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ANNEX

ANNEX

to the

COMMISSION DELEGATED REGULATION (EU) .../...

amending Delegated Regulation (EU) 2017/655 as regards the adaptation of the provisions on monitoring of gaseous pollutant emissions from in-service internal combustion engines installed in non-road mobile machinery to engines with power of less than 56 kW and more than 560 kW

ANNEX

The Annex to Delegated Regulation (EU) 2017/655 is amended as follows:

(1) The following points 1.2.a and 1.2.b are inserted after point 1.2:

1.2.a. In-Service Monitoring Engine Grouping (ISM Group)

For the carrying out of in-service testing, all engine types and engine families produced by the manufacturer shall be grouped in accordance with its sub-category as set out in Table 1 and illustrated in Figure 1. One manufacturer may have one ISM Group for each possible type of ISM Group.

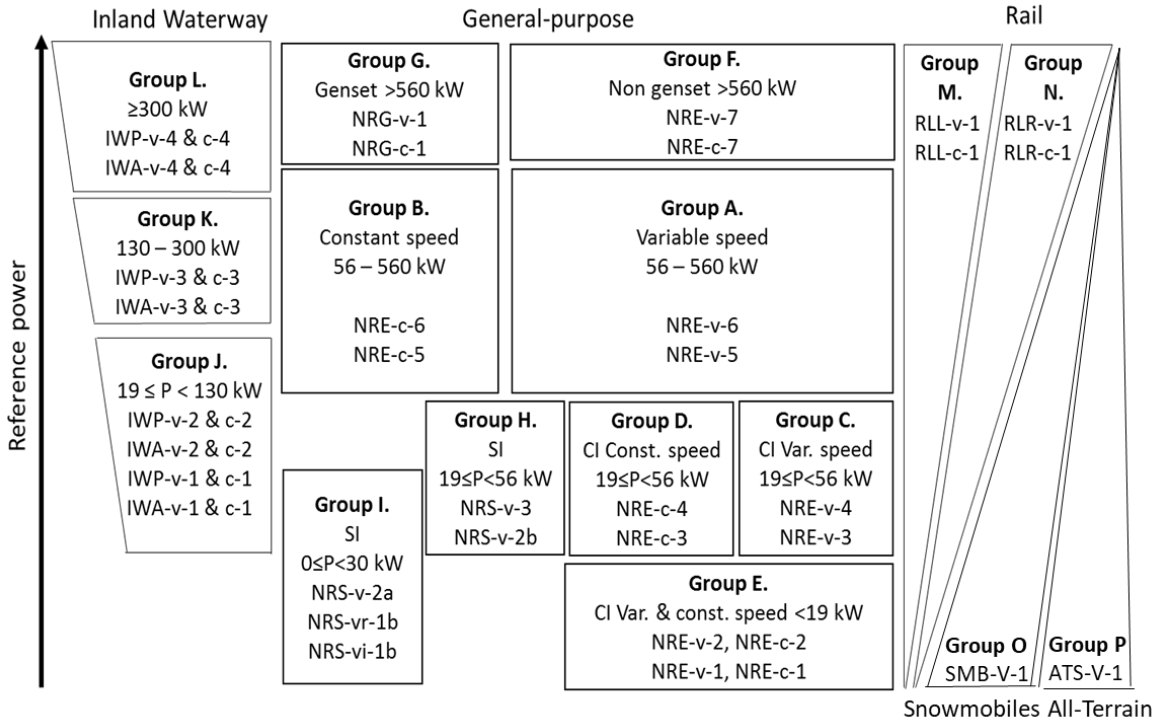
Table 1

ISM Groups

ISM Group	Engine (sub-)categories
A	NRE-v-5, NRE-v-6
B	NRE-c-5, NRE-c-6
C	NRE-v-3, NRE-v-4
D	NRE-c-3, NRE-c-4
E	NRE-v-1, NRE-c-1, NRE-v-2, NRE-c-2
F	NRE-v-7, NRE-c-7
G	NRG-v-1, NRG-c-1
H	NRS-v-2b, NRS-v-3
I	NRS-vr-1b, NRS-vi-1b, NRS-v-2a
J	IWP-v-1, IWP-c-1, IWA-v-1, IWA-c-1, IWP-v-2, IWP-c-2, IWA-v-2, IWA-c-2
K	IWP-v-3, IWP-c-3, IWA-v-3, IWA-c-3
L	IWP-v-4, IWP-c-4, IWA-v-4, IWA-c-4
M	RLL-v-1, RLL-c-1
N	RLR-v-1, RLR-c-1
O	SMB-v-1
P	ATS-v-1

Figure 1

Illustration of ISM Groups



1.2.b. The approval authority ensuring the compliance with this Regulation shall be either:

a) the approval authority that granted the type-approval of the engine type or engine family, in case that the ISM Group contains a single type-approval;

b) the approval authority that granted the type-approval of several engine types and/or engine families within the same ISM Group;

c) in the case that the ISM Group contains engine types, and/or engine families, approved by different approval authorities, the approval authority designated by all approval authorities involved

(2) in point 1.3, sub-point (b) is deleted:

(3) point 1.4 is replaced by the following:

‘1.4. Engines with an Electronic Control Unit (ECU) and a communication interface intended to provide the necessary data as specified in Appendix 7 but with a missing interface or missing data, or where it is not possible to achieve clear identification and validation of the necessary signals, shall not be eligible for in-service monitoring test, and an alternative engine shall be selected.

The approval authority shall not accept the absence of an ECU or interface, or absent or invalid signals, or lack of conformity of the ECU torque signal, as a reason to reduce the number of engines to be tested under this Regulation.’;

(4) point 2.1 is replaced by the following:

‘2.1. The manufacturer shall submit the initial plan for monitoring each ISM Group to the approval authority within:

(a) for ISM Group A, one month of the start of production of any engine type or engine family within the ISM Group;

(b) for any other ISM Group, the later date of the following:

(i) [*Please OJ insert the date six months after the day of entry into force of this Regulation*];

(ii) 1 month after the start of production of any engine type or engine family within the ISM Group.';

(5) in point 2.2., the introductory sentence is replaced by the following:

'2.2. The initial plan shall include the list of engine types and engine families in the ISM Group, together with the criteria used for and the justification of the selection of:';

(6) point 2.3 is replaced by the following:

'2.3. Manufacturers shall submit to the approval authority an updated plan for monitoring in-service engines whenever the list of engine families in the ISM Group changes or the list of particular engine(s) and non-road mobile machinery selected is completed or revised. The updated plan shall include a justification of the criteria used for the selection and the reasons for revising the previous list, if applicable. Where the number of engine families in the ISM Group or the annual production volume for the Union market changes, the number of tests to be executed in accordance with point 2.7, the plan shall also be adjusted accordingly.';

(7) Points 2.6 to 2.6.4 are replaced by the following:

'2.6. Criteria for selection of engines to be tested

The number of engines to be tested refers to the ISM group, and not to the engine sub-categories, engine families or engine types belonging to ISM group.

The manufacturer shall select engines that represent, in a balanced manner, the sub-categories, engine families and engine types belonging to the ISM group. This should not necessarily imply testing engines belonging to each engine sub-category, engine family or engine type.

For ISM groups containing both category IWP and IWA the engine selection shall include, to the extent possible, engines of both categories.

2.6.1. Testing scheme for ISM group A

The manufacturer shall choose one of the following testing schemes described in points 2.6.1.1 and in 2.6.1.2 for in-service monitoring.

