.1.6.9. Number of forward gears.

10.1.6.10. Odometer reading at test start [km].

10.1.6.11. Gross vehicle combination weight rating (GVW) [kg].

10.1.6.12. Tire size [Not mandatory].

10.1.6.13. Tail pipe diameter [mm] [Not mandatory].

10.1.6.14. Number of axles.

10.1.6.15. Fuel tank(s) capacity [litres] [Not mandatory].

10.1.6.16. Number of fuel tanks [Not mandatory].

10.1.6.17. Reagent tank(s) capacity [litres] [Not mandatory].

10.1.6.18. Number of reagent tanks [Not mandatory].

10.1.7. *Test route characteristics*

10.1.7.1. Odometer reading at test start [km]

10.1.7.2. Duration [s]

10.1.7.3. Average ambient conditions (as calculated from the instantaneous measured data)

10.1.7.4. Ambient conditions sensor information (type and location of sensors)

10.1.7.5. Vehicle speed information (for example cumulative speed distribution)

10.1.7.6. Shares of the time of the trip characterised by urban, rural and motorway operation as described in point 4.5.

10.1.7.7. Shares of the time of the trip characterised by accelerating, decelerating, cruising and stop as described in point 4.5.5.

10.1.8. *Instantaneous measured data*

10.1.8.1. THC concentration [ppm].

10.1.8.2. CO concentration [ppm].

10.1.8.3. NO_x concentration [ppm].

10.1.8.4. CO_2 concentration [ppm].

10.1.8.5. CH_4 concentration [ppm] for P.I. engines only.

10.1.8.6. Exhaust gas flow [kg/h].

10.1.8.7. Exhaust temperature [°C].

10.1.8.8. Ambient air temperature [°C].

10.1.8.9. Ambient pressure [kPa].

10.1.8.10. Ambient humidity [g/kg] [Not mandatory].

10.1.8.11. Engine torque [Nm].

10.1.8.12. Engine speed [rpm].

10.1.8.13. Engine fuel flow [g/s].

10.1.8.14. Engine coolant temperature [°C].

10.1.8.15. Vehicle ground speed [km/h] from ECU and GPS.

10.1.8.16. Vehicle latitude [degree] (Accuracy needs to be sufficient to enable the traceability of the test route).

10.1.8.17. Vehicle longitude [degree].

10.1.9. *Instantaneous calculated data*

10.1.9.1. THC mass [g/s].

10.1.9.2. CO mass [g/s].

10.1.9.3. NO_x mass [g/s].

10.1.9.4. CO_2 mass [g/s].

10.1.9.5. CH_4 mass [g/s] for P.I. engines only.

10.1.9.6. THC cumulated mass [g].

10.1.9.7. CO cumulated mass [g].

10.1.9.8. NO_x cumulated mass [g].

10.1.9.9. CO_2 cumulated mass [g].

10.1.9.10. CH_4 cumulated mass [g] for P.I. engines only.

10.1.9.11. Calculated fuel rate[g/s].

10.1.9.12. Engine power [kW].

10.1.9.13. Engine work [kWh].

10.1.9.14. Work window duration [s].

10.1.9.15. Work window average engine power [%].

10.1.9.16. Work window THC conformity factor [-].

10.1.9.17. Work window CO conformity factor [-].

10.1.9.18. Work window NO_x conformity factor [-].

10.1.9.19. Work window CH_4 conformity factor [-] for P.I. engines only.

10.1.9.20. CO_2 mass window duration [s].

10.1.9.21. CO_2 mass window THC conformity factor [-].

10.1.9.22. CO_2 mass window CO conformity factor [-].

10.1.9.23. CO_2 mass window NO_x conformity factor [-].

10.1.9.24. CO_2 mass window CH_4 conformity factor [-] for P.I. engines only.

10.1.10. *Averaged and integrated data*

10.1.10.1. Average THC concentration [ppm] [Not mandatory].

10.1.10.2. Average CO concentration [ppm] [Not mandatory].

10.1.10.3. Average NO_x concentration [ppm] [Not mandatory].

10.1.10.4. Average CO_2 concentration [ppm] [Not mandatory].

10.1.10.5. Average CH_4 concentration [ppm] for gas engines only [Not mandatory].