2.6.1.1. Testing scheme based on the Emission Durability Period (EDP)

2.6.1.1.1 Testing 9 engines from the ISM group with an accumulated service of less than a % of the EDP, in accordance with Table 2. Test results shall be submitted to the approval authority by [*Please OJ insert the date twenty-four months after the day of entry into force of this Regulation*].

2.6.1.1.2. Testing 9 engines from the ISM group with an accumulated service higher than b % of the EDP, in accordance with Table 2. Test reports shall be submitted to the approval authority by [*Please OJ insert the date forty-eight months after the day of entry into force of this Regulation*].

2.6.1.1.3. When the manufacturer cannot fulfil the requirement under point 2.6.1.1 due to unavailability of engines with the required service accumulation of point 2.6.1.1.2, the approval authority may permit testing of engines under this point with an accumulated service between 2 times a % and b % of the EDP, subject to the manufacturer providing robust evidence that they have selected engines with the highest available service accumulation. As an alternative, the approval authority shall accept a change to the testing scheme based on a 4-year period set out in point 2.6.1.2. In that case, the total number of engines to be tested under point 2.6.1.2 shall be reduced by the number of engines already tested and reported in accordance with point 2.6.1.1.

Table 2

% of EDP values for ISM group defined in 2.6.1

Reference power of selected engine (kW)	**a**	**b**
$56 \leq P < 130$	20	55
$130 \leq P \leq 560$	30	70

2.6.1.2. Testing scheme based on a 4-year period

Every manufacturer shall test an average of nine engines per year from the ISM group during 4 consecutive years. To the extent possible, also test reports shall be submitted to the approval authority every year. The schedule for testing and submitting results shall be included in the initial plan, and in any subsequently updated plan, for monitoring in-service engines submitted by the manufacturer and approved by the approval authority.

2.6.1.2.1. The test results of the first nine engines shall be submitted not later than 24 months after the first engine was installed in non-road mobile machinery and not later than 30 months after starting the production of an approved engine type or engine family within the ISM group.

2.6.1.2.2. Where the manufacturer demonstrates to the approval authority that no engine has been installed in non-road mobile machinery 30 months after starting the production, the test results shall be submitted after the installation of the first engine, on a date agreed with the approval authority.

2.6.1.2.3. Small-volume manufacturers

The number of engines tested shall be adapted in case of small-volume manufacturers as follows:

(a) manufacturers producing only two engine families within an ISM group shall submit an average of six engine test results per year;

(b) manufacturers producing for the Union market more than 250 engines per year of an ISM group containing only one single engine family shall submit an average of three engine test results per year;

(c) manufacturers producing for the Union market between 125 and 250 engines per year of an ISM group containing only one single engine family shall submit an average of two engine's test results per year;

(d) manufacturers producing for the Union market fewer than 125 engines per year of an ISM group containing only one single engine family shall submit an average of one engine's test results per year.

The approval authority shall verify the declared production quantities are not exceeded during the 4-year period that the manufacturer conducts testing. If these quantities are exceeded at any point, the manufacturer shall test an average of nine engines per year for the remaining years of the 4-4year period for which results have not been reported.

2.6.2. Testing scheme for ISM groups B, F, G, J, K, L, M and N

The manufacturer shall choose, for each group, one of the following testing schemes described in points 2.6.2.1 and in 2.6.2.2 for in-service monitoring.

2.6.2.1. Testing scheme based on the Emission Durability Period (EDP)

2.6.2.1.1. Testing x engines from the ISM group with an accumulated service of less than c % of the EDP, in accordance with Table 3. Test results shall be submitted to the approval authority by [*Please OJ insert the date twenty-four months after the day of entry into force of this Regulation*].

2.6.2.1.2. Testing x engines from the ISM group with an accumulated service higher than d % of the EDP, in accordance with Table 3. Test results shall be submitted to the approval authority by [*Please OJ insert the date forty-eight months after the day of entry into force of this Regulation*].

2.6.2.1.3. When the manufacturer cannot fulfil the requirements set out in points 2.6.2.1.1 and 2.6.2.1.2 due to unavailability of engines with the required service accumulation, the approval authority may permit testing of engines under this point with an accumulated service between 2 times c % and d % of the EDP, subject to the manufacturer providing robust evidence that they have selected engines with the highest available service accumulation. As an alternative, the approval authority shall accept a change to the testing scheme based on a 4-year period set out in point 2.6.2.2. In that case, the total number of engines to be tested under point 2.6.2.2 shall be reduced by the number of engines already tested and reported in accordance with points 2.6.2.1.1 and 2.6.2.1.2.

2.6.2.1.4. When the test report of a Stage IIIB engine family equivalent to category RLL is used to obtain a corresponding Stage V type-approval for that engine family in accordance with Article 7(2) of Implementing Regulation (EU) 2017/656 and the engine manufacturer cannot fulfil the requirements under points 2.6.2.1.1 and 2.6.2.1.2 due to unavailability of Stage V engines with the required service accumulation, the approval authority shall accept the selection of a Stage IIIB engine to comply with the requirements of points 2.6.2.1.1 and 2.6.2.1.2.

Table 3

% of EDP values for ISM groups defined in 2.6.2.1

Reference power of selected engine (kW)	**c**	**d**
P < 56	10	40
56 ≤ P < 130	20	55
P ≥ 130	30	70

Table 4

Number of engines to be tested for ISM groups defined in 2.6.2 and 2.6.3.1

N	**CA**	**x**
1	-	1
2 ≤ N ≤4	-	2
> 4	≤ 50	2
5 ≤ N ≤6	> 50	3
≥ 7	> 50	4

Where:

N = Total number of EU engine families produced by the manufacturer within the ISM group

CA = Combined annual production for EU market for the remaining engine families produced by manufacturer within group after discarding the four families with the highest annual production for EU market.

x = Number of engines to be tested

2.6.2.2. Testing scheme based on a 4-year period

Testing an average of x engines from the ISM group per year during 4 consecutive years, in accordance with Table 4. Test reports shall be submitted to the approval authority every year and the years shall be consecutive. The schedule for testing and submitting results shall be included in the initial plan, and in any subsequently updated plan, for monitoring in-service engines submitted by the manufacturer and approved by the approval authority.

2.6.2.2.1. The test results of the first x engines shall be submitted before the later date of the following:

(a) [*Please OJ insert the date twenty-four months after the day of entry into force of this Regulation*];

(b) 12 months after the first engine was installed innon-road mobile machinery;

(c) 18 months after starting the production of an approved engine type or engine family within the ISM group.

2.6.2.2.2. When the manufacturer demonstrates to the approval authority that no engine has been installed in non-road mobile machinery 18 months after starting the production, the test results shall be submitted after the installation of the first engine, on a date agreed with the approval authority.

2.6.2.2.3. Small-volume manufacturers

The number of engines tested shall be adapted in case that the combined annual production across all engine families in an ISM group does not exceed 50 engines (small volume manufacturers), as follows:

(a) manufacturers producing a total between 25 and 50 engines per year for the Union market across all families in a given ISM group shall submit either:

(i) one engine test results with an accumulated service between c % and d % of EDP as defined in Table 3 by [*Please OJ insert the date thirty-six months after the day of entry into force of this Regulation*], or;

(ii) an average of one engine test results per year over 2 years, starting 12 months after the first engine was installed in non-road mobile machinery,

(b) manufacturers producing a total of fewer than 25 engines per year for the EU market across all families in a given ISM group need not submit any engine test unless the production exceeds 35 engines in a two-year rolling period, in which case the manufacturer shall follow the same scheme as set out in sub-point (a).