10.1.10.6. Average Exhaust gas flow [kg/h] [Not mandatory].

10.1.10.7. Average Exhaust temperature [°C] [Not mandatory].

10.1.10.8. THC emissions [g].

10.1.10.9. CO emissions [g].

10.1.10.10. NO_x emissions [g].

10.1.10.11. CO_2 emissions [g].

10.1.10.12. CH_4 emissions [g] for gas engines only.

10.1.11. *Pass-fail results*

10.1.11.1. Minimum, maximum, and 90 % cumulative percentile for:

10.1.11.2. Work window THC conformity factor [-].

10.1.11.3. Work window CO conformity factor [-].

10.1.11.4. Work window NO_x conformity factor [-].

10.1.11.5. Work window CH_4 conformity factor [-] for P.I. engines only.

10.1.11.6. CO_2 mass window THC conformity factor [-].

10.1.11.7. CO_2 mass window CO conformity factor [-].

10.1.11.8. CO_2 mass window NO_x conformity factor [-].

10.1.11.9. CO_2 mass window CH_4 conformity factor [-] for P.I. engines only.

10.1.11.10. Work window: Minimum and maximum average window power [%].

10.1.11.11. CO_2 mass window: Minimum and maximum window duration [s].

10.1.11.12. Work window: Percentage of valid windows.

10.1.11.13. CO_2 mass window: Percentage of valid windows.

10.1.12. *Test verifications*

10.1.12.1. THC analyser zero, span and audit results, pre and post test.

10.1.12.2. CO analyser zero, span and audit results, pre and post test.

10.1.12.3. NO_x analyser zero, span and audit results, pre and post test.

10.1.12.4. CO_2 analyser zero, span and audit results, pre and post test.

10.1.12.5. Data consistency check results, according to Section 3.2 of Appendix 1 to this Annex.

10.1.13. List of further attachments where these exist.

Appendix 1

Test procedure for vehicle emissions testing with portable emissions measurement systems

1. INTRODUCTION

This Appendix describes the procedure to determine gaseous emissions from on-vehicle on-road measurements using Portable Emissions Measurement Systems (hereinafter 'PEMS'). The gaseous emissions to be measured from the exhaust of the engine include the following components: carbon monoxide, total hydrocarbons and nitrogen oxides for diesel engines with the addition of methane for gas engines. Additionally, carbon dioxide shall be measured to enable the calculation procedures described in Sections 4 and 5.

2. TEST PROCEDURE

2.1. **General requirements**

The tests shall be carried out with a PEMS comprised of:

2.1.1. Gas analysers to measure the concentrations of regulated gaseous pollutants in the exhaust gas.

2.1.2. An exhaust mass flow meter based on the averaging Pitot or equivalent principle.

2.1.3. A Global Positioning System (hereinafter 'GPS').

2.1.4. Sensors to measure the ambient temperature and pressure.

2.1.5. A connection with the vehicle ECU).

2.2. **Test parameters**

The parameters summarised in Table 1 shall be measured and recorded:

TABLE 1

Test parameters

Parameter	Unit	Source
THC concentration[a]	ppm	Analyser
CO concentration[a]	ppm	Analyser
NO_x concentration[a]	ppm	Analyser
CO_2 concentration[a]	ppm	Analyser
CH_4 concentration[ab]	ppm	Analyser

a	Measured or corrected to a wet basis.
b	Gas engines only.
c	Use the ambient temperature sensor or an intake air temperature sensor.
d	The recorded value shall be either (a) the net torque or (b) the net torque calculated from the actual engine percent torque, the friction torque and the reference torque, according to the SAE J1939-71 standard.

Exhaust gas flow	kg/h	Exhaust Flow Meter (hereinafter 'EFM')
Exhaust temperature	°K	EFM
Ambient temperature[c]	°K	Sensor
Ambient pressure	kPa	Sensor
Engine torque[d]	Nm	ECU or Sensor
Engine speed	rpm	ECU or Sensor
Engine fuel flow	g/s	ECU or Sensor
Engine coolant temperature	°K	ECU or Sensor
Engine intake air temperature[c]	°K	Sensor
Vehicle ground speed	km/h	ECU and GPS
Vehicle latitude	degree	GPS
Vehicle longitude	degree	GPS

a Measured or corrected to a wet basis.

b Gas engines only.

c Use the ambient temperature sensor or an intake air temperature sensor.

d The recorded value shall be either (a) the net torque or (b) the net torque calculated from the actual engine percent torque, the friction torque and the reference torque, according to the SAE J1939-71 standard.

2.3. **Preparation of the vehicle**

The preparation of the vehicle shall include the following:

(a) the check of the OBD system: any identified problems once solved shall be recorded and presented to the approval authority;

(b) the replacement of oil, fuel and reagent, if any.

2.4. **Installation of the measuring equipment**

2.4.1. *Main Unit*

Whenever possible, PEMS shall be installed in a location where it will be subject to minimal impact from the following:

(a) ambient temperature changes;

(b) ambient pressure changes;

(c) electromagnetic radiation;

(d) mechanical shock and vibration;

(e) ambient hydrocarbons — if using a FID analyser that uses ambient air as FID burner air.

The installation shall follow the instructions issued by the PEMS manufacturer.

2.4.2. *Exhaust flow meter*

The exhaust flow meter shall be attached to the vehicle's tailpipe. The EFM sensors shall be placed between two pieces of straight tube whose length should be at least 2 times the EFM diameter (upstream and downstream). It is recommended to place the EFM after the vehicle silencer, to limit the effect of exhaust gas pulsations upon the measurement signals.

2.4.3. *Global Positioning System*

The antenna shall be mounted at the highest possible location, without risking interference with any obstructions encountered during on-road operation.

2.4.4. *Connection with the vehicle ECU*

A data logger shall be used to record the engine parameters listed in Table 1. This data logger can make use of the Control Area Network (hereinafter 'CAN') bus of the vehicle to access the ECU data broadcasted on the CAN according to standard protocols such as SAE J1939, J1708 or ISO 15765-4.

2.4.5. *Sampling of gaseous emissions*

The sample line shall be heated according to the specifications of point 2.3 of Appendix 2 and properly insulated at the connection points (sample probe and back of the main unit), to avoid the presence of cold spots that could lead to a contamination of the sampling system by condensed hydrocarbons.

The sample probe shall be installed in the exhaust pipe in accordance with the requirements of Section 9.3.10 of Annex 4B to UN/ECE Regulation No 49.

If the length of the sample line is changed, the system transport times shall be verified and if necessary corrected.

2.5. **Pre-test procedures**

2.5.1. *Starting and stabilising the PEMS instruments*

The main units shall be warmed up and stabilised according to the instrument manufacturer specifications until pressures, temperatures and flows have reached their operating set points.

2.5.2. *Cleaning the sampling system*

To prevent system contamination, the sampling lines of the PEMS instruments shall be purged until sampling begins, according to the instrument manufacturer specifications.

2.5.3. *Checking and calibrating the analysers*

The zero and span calibration and the linearity checks of the analysers shall be performed using calibration gases meeting the requirements of Section 9.3.3 of Annex 4B to UN/ECE Regulation No 49.

2.5.4. *Cleaning the EFM*

The EFM shall be purged at the pressure transducer connections in accordance with the instrument manufacturer specifications. This procedure shall remove condensation and diesel particulate matter from the pressure lines and the associated flow tube pressure measurement ports.

2.6. **Emissions test run**

2.6.1. *Test start*

Emissions sampling, measurement of the exhaust parameters and recording of the engine and ambient data shall start prior to starting the engine. The data evaluation shall start after the coolant temperature has reached 343K (70 °C) for the first time or after the coolant temperature is stabilised within +/– 2K over a period of 5 minutes whichever comes first but no later than 20 minutes after engine start.