The approval authority shall verify that the declared production quantities are not exceeded during the periods set out in the first paragraph, sub-point (a). If those quantities are exceeded at any point, the manufacturer shall change to one of the testing schemes set out in points 2.6.2.1. and 2.6.2.2. In that case, the total number of engines to be tested under those points shall be reduced by the number of engines already tested and reported in accordance with this point.

2.6.3. ISM groups C, D, E, H and I

The manufacturer shall choose, for each group, one of the testing schemes described in point 2.6.2 or the testing scheme based on age of equipment described in section 2.6.3.1 for in-service monitoring.

2.6.3.1. Testing scheme based on the age of non-road mobile machinery (see Figure 2 for reference)

2.6.3.1.1. Testing x engines from the ISM group with non-road mobile machinery production year not more than 2 years prior to the date of that test, (see Figure 2), in accordance with Table 4. Test results shall be submitted to the approval authority by [*Please OJ insert the date twenty-four months after the day of entry into force of this Regulation*].

2.6.3.1.2. Testing x engines from the ISM group with non-road mobile machinery production year not less than 4 years prior to year of test, (see Figure 2), in accordance with Table 4. Test results shall be submitted to the approval authority

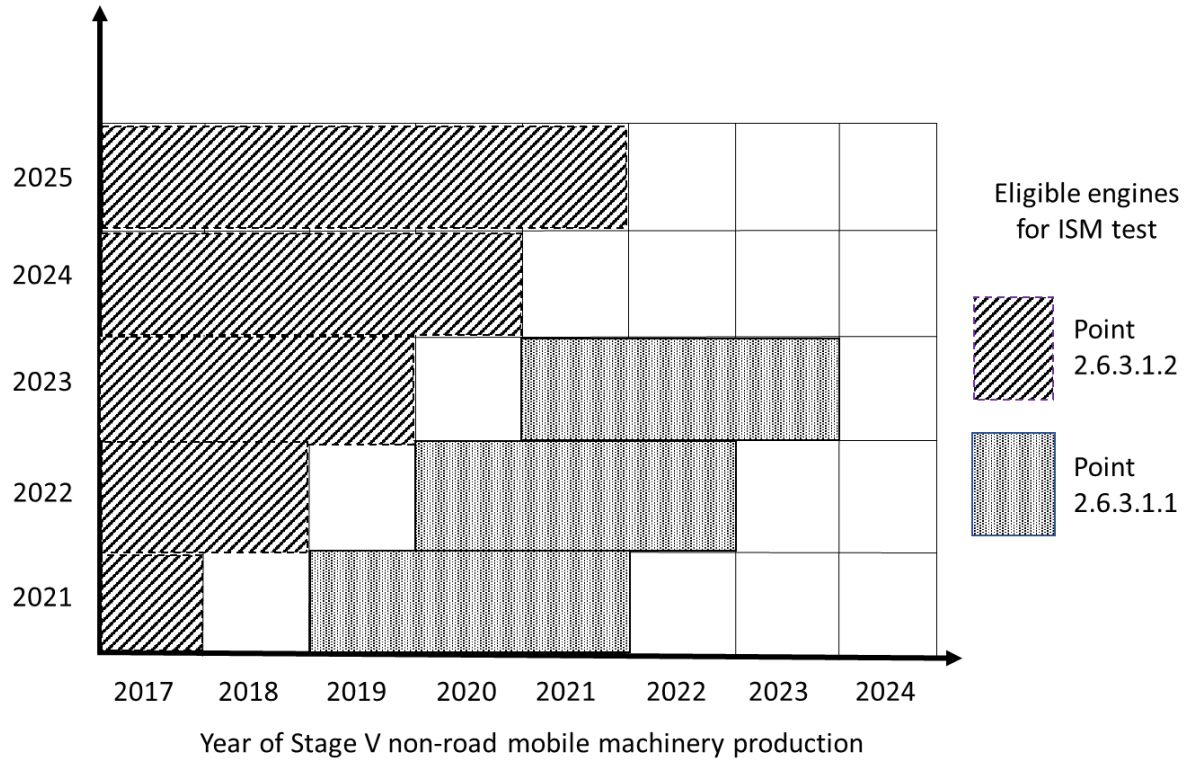
by [*Please OJ insert the date forty-eight months after the day of entry into force of this Regulation*].

2.6.3.1.2.1. Robust evidence shall be provided to the approval authority that each engine selected for testing under point 2.6.3.1.2 has been used each year in a manner and to an extent similar to that of the population of corresponding engines placed on the Union market. Suitable evidence may include characteristics demonstrating normal wear, records of use, records of maintenance and records of fuel consumed.

2.6.3.1.3. When the manufacturer cannot fulfil the requirements set out in points 2.6.3.1.1 and 2.6.3.1.2 due to unavailability of engines with the required non-road mobile machinery production year or insufficient evidence of use, the approval authority shall accept a change to the testing scheme based on a 4-year period set out in point 2.6.2.2. In that case, the total number of engines to be tested under point 2.6.2.2 shall be reduced by the number of engines already tested and reported in accordance with points 2.6.3.1.1 and 2.6.3.1.2.

Figure 2

Illustration of eligible engines for ISM test based on age of non-road mobile machinery



2.6.4. ISM groups O and P

The manufacturer shall choose, for each group, one of the testing schemes described in point 2.6.2 or the testing scheme based on the odometer reading described in point 2.6.4.1 for in-service monitoring.

In case that the manufacturer choses the procedure set out in point 2.6.2.1, the required accumulated service shall be the one stated in Table 5 instead of the one stated in Table 3.

Table 5

% of EDP values for ISM groups O and P

Group	c	d
O	20	55
P	10	40

2.6.4.1. Testing scheme based on the odometer reading of non-road mobile machinery

2.6.4.1.1. Testing x engines from the ISM group with non-road mobile machinery odometer reading an accumulated service of less than c (km) in accordance with Table 6. Test results shall be submitted to the approval authority by [*Please OJ insert the date twenty-four months after the day of entry into force of this Regulation*].

2.6.4.1.2. Testing x engines from the ISM group with non-road mobile machinery odometer reading an accumulated service of more than d (km) in accordance with Table 6. Test results shall be submitted to the approval authority by [*Please OJ insert the date forty-eight months after the day of entry into force of this Regulation*].

Table 6

Accumulated service for ISM groups O and P

Group	Engine swept volume (cm^3)	c (km)	d (km)
O	Any	1 600	4 400
P	< 100	1 350	5 400
	≥ 100	2 700	10 800

(8) The following points 2.6.5 and 2.6.6 are inserted after point 2.6.4.1.2:

2.6.5. The manufacturer may conduct and report more tests than those established by the testing schemes set out in points 2.6.1, 2.6.2, 2.6.3 and 2.6.4.

2.6.6. Multiple testing of the same engine to provide data for the consecutive service accumulation stages in accordance with points 2.6.1, 2.6.2, 2.6.3 and 2.6.4 is recommended but not mandatory.';

(9) point 3.4.2 is replaced by the following:

'3.4.2. To demonstrate compliance with point 3.4, samples shall be taken and retained until at least, whichever is the shortest period of time form the following:

(a) 12 months following the completion of the test, or

(b) 1 month after the manufacturer submits the respective test report to the approval authority.'

(10) the following point 3.6. is inserted after point 3.5:

'3.6. Where testing is undertaken outside the Union, the manufacturer must provide evidence to the approval authority that the following conditions are representative of the test conditions to which the non-road mobile machinery would be subject if tested in the Union:

(a) non-road mobile machinery's operation;

(b) ambient conditions;

(c) lubricating oil, fuel and reagent; and

(d) operating conditions.';

(11) point 4.1.1 is deleted.

(12) point 4.2.2 is replaced by the following:

'4.2.2. The following additional requirements shall be fulfilled when applying combined data sampling:

(a) the different operating sequences shall be obtained using the same non-road mobile machinery and engine;

(b) the combined data sampling of tests performed at ambient temperature above 273,15 K shall contain a maximum of three operating sequences;

(c) the combined data sampling of tests performed at ambient temperature equal or below 273,15 K shall contain a maximum of six operating sequences;

(d) the maximum period elapsed between the first and last operating sequence shall be 72 hours;

(e) combined data sampling shall not be used if an engine malfunction occurs, as set out in point 8 of Appendix 2;

(f) to be eligible for combined data sampling each operating sequence of an in-service monitoring test shall contain the following minimum amount of work (kWh) or CO_2 mass (g/cycle):

(i) for engines in ISM Groups A and C, a minimum of one hot-start NRTC reference work or CO_2 reference mass;

(ii) for engines in ISM Group H, a minimum of one LSI-NRTC reference work or CO_2 reference mass;

(iii) for engines in all other ISM Groups, a minimum of one steady-state cycle reference work or CO_2 reference mass determined using the method set out in Appendix 9.

In case of an in-service test of an engine type within an engine family, the reference value shall be that for the parent engine type;

(g) prior to joining the operating sequences, all necessary pre-processing shall be completed individually for each sequence in accordance with the requirements set out in point 6.3;

(h) the operating sequences in the combined data sampling shall be joined in a chronological order including all data not excluded by sub-point (f);

(i) the combined data sampling shall be considered one ISM test;

(j) the determination of working events set out in point 6.4 and calculations set out in point 8 shall be applied to the complete combined data sampling.';

(13) the following point 4.3 is inserted after point 4.2.2:

'4.3 Temporary signal loss

Parameter recording shall reach a data completeness of not less than 98%, meaning that a maximum of 2 % of data with no consecutive period of more than 30 seconds duration may be excluded from each operating sequence due to one or several episodes of unintended temporary signal loss in the original data recording. No signal loss shall be created during pre-processing, combination or post-processing of any operating sequence.';

(14) Points 5 to 5.2.2 are replaced by the following:

'**5. ECU data stream**

5.1. Engines fitted with an ECU and a communication interface shall provide data stream information to the measurement instruments or data logger of the PEMS in accordance with the requirements set out in Appendix 7.

5.2. Prior to the in-service test, the availability of the measurement data requested by Appendix 7 shall be validated.

(15) Points 5.3 to 5.4 are inserted after point 5.2:

5.3. The conformity of the ECU torque signal shall be validated during the in-service monitoring in accordance with the method set out in Appendix 6.

5.4. Where an engine fitted with an ECU and a communication interface does not permit fulfilling the requirements set out in points 5.1., 5.2 or 5.3., point 1.4. shall apply.';

(16) point 6.4 is replaced by the following:

'6.4. Manufacturers shall follow the procedures set out in Appendix 4 for the determination of working and non-working events for gaseous pollutant emissions calculation following an in-service monitoring test of engines installed on non-road mobile machinery using a PEMS.';

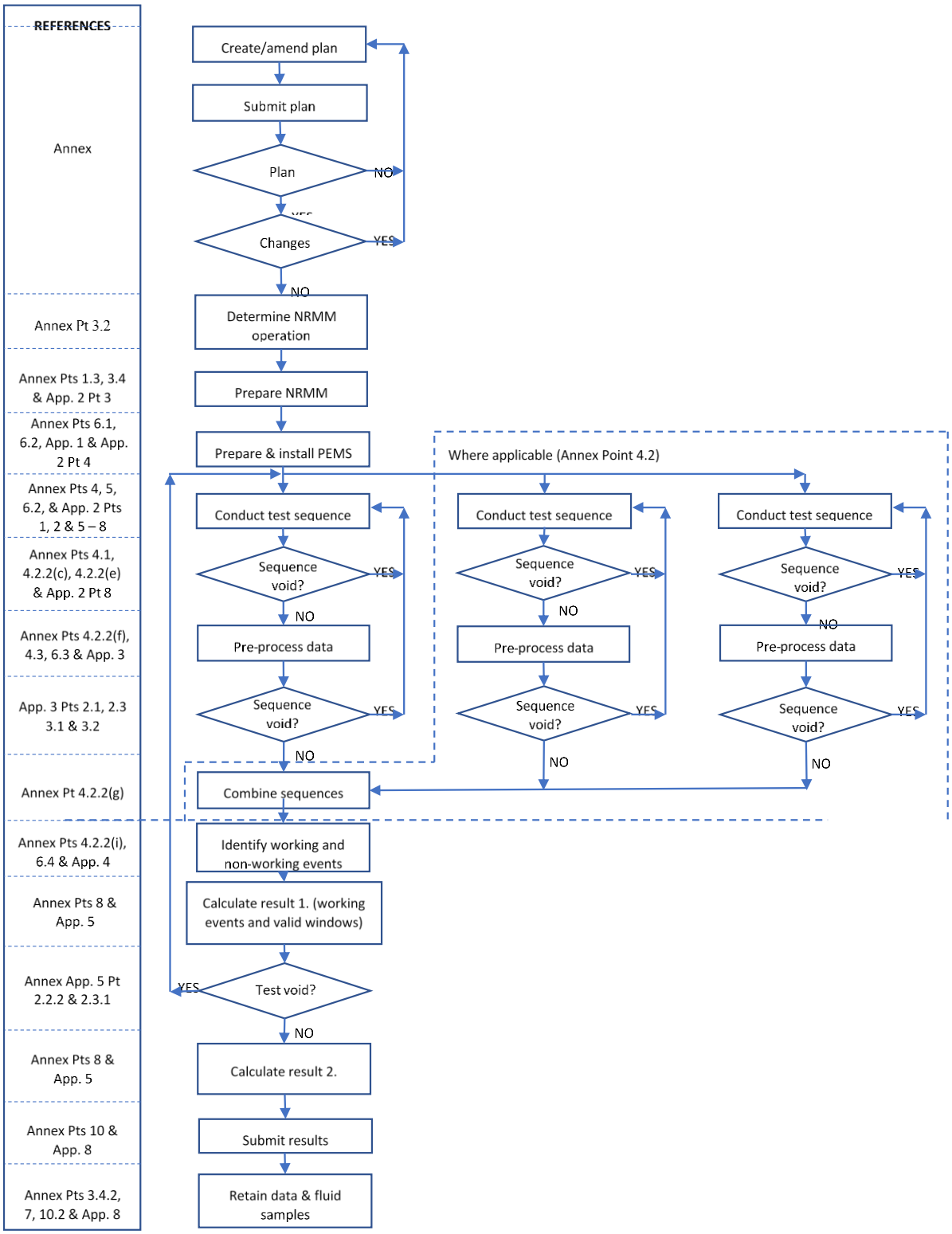
(17) the following points 6.5 and 6.6 are inserted after point 6.4:

'6.5. In accordance with point 4.2.2, where combined data sampling is used, the requirements of points 6.1 to 6.3 shall apply individually to each operating sequence prior to combining operating sequences. The determination of working and non-working events set out in point 6.4 and calculations set out in point 8. shall be applied to the complete combined data sampling.