2.6.2. *Test run*

Emission sampling, measurement of the exhaust parameters and recording of the engine and ambient data shall continue throughout the normal in-use operation of the engine. The engine may be stopped and started, but emissions sampling shall continue throughout the entire test.

Periodic checks of the PEMS gas analysers shall be conducted at least every 2 hours. The data recorded during the checks shall be flagged and shall not be used for the emission calculations.

2.6.3. *End of test sequence*

At the end of the test, sufficient time shall be given to the sampling systems to allow their response times to elapse. The engine may be shut down before or after sampling is stopped.

2.7. **Verification of the measurements**

2.7.1. *Checking of the analysers*

The zero, span and linearity checks of the analysers as described in point 2.5.3 shall be performed using calibration gases meeting the requirements of Section 9.3.3 of Annex 4B to UN/ECE Regulation No 49.

2.7.2. *Zero drift*

Zero response is defined as the mean response, including noise, to a zero gas during a time interval of at least 30 seconds. The drift of the zero response shall be less than 2 % of full scale on the lowest range used.

2.7.3. *Span drift*

Span response is defined as the mean response, including noise, to a span gas during a time interval of at least 30 seconds. The drift of the span response shall be less than 2 % of full scale on the lowest range used.

2.7.4. *Drift verification*

This shall apply only if, during the test, no zero drift correction was made.

As soon as practical but no later than 30 minutes after the test is complete the gaseous analyser ranges used shall be zeroed and spanned to check their drift compared to the pre-test results.

The following provisions shall apply for analyser drift:

(a) if the difference between the pre-test and post-test results is less than 2 % as specified in points 2.7.2 and 2.7.3, the measured concentrations may be used uncorrected or may be corrected for drift according to point 2.7.5;

(b) if the difference between the pre-test and post-test results is equal to or greater than 2 % as specified in points 2.7.2 and 2.7.3, the test shall be voided or the measured concentrations shall be corrected for drift according to point 2.7.5.

2.7.5. *Drift correction*

If drift correction is applied in accordance with point 2.7.4, the corrected concentration value shall be calculated according to Section 8.6.1 of Annex 4B to UN/ECE Regulation No 49.

The difference between the uncorrected and the corrected brake-specific emission values shall be within ± 6 % of the uncorrected brake-specific emission values. If the drift is greater than 6 %, the test shall be voided. If drift correction is applied, only the drift-corrected emission results shall be used when reporting emissions.

3. CALCULATION OF THE EMISSIONS

The final test result shall be rounded in one step to the number of places to the right of the decimal point indicated by the applicable emission standard plus one additional significant figure, in accordance with ASTM E 29-06b. No rounding of intermediate values leading to the final brake-specific emission result shall be allowed.

3.1. **Time alignment of data**

To minimise the biasing effect of the time lag between the different signals on the calculation of mass emissions, the data relevant for emissions calculation shall be time aligned, as described in points 3.1.1 to 3.1.4.

3.1.1. *Gas analysers data*

The data from the gas analysers shall be properly aligned using the procedure in Section 9.3.5 of Annex 4B to UN/ECE Regulation No 49.

3.1.2. *Gas analysers and EFM data*

The data from the gas analysers shall be properly aligned with the data of the EFM using the procedure in point 3.1.4.

3.1.3. *PEMS and engine data*

The data from the PEMS (gas analysers and EFM) shall be properly aligned with the data from the engine ECU using the procedure in point 3.1.4.

3.1.4. *Procedure for improved time-alignment of the PEMS data*

The test data listed in Table 1 are split into 3 different categories:

1 : Gas analysers (THC, CO, CO_2, NO_x concentrations);
2 : Exhaust Flow Meter (Exhaust mass flow and exhaust temperature);
3 : Engine (Torque, speed, temperatures, fuel rate, vehicle speed from ECU).

The time alignment of each category with the other categories shall be verified by finding the highest correlation coefficient between two series of parameters. All the parameters in a category shall be shifted to maximise the correlation factor. The following parameters shall be used to calculate the correlation coefficients:

To time-align:

(a) categories 1 and 2 (Analysers and EFM data) with category 3 (Engine data): the vehicle speed from the GPS and from the ECU;

(b) category 1 with category 2: the CO_2 concentration and the exhaust mass;

(c) category 2 with category 3: the CO_2 concentration and the engine fuel flow.

3.2. **Data consistency checks**

3.2.1. *Analysers and EFM data*

The consistency of the data (exhaust mass flow measured by the EFM and gas concentrations) shall be verified using a correlation between the measured fuel flow from the ECU and the fuel flow calculated using the formula in Section 8.4.1.6 of Annex 4B to UN/ECE Regulation No 49. A linear regression shall be performed for the measured and calculated fuel rate values. The method of least squares shall be used, with the best fit equation having the form:

$y = mx + b$

where:

— y is the calculated fuel flow [g/s]
— m is the slope of the regression line
— x is the measured fuel flow [g/s]
— b is the y intercept of the regression line

The slope (m) and the coefficient of determination (r^2) shall be calculated for each regression line. It is recommended to perform this analysis in the range from 15 % of the maximum value to the maximum value and at a frequency greater or equal to 1 Hz. For a test to be considered valid, the following two criteria shall be evaluated:

TABLE 2

Tolerances

Slope of the regression line, m	0,9 to 1,1 — Recommended
Coefficient of determination r^2	min. 0,90 — Mandatory

3.2.2. *ECU torque data*

The consistency of the ECU torque data shall be verified by comparing the maximum ECU torque values at different engine speeds with the corresponding values on the official engine full load torque curve according to Section 5 of Annex II.

3.2.3. *Brake-Specific Fuel Consumption*

The Brake Specific Fuel Consumption (BSFC) shall be checked using:

(a) the fuel consumption calculated from the emissions data (gas analyser concentrations and exhaust mass flow data), according to the formulae in Section 8.4.1.6 of Annex 4B to UN/ECE Regulation No 49;

(b) the work calculated using the data from the ECU (Engine torque and engine speed).

3.2.4. *Odometer*

The distance indicated by the vehicle odometer shall be checked against the GPS data and verified.

3.2.5. *Ambient pressure*

The ambient pressure value shall be checked against the altitude indicated by the GPS data.

3.3. **Dry-Wet correction**

If the concentration is measured on a dry basis, it shall be converted to a wet basis according to the formula in Section 8.1 of Annex 4B to UN/ECE Regulation No 49.

3.4. **NO_x correction for humidity and temperature**

The NO_x concentrations measured by the PEMS shall not be corrected for ambient air temperature and humidity.

3.5. **Calculation of the instantaneous gaseous emissions**

The mass emissions shall be determined as described in Section 8.4.2.3 of Annex 4B to UN/ECE Regulation No 49.

4. DETERMINATION OF EMISSIONS AND CONFORMITY FACTORS

4.1. **Averaging window principle**

The emissions shall be integrated using a moving averaging window method, based on the reference CO_2 mass or the reference work. The principle of the calculation is as follows: The mass emissions are not calculated for the complete data set, but for sub-sets of the complete data set, the length of these sub-sets being determined so as to match the engine CO_2 mass or work measured over the reference laboratory transient cycle. The moving average calculations are conducted with a time increment Δt equal to the data sampling period. These sub-sets used to average the emissions data are referred to as 'averaging windows' in the following Sections.

Any Section of invalidated data shall not be considered for the calculation of the work or CO_2 mass and the emissions of the averaging window.

The following data shall be considered as invalidated data:

(a) the periodic verification of the instruments and/or after the zero drift verifications;

(b) the data outside the conditions specified in points 4.2 and 4.3 of Annex II.