6.6. Figure 3 outlines the complete sequence for conducting in-service monitoring including planning, PEMS preparation and installation, test procedures, data pre-processing, data calculations and validation.

Figure 3

Illustration of the complete sequence for conducting in-service monitoring



’;

(18) points 7 and 8 are replaced by the following:

‘**7. Test data availability**

No data shall be modified or removed from the raw test data file(s) used for the completion of point 6. Those raw test data file(s) shall be retained at least for 10 years by the manufacturer and made available upon request to the approval authority and the Commission.

8. Calculations

Manufacturers shall follow the procedures set out in Appendix 5 for the gaseous pollutant emissions calculations for the in-service monitoring of engines installed on on-non-road mobile machinery using a PEMS.

8.1. In the case of engines with an ECU that were produced with a communication interface intended to permit the collection of the engine torque and speed data as specified in Table 1 of Appendix 7, the calculations shall be conducted and results reported for both the work-based method and the CO_2 mass-based method. In all other cases, the calculations shall be conducted and results reported for the CO_2 mass based method only.

8.2. In all cases, the calculations shall be conducted twice following the pre-processing of data in accordance with point 6.3 of this Annex:

(a) firstly, using only working events determined in accordance with point 6.4 of this Annex and valid windows, and;

(b) secondly, using all data not excluded by point 6.3 of this Annex, without applying point 6.4 of this Annex, and without exclusion of invalid windows as set out in points 2.2.2 and 2.3.1 of Appendix 5.’;

(19) Appendix 1 is amended as follows:

(a) in point 1, point (b) is replaced by the following:

‘

(b) an Exhaust Flow Meter (EFM) based on the averaging Pitot or equivalent principle, except where indirect exhaust flow measurement may be applied as permitted by note (3) to the table in point 1 of Appendix 2;’;

(b) points 2 to 2.2.2 are replaced by the following:

‘2. Measurement instruments requirements

2.1. Measurement Instruments shall meet the requirements on calibration and performance checks set out in Section 8.1 of Annex VI to Commission Delegated Regulation (EU) 2017/654* except as set out in points 2.1.1 and 2.1.2. Special attention shall be given to perform the following actions:

(a) the vacuum-side leak verification of the PEMS as set out in Section 8.1.8.7 of Annex VI to Delegated Regulation (EU) 2017/654;

(b) the response and updating-recording verification of the gas analyser as set out in Section 8.1.5 of Annex VI to Delegated Regulation (EU) 2017/654.

2.1.1. The minimum frequency for gas analyser linearity verification and NO2-to-NO converter conversion verification set out in Tables 6.4 and 6.5 of Annex VI to Delegated Regulation (EU) 2017/654 may be increased to 3 months.

2.1.2 The minimum frequency of EFM performance and calibration checks, and the details of those checks, shall be those specified by the instrument manufacturer.

2.2. Measurement instruments shall meet the specifications set out in Section 9.4 of Annex VI to Delegated Regulation (EU) 2017/654.

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*Commission Delegated Regulation (EU) 2017/654 of 19 December 2016 supplementing Regulation (EU) 2016/1628 of the European Parliament and of the Council with regard to technical and general requirements relating to emission limits and type-approval for internal combustion engines for non-road mobile machinery (OJ L 102, 13.4.2017, p. 1).';

(c) the following points 2.3 and 3 are inserted after point 2.2:

2.3. The analytical gases used for calibrating the measurement instruments shall meet the requirements set out in Section 9.5.1 of Annex VI to Delegated Regulation (EU) 2017/654.';

'3. Transfer line and sampling probe requirements

3.1. The transfer line shall meet the requirements set out in Section 9.3.1.2 of Annex VI to Delegated Regulation (EU) 2017/654.

3.2. The sampling probe shall meet the requirements set out in Section 9.3.1.1 of Annex VI to Delegated Regulation (EU) 2017/654.';

(20) Appendix 2 is amended as follows:

(a) Points 1. to 4.1. are replaced by the following:

'**1. Test Parameters**

1.1 The gaseous pollutant emissions to be measured and recorded during the in-service monitoring test are carbon monoxide (CO), total hydrocarbons (HC) and nitrogen oxides (NO_x). Additionally, carbon dioxide (CO_2) shall be measured to enable the calculation procedures described in Appendix 5.

1.2. Where the manufacturer demonstrates to the approval authority that it is not practical to combine the flow from multiple exhaust stacks, and there is similarity in the technical configuration and operation of the part of the engine exhausting into each stack, it shall be sufficient to measure the emissions and exhaust mass flow from one exhaust stack. In that case, when performing the calculations set out in Appendix 5 the instantaneous mass flow rate of emissions from the measured stack shall be multiplied by the total number of stacks to obtain the total instantaneous mass flow rate of emissions for the engine.

1.3 The parameters set out in the Table shall be measured and recorded at a data sampling period of 1 second or less during the in-service monitoring test:

Table

Test parameters

Parameter	Unit (1)	Source
HC concentration (2)	ppm	Gas analyser
CO concentration (2)	ppm	Gas analyser

NOx concentration [2]	ppm	Gas analyser
CO_2 concentration [2]	ppm	Gas analyser
Exhaust mass flow [3]	kg/h	EFM
Exhaust temperature [4]	K	EFM or ECU or Sensor
Ambient temperature [5]	K	Sensor
Ambient pressure	kPa	Sensor
Relative humidity	%	Sensor
Engine torque [6] [7]	Nm	ECU or Sensor
Engine speed [7]	rpm	ECU or Sensor
Engine fuel flow [7]	g/s	ECU or Sensor
Engine coolant temperature [8]	K	ECU or Sensor
Engine intake air temperature	K	ECU or Sensor
Non-road mobile machinery latitude	degree	GPS (optional)
Non-road mobile machinery longitude	degree	GPS (optional)

[1] Where the available data stream uses different units to those required by the table, that data stream shall be transformed into the required units during the data pre-processing set out in Appendix 3.

[2] Measured or corrected to a wet basis.

[3] Direct measurement of exhaust mass flow shall be used unless one of the following is applicable:

(a) the exhaust system installed in the non-road mobile machinery results in dilution of the exhaust by air upstream of the location where an EFM could be installed. In that case the exhaust sample shall be taken upstream of the point of dilution; or,

(b) the exhaust system installed in the non-road mobile machinery diverts a portion of the exhaust to another part of the non-road mobile machinery (e.g. for heating) upstream of the location where an EFM could be installed.

(c) the engine to be tested is of a reference power greater than 560 kW or is installed in an inland waterway vessel or a railway vehicle and the manufacturer demonstrates to the approval authority that installation of an EFM is impractical due to either the size or location of the exhaust on the NRMM;

(d) engines of category SMB and the manufacturer demonstrates to the approval authority that installation of an EFM is impractical due to location of the exhaust on the NRMM.

In those cases, where the manufacturer is able to provide robust evidence to the approval authority of the correlation between the fuel mass flow estimated by the ECU and the fuel mass flow measured on the engine dynamometer test bench, the EFM may be omitted and indirect exhaust flow measurements (from fuel and intake air flows or fuel flow and carbon balance) may be applied.

[4] In order to determine the duration of the take-off phase after a long non-working event for an engine equipped with an after-treatment device used for NOx reduction, as set out in point 2.2.2 of Appendix 4, the exhaust gas temperature shall be measured during the operating sequence within 30 cm of the outlet of the after-treatment device used for NOx reduction. Where installing a sensor within 30 cm would result in damage to the after-treatment the sensor shall be installed as close to this location as can be practically achieved.

[5] Use the ambient temperature sensor or an intake air temperature sensor. Use of an intake air temperature sensor shall comply with the requirements set out in the second paragraph of point 5.1.

[6] 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, in accordance with standards set out in point 2.1.1 of Appendix 7. The basis for the net torque shall be uncorrected net torque delivered by the engine inclusive of the equipment and auxiliaries to be included for an emissions test in accordance with Appendix 2 of Annex VI to Delegated Regulation (EU) 2017/654.

[7] Not required for engines tested under this Regulation that are not designed to have a communication interface capable to provide these data streams.

(8) In the case of air-cooled engines, the temperature at the reference point location identified in point 3.7.2.2.1 of PART C of Appendix 3 of Annex I to Implementing Regulation (EU) 2017/656 shall be recorded in place of the coolant temperature.

2. Test duration

2.1. The test duration, comprising all operating sequences, shall be long enough to obtain the following amount of working events:

(a) for engines in ISM groups A and C, between five and seven times the reference work in kWh performed on the hot-start NRTC run during the type-approval test or to produce between five and seven times the CO_2 reference mass in g/cycle from the hot-start NRTC run of the type-approval test as specified in points 11.3.1. and 11.3.2. of the addendum to the EU type approval certificate of the engine type or the engine family set out in Annex IV to Implementing Regulation (EU) 2017/656;

(b) for engines in ISM group H, between five and seven times the reference work in kWh performed on the LSI-NRTC during the type-approval test or to produce between five and seven times the CO_2 reference mass in g/cycle of the LSI-NRTC during the type-approval test as specified in points 11.3.1 and 11.3.2 of the addendum to the EU type approval certificate of the engine type or the engine family set out in Annex IV to Implementing Regulation (EU) 2017/656;

(c) for engines in ISM groups E, I, O and P between three and five times the applicable reference work in kWh or CO_2 reference mass in g/cycle determined from the type-approval test result using the method set out in Appendix 9;

(d) for engines in ISM groups not listed in sub-points (a), (b) or (c), between five and seven times the applicable reference work in kWh or CO_2 reference mass in g/cycle determined from the type-approval test result using the method set out in Appendix 9.

2.2. All data collected during all operating sequences shall be assembled chronologically even if the maximum amount of work or CO_2 mass specified in point 2.1, sub-points (a) to (d) is exceeded. In that case, during the calculation set-out in Appendix 5 of this Regulation:

(a) when the amount of work or CO_2 reference mass in the working events exceeds that maximum, the calculation shall be truncated at the end of the time increment in which that occurs; and,

(b) the results reported for the ISM test in accordance with point 10 of this Annex to this Regulation shall be those of that truncated calculation.

3. Preparation of the non-road mobile machinery

The preparation of the non-road mobile machinery whose engine has been selected for testing in accordance with point 1.3 of this Annex shall comprise of at least the following:

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

(b) the replacement of the oil, fuel and reagent, if any, where no documented evidence is available that the fluid in question complies with the specification

listed in the type-approval information package applicable to the engine type, and it is practically and economically feasible to do so;

(c) engines fitted with an ECU and a communication interface shall comply with point 5 of this Annex.

4. Installation of the PEMS

4.1 Installation constraints

4.1.1. The installation of the PEMS shall not influence the non-road mobile machinery gaseous pollutant emissions or performance.

4.1.2. The installation shall comply with the locally applicable safety regulations and insurance requirements and shall follow the instructions issued by the PEMS, measurement instruments, transfer line and sampling probe manufacturer.

4.1.3. Where for engines of ISM groups M and N it is not possible to install the PEMS systems without exceeding the loading gauge applicable to the rail network, the use of point 3.2.2 of this Annex shall include testing of the railway vehicle whilst stationary using a representative test duty cycle determined by the manufacturer and agreed with the approval authority.

4.1.4. For engines of ISM groups E, I, O and P the engine may be removed from the non-road mobile machinery and the in-service monitoring test conducted on a dynamometer test bench. In that case, the following shall apply:

(a) the engine inclusive of the entire emission control system shall be removed from the non-road mobile machinery and installed on the dynamometer test bench without adjustment to the emission control system;

(b) it shall not be necessary to demonstrate to the Approval Authority that it is not possible to comply with point 3.2.1 of this Annex;

(c) notwithstanding sub-points (a) and (b), the in-service monitoring test shall be conducted in accordance with this Regulation;

(d) the procedure for removing engine from non-road mobile machinery and installing in test cell to replicate operation in the non-road mobile machinery shall be agreed with the approval authority prior to conducting the ISM test;

(e) a representative test duty cycle shall be used as determined by the manufacturer and agreed with the approval authority in accordance with point 3.2.2 of this Annex;

(f) the test duty cycle of sub-point (e) shall span a range of speed and load that represents the operation of the selected machine when used in the field. Methods to establish that range shall include, but are not limited to, logging operational data for one or more comparable machines operated in the field;

(g) to establish data on the extent to which results obtained from use of a PEMS system differ from those obtained from the use of a test bench system, in-service monitoring measurements performed on the dynamometer test bench using the PEMS system may be supplemented by concurrent measurements using test bench instrumentation and an emission measurement system complying with the requirements of Section 9 of Annex VI to Delegated Regulation (EU) 2017/654, operated in accordance with the requirements of section 8 of that Annex;

(h) the requirements of points 6, 7, 8 and 10 of this Annex shall additionally apply to any concurrent measurements in accordance with sub-point (g) and the test data and test report shall include these measurements.';

(b) point 4.6 is replaced by the following:

'4.6. Data logger

Where ECU data is to be used, a data logger shall be connected with the engine ECU to record the available engine parameters listed in Table 1 of Appendix 7, and, where applicable, the engine parameters listed in Table 2 of Appendix 7.';

(c) point 5.1 is replaced by the following:

'5.1. Ambient temperature measurement

The ambient temperature shall at a minimum be measured at the beginning of the operating sequence and at the end of the operating sequence. The measurement shall be made within a reasonable distance from the non-road mobile machinery. A sensor or ECU signal for engine intake air temperature may be used.

If intake air temperature is used to estimate the ambient temperature, the recorded ambient temperature shall be the intake air temperature adjusted by the applicable nominal offset between ambient and intake air temperature as specified by the manufacturer. ';

(d) Points 6 to 8.2 are replaced by the following:

'6. In-service monitoring test data logging

6.1. Before the operating sequence

Gaseous pollutant emissions data sampling, measurement of the exhaust parameters and recording of the engine and ambient data shall start prior to starting the engine.

6.2. During the operating sequence

Gaseous pollutant emissions data 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 the gaseous pollutant emissions data sampling, measurement of the exhaust parameters, recording of the engine and ambient data shall continue throughout the entire in-service monitoring operating sequence.

6.3. After the operating sequence

At the end of the in-service monitoring operating sequence, sufficient time shall be given to the measurement instruments and data logger to allow their response times to elapse. The engine may be shut down before or after data logging is stopped.

7. Checking of gas analysers

7.1. Periodic zero verification during the operating sequence

Where practical and safe to perform, zero verification of the gas analysers may be conducted every 2 hours during an operating sequence.

7.2. Periodic zero correction during the operating sequence

The results obtained with the checks performed in accordance with point 7.1 may be used to perform a zero drift correction during that operating sequence.