The mass emissions (mg/window) shall be determined as described in Section 8.4.2.3 of Annex 4B to UN/ECE Regulation No 49.
Figure 1

Vehicle speed versus time and Vehicle averaged emissions, starting from the first averaging window, versus time

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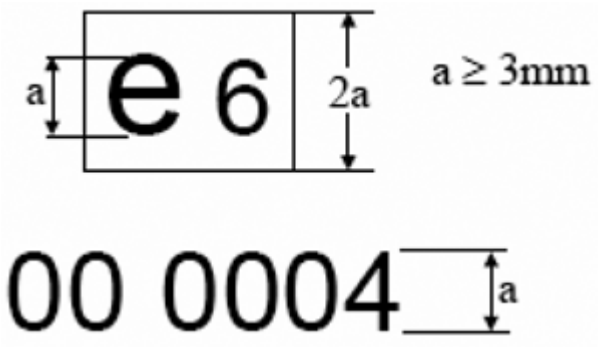
4.2. **Work based method**
Figure 2

Work based method



The duration ($t_{2,i} - t_{1,i}$) of the i[th] averaging window is determined by:

$$W(t_{2,i}) - W(t_{1,i}) \geq W_{ref}$$

where:

— $W(t_{j,i})$ is the engine work measured between the start and time $t_{j,i}$, kWh;

— W_{ref} is the engine work for the WHTC, kWh;

— $t_{2,i}$ shall be selected such that:

$$W(t_{2,i} - \Delta t) - W(t_{1,i}) < W_{ref} \leq W(t_{2,i}) - W(t_{1,i})$$

Where Δt is the data sampling period, equal to 1 second or less.

4.2.1. *Calculation of the specific emissions*

The specific emissions e_{gas} (mg/kWh) shall be calculated for each window and each pollutant in the following way:

$$e_{gas} = \frac{m}{W(t_{2,i}) - W(t_{1,i})}$$

where:

— m is the mass emission of the component, mg/window

— $W(t_{2,i}) - W(t_{1,i})$ is the engine work during the i[th] averaging window, kWh

4.2.2. *Selection of valid windows*

The valid windows are the windows whose average power exceeds the power threshold of 20 % of the maximum engine power. The percentage of valid windows shall be equal or greater than 50 %.

4.2.2.1. If the percentage of valid windows is less than 50 %, the data evaluation shall be repeated using lower power thresholds. The power threshold shall be reduced in steps of 1 % until the percentage of valid windows is equal to or greater than 50 %.

4.2.2.2. In any case, the lower threshold shall not be lower than 15 %.

4.2.2.3. The test shall be void if the percentage of valid windows is less than 50 % at a power threshold of 15 %.

4.2.3. *Calculation of the conformity factors*

The conformity factors shall be calculated for each individual valid window and each individual pollutant in the following way:

$$CF = \frac{e}{L}$$

where:

— e is the brake-specific emission of the component, mg/kWh;

— L is the applicable limit, mg/kWh.

4.3. **CO_2 mass based method**

Figure 3

CO_2 mass based method

$\overline{IUPR_g}$

The duration ($t_{2,i} - t_{1,i}$) of the i[th] averaging window is determined by:

$$m_{CO2}(t_{2,i}) - m_{CO2}(t_{1,i}) \geq m_{CO2,ref}$$

where:

— $m_{CO2}(t_{j,i})$ is the CO_2 mass measured between the test start and time $t_{j,i}$, kg;

— $m_{CO2,ref}$ is the CO_2 mass determined for the WHTC, kg;

— $t_{2,i}$ shall be selected such as:

$$m_{CO2}(t_{2,i} - \Delta t) - m_{CO2}(t_{1,i}) < m_{CO2,ref} \leq m_{CO2}(t_{2,i}) - m_{CO2}(t_{1,i})$$

Where Δt is the data sampling period, equal to 1 second or less.

The CO_2 masses are calculated in the windows by integrating the instantaneous emissions calculated according to the requirements introduced in point 3.5.

4.3.1. *Selection of valid windows*

The valid windows shall be the windows whose duration does not exceed the maximum duration calculated from:

$$D_{max} = 3600 \cdot \frac{W_{ref}}{0.2 \cdot P_{max}}$$

where:

— D_{max} is the maximum window duration, s;

— P_{max} is the maximum engine power, kW.