7.3. Drift verification after the operating sequence

The drift verification shall be performed only if no zero drift correction was made during the operating sequence in accordance with point 7.2.

7.3.1. No later than 30 minutes after the operating sequence is completed, the gas analysers shall be zeroed and spanned in order to verify their drift compared to the pre-test results.

7.3.2. The zero, span and linearity checks of the gas analysers shall be performed as set out in point 5.4.

8. Engine or machine malfunction

8.1. In the case that a malfunction occurs during an operating sequence that affects engine operation and either:

(a) the non-road mobile machinery operator is clearly notified of that malfunction by the on-board diagnostics system via a malfunction visual warning, text message or other indicator; or,

(b) the non-road mobile machinery is not fitted with a malfunction diagnostic or warning system, but the malfunction is clearly detected by aural or visual means;

the operating sequence shall be considered void.

8.2. Any malfunction shall be corrected before any further operating sequence is conducted on the engine.';

(21) in Appendix 3, points 2 to 6 are replaced by the following:

'**2. Exclusion of data**

2.1. Temporary signal loss

2.1.1 Any episodes of temporary signal loss shall be identified.

2.1.2. A maximum of 2 % of data with no consecutive period more than 30 seconds duration may be excluded from each operating sequence due to one or several episodes of unintended temporary signal loss in the original data recording, in accordance with point 4.3 of the Annex.

2.1.3. In the case that the test sequence contains episodes of signal loss either greater than 2 % of data or for a consecutive period greater than 30 seconds, that entire sequence shall be considered void and a further test shall be run.

2.2. Periodic checks of measurement instruments

2.2.1. Any data points corresponding with checking of gas analysers in accordance with point 7 of Appendix 2 shall be identified and excluded from further processing of an operating sequence except as required to perform the drift correction in point 3 of this Appendix.

2.3. Ambient conditions

2.3.1. Any data points in an operating sequence corresponding with ambient conditions that do not comply with the requirements set out in point 3.3 of this Annex shall be identified.

2.3.2. If the proportion of data points identified at Point 2.3.1 of this Appendix exceeds 1 % that entire sequence shall be considered void and a further test shall be run.

2.3.2 In the case that ambient conditions are only measured at the start and the end of the test the entire test sequence shall be considered void if either measurement does not comply with the requirements set out in point 3.3 of the Annex.

2.4 Cold start data

Cold start gaseous pollutant emissions measured data shall be excluded prior to the gaseous pollutant emissions calculations.

2.4.1. Liquid-cooled engines

Valid measured data for gaseous pollutant emissions calculations shall start after the engine coolant temperature has reached 343 K (70 °C) for the first time or after the engine coolant temperature is stabilised within +/– 2 K over a period of 5 minutes, whichever comes first; in any case, it shall start no later than 20 minutes after starting the engine.

2.4.2. Air-cooled engines

Valid measured data for gaseous pollutant emissions calculations shall start after the temperature measured at the reference point identified in point 3.7.2.2.1 of PART C of Appendix 3 of Annex I to Implementing Regulation (EU) 2017/656 is stabilised within +/– 5 % over a period of 5 minutes; in any case, it shall start no later than 20 minutes after starting the engine.

3. Drift correction

3.1. Maximum drift allowed

Drifts of the zero response and the span response shall be less than 2 % of full scale on the lowest range used:

(a) if the difference between the pre-test and post-test results is less than 2 %, the measured concentrations may be used uncorrected or may be corrected for driftin accordance with point 3.2;

(b) if the difference between the pre-test and post-test results is equal to or greater than 2 %, the measured concentrations shall be drift corrected in accordance with point 3.2. If no correction is made, the test shall be considered void.

3.2. Drift correction

3.2.1. The corrected drift concentration value shall be calculated in accordance with the requirements set out in Sections 2.1 or 3.5 of Annex VII to Delegated Regulation (EU) 2017/654.

3.2.2. The difference between the uncorrected and the corrected brake-specific gaseous pollutant emission values shall be within ± 6 % of the uncorrected brake-specific gaseous pollutant emission values. If the drift is greater than 6 %, the test shall be considered void.

3.2.2.1 Each brake-specific gaseous pollutant emission value shall be calculated from the integrated mass of gaseous pollutant emission of the test sequence divided by the total work performed during the test sequence. That calculation shall be performed prior to determination of working events in accordance with Appendix 4 or calculation of gaseous pollutant emissions in accordance with Appendix 5.

3.2.3. If drift correction is applied, only the drift-corrected gaseous pollutant emission results shall be used when reporting gaseous pollutant emissions.

4. Time alignment

To minimise the biasing effect of the time lag between the different signals on the calculations of the mass of the gaseous pollutant emissions, the data relevant for gaseous pollutant emissions calculations shall be time aligned, in accordance with the requirements set out in points 4.1 to 4.4.

4.1. Gas analysers data

The data from the gas analysers shall be properly aligned in accordance with the requirements set out in Section 8.1.5.3 of Annex VI to Delegated Regulation (EU) 2017/654.

4.2. Gas analysers and EFM data

The data from the gas analysers shall be properly aligned with the data of the EFM using the procedure set out in point 4.4.

4.3. 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 4.4.

4.4. Procedure for improved time alignment of the PEMS data

The test parameters listed in the Table of Appendix 2 are split into three different categories:

Category 1: Gas analysers (HC, CO, CO_2, NO_x concentrations);

Category 2: EFM (Exhaust mass flow and exhaust temperature);

Category 3: Engine (Torque, speed, temperatures, fuel rate from ECU).

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

(a) Categories 1 and 2 (Gas analysers and EFM data) with Category 3 (Engine data): the exhaust mass flow from the EFM with torque from the ECU;

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

(c) Category 1 with Category 3: the CO_2 concentration and the engine fuel flow.

4.4.1 In the case of engines not designed to have a communication interface to permit the collection of the ECU data as specified in Appendix 7 the correlation at point 4.4, sub-points (a) and (c) shall be omitted.

4.4.2 In the case of engines for which direct measurement of exhaust mass flow was omitted in accordance with note (3) to the Table of Appendix 2 the correlation at point 4.4, sub-point (a) shall be omitted.

5. Data consistency check

5.1. Gas analysers and EFM data

For engines designed to have a communication interface capable to provide fuel flow in accordance with Table 2 of Appendix 7 the consistency of the data (exhaust mass flow measured by the EFM and gas concentrations) shall be verified using a correlation between the measured engine fuel flow from the ECU and the engine fuel flow calculated in accordance with the procedure set out in Section 2.1.6.4 of Annex VII to Delegated Regulation (EU) 2017/654.

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:

– (a) y is the calculated fuel flow [g/s];

– (b) m is the slope of the regression line;

– (c) x is the measured fuel flow [g/s];

– (d) 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 1

Tolerances

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

5.2. ECU torque data

Where ECU torque data is to be used in the calculations the consistency of the ECU torque data shall be verified by comparing the maximum ECU torque values at different (if appropriate) engine speeds with the corresponding values on the official engine full load torque curve and in accordance with Appendix 6.

5.3. Brake-Specific Fuel Consumption (BSFC)

Where ECU data is available the BSFC shall be checked using:

(a) the fuel consumption calculated from the gaseous pollutant emissions data (gas analysers concentrations and exhaust mass flow data), in accordance with the procedure set out in Section 2.1.6.4 of Annex VII to Delegated Regulation (EU) 2017/654;

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

5.4. Ambient pressure

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

5.5. The approval authority may consider the test void if it is not satisfied with the results of the data consistency check.