4.3.2. *Calculation of the conformity factors*

The conformity factors shall be calculated for each individual window and each individual pollutant in the following way:

$$CF = \frac{CF_I}{CF_C}$$

with

$$CF_I = \frac{m}{m_{CO2}(t_{2,i}) - m_{CO2}(t_{1,i})}$$

(in service ratio) and

$$CF_C = \frac{m_L}{m_{CO2,ref}}$$

(certification ratio)

where:

— m is the mass emission of the component, mg/window;

— $m_{CO2}(t_{2,i}) - m_{CO2}(t_{1,i})$ is the CO_2 mass during the i[th] averaging window, kg;

— $m_{CO2,ref}$ is the engine CO_2 mass determined for the WHTC, kg;

— m_L is the mass emission of the component corresponding to the applicable limit on the WHTC, mg.

Appendix 2

Portable measurement equipment

1. GENERAL

The gaseous emissions shall be measured according to the procedure set out in Appendix 1. The present Appendix describes the characteristics of the portable measurement equipment that shall be used to perform such tests.

2. MEASURING EQUIPMENT

2.1. **Gas analysers general specifications**

The PEMS gas analysers specifications shall meet the requirements set out in Section 9.3.1 of Annex 4B to UN/ECE Regulation No 49.

2.2. **Gas analysers technology**

The gases shall be analysed using the technologies specified in Section 9.3.1 of Annex 4B to UN/ECE Regulation No 49.

The oxides of nitrogen analyser may also be of the Non-Dispersive Ultra Violet (NDUV) type.

2.3. **Sampling of gaseous emissions**

The sampling probes shall meet the requirements defined in Section 3.1.2 of Appendix 3 to Annex 4B to UN/ECE Regulation No 49. The sampling line shall be heated to 190 °C (+/– 10 °C).

2.4. **Other instruments**

The measuring instruments shall satisfy the requirements given in Table 7 and Section 9.3.1 to Annex 4B to UN/ECE Regulation No 49.

3. AUXILIARY EQUIPMENT

3.1. **Exhaust Gas Flow Meter (EFM) tailpipe connection**

The installation of the EFM shall not increase the backpressure by more than the value recommended by the engine manufacturer, nor increase the length of the tailpipe by more than 1,2 m. As for the all the components of the PEMS equipment, the installation of the EFM shall comply with the locally applicable road safety regulations and insurance requirements.

3.2. **PEMS location and mounting hardware**

The PEMS equipment shall be installed as specified in Section 2.4 of Appendix 1.

3.3. **Electrical power**

The PEMS equipment shall be powered using the method described in point 4.6.6 of Annex II.

Appendix 3

Calibration of portable measurement equipment

1. EQUIPMENT CALIBRATION AND VERIFICATION

1.1. Calibration gases

The PEMS gas analysers shall be calibrated using gases meeting the requirements as set out in Section 9.3.3 of Annex 4B to UN/ECE Regulation No 49.

1.2. Leakage test

The PEMS leakage tests shall be conducted following the requirements defined in Section 9.3.4 of Annex 4B to UN/ECE Regulation No 49.

1.3. Response time check of the analytical system

The response time check of the PEMS analytical system shall be conducted in accordance with the requirements set out in Section 9.3.5 of Annex 4B to UN/ECE Regulation No 49.

Appendix 4

Method to check the conformity of the ECU torque signal

1. INTRODUCTION

This Appendix describes in a non-detailed manner the method used to check the conformity of the ECU torque signal during ISC-PEMS testing.

The detailed applicable procedure is left to the engine manufacturer, subject to approval of the approval authority.

2. THE ‘MAXIMUM TORQUE’ METHOD

2.1. The ‘maximum torque’ method consists of demonstrating that a point on the reference maximum torque curve as a function of the engine speed has been reached during vehicle testing.

2.2. If a point on the reference maximum torque curve as a function of the engine speed has not been reached during the ISC PEMS emissions testing, the manufacturer is entitled to modify the load of the vehicle and/or the testing route as necessary in order to perform that demonstration after the ISC PEMS emissions test.

(**1**) Directive 2001/85/EC of the European Parliament and of the Council of 20 November 2001 relating to special provisions for vehicles used for the carriage of passengers comprising more than eight seats in addition to the driver's seat, and amending Directives 70/156/EEC and 97/27/EC (OJ L 42, 13.2.2002, p. 1).