6. Dry-wet correction

If the concentration is measured on a dry basis, it shall be converted to a wet basis in accordance with the procedure set out in Section 2 or 3 of Annex VII to Delegated Regulation (EU) 2017/654.

7. NOx correction for humidity and temperature

The NOx concentrations measured by the gas analysers shall not be corrected for ambient air temperature and humidity.';

(22) in Appendix 4, points 2. and 3. are replaced by the following:

'**2. Procedure to determine non-working events**

2.1. Non-working events are those where either:

(a) for engines not designed to have a communication interface capable to provide torque and speed data in accordance with Table 1 of Appendix 7, the instantaneous proxy power determined in accordance with the procedure set-out in Appendix 10, or;

(b) in all other cases, the instantaneous engine power,

is below 10 % of the engine reference power, as defined in Article 3, point (26) of Regulation (EU) 2016/1628 and listed in Annex I to that Regulation for each engine (sub-)category, for the engine type subject to ISM test.

2.1.1 For engines tested under this Regulation that are not designed to have a communication interface capable to provide torque and speed data in accordance with Table 1 of Appendix 7 the instantaneous proxy power shall be calculated using the procedure described in Appendix 10 prior to applying the procedure in this Appendix.

2.2. The following additional steps shall be conducted:

2.2.1. Non-working events shorter than D0 shall be considered as working events and merged with the surrounding working events (see Table 2 for the values of D0).

2.2.2. Working events shorter than D0 surrounded by non-working events of duration longer than D1 shall be considered non-working events and merged with the surrounding non-working events (see Table 2 for the values of D1)

2.2.3. The take-off phase following long non-working events (> D2) for engines equipped with an after-treatment device used for NOx reduction and exhaust gas temperature measurement in accordance with note (4) to the Table of Appendix 2 shall also be considered as a non-working event until the exhaust gas temperature reaches 523 K. If the exhaust gas temperature does not reach 523 K within D3 minutes, all events after D3 shall be considered as working events (see Table 2 for the values of D2 and D3).

2.2.4. For all non-working events, the first D1 minutes of the event shall be considered as working event.

3. 'Machine work' marking algorithm to implement the requirements of point 2

Point 2 shall be implemented in the sequence set out in points 3.1 to 3.4

3.1. Step 1: Detect and split into working events and non-working events.

(a) identify the working events and non-working events in accordance with point 2.1;

(b) calculate the duration of non-working events;

(c) mark the non-working events shorter than D0 as working events;

(d) calculate the duration of the working events.

3.2. Step 2: Merge short working events (≤ D0) into non-working events.

Mark as non-working events those working events shorter than D0 that are both preceded and followed by remaining non-working events of duration longer than D1.

3.3. Step 3: Exclude working events after long non-working events (take-off phase).

Where point 2.2.3 is applicable, mark as non-working events those working events after long non-working events (> D2) until either;

(a) the exhaust gas temperature reaches 523 K; or

(b) D3 minutes have elapsed;

whatever happens first.

3.4. Step 4: Include non-working events after working events.

Include D1 minutes of non-working event following any working event as part of that working event.

Table 2

Values for the parameters D0, D1, D2 and D3

Parameters	Value
D0	2 minutes
D1	2 minutes
D2	10 minutes
D3	4 minutes

’;

(23) In Appendix 5, points 2.1 to 2.3.2 are replaced by the following:

‘2.1. Averaging window method

2.1.1. General requirements

Averaging window is the sub-set of the complete calculated data set during the in-service monitoring test whose work or CO_2 mass is equal to the engine work or CO_2 mass measured over the reference laboratory test cycle.The mass of the gaseous pollutant emissions and the conformity factors shall be calculated using the moving averaging window method, based on the reference work (procedure

set out point 2.2) and the reference CO_2 mass (procedure set out in point 2.3) measured over the reference laboratory test cycle.

The engine power versus time and averaging window gaseous pollutant emissions, starting from the first averaging window.

The calculations shall be conducted in accordance with the following sub-points:

(a) any data excluded, under the terms of Appendix 4, shall not be considered for the calculations of the work or CO_2 mass and the gaseous pollutant emissions and conformity factors of the averaging windows, except as required by point 4(f) of this Appendix;

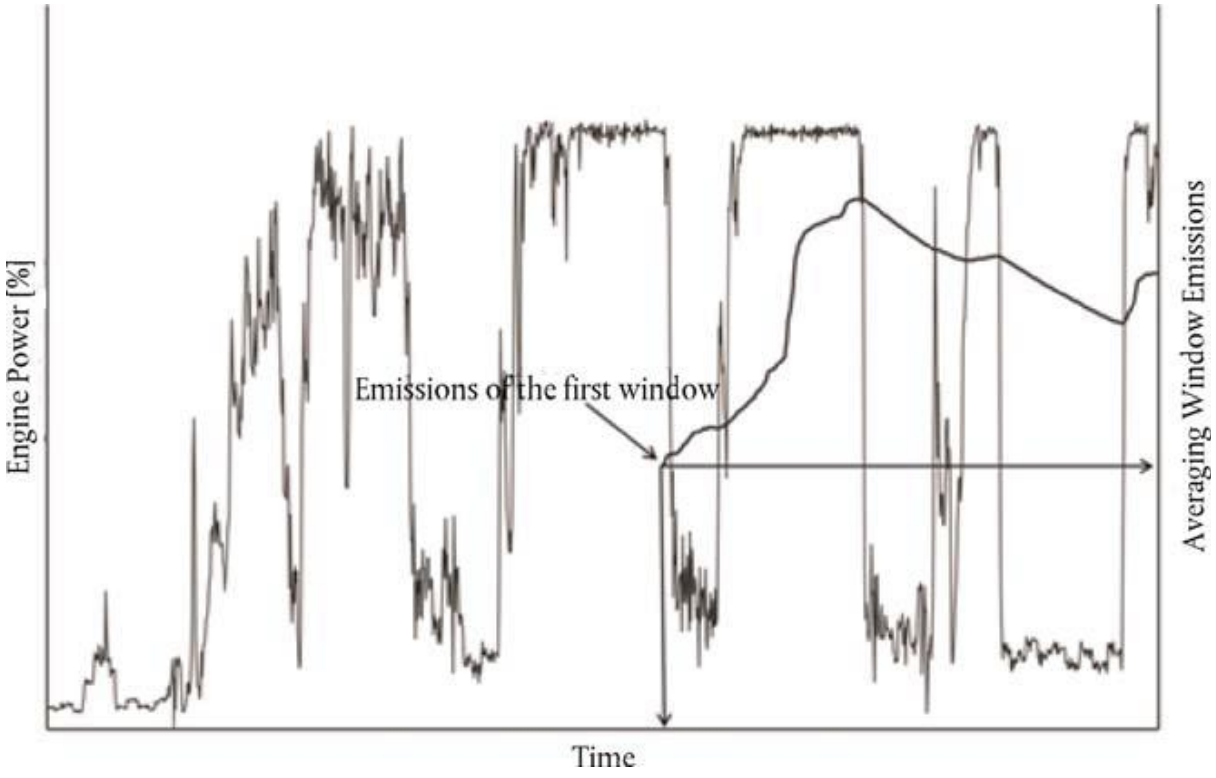
(b) the moving averaging window calculations shall be conducted with a time increment Δt equal to the data sampling period. The start of the moving average window shall be incremented by that amount at each iteration;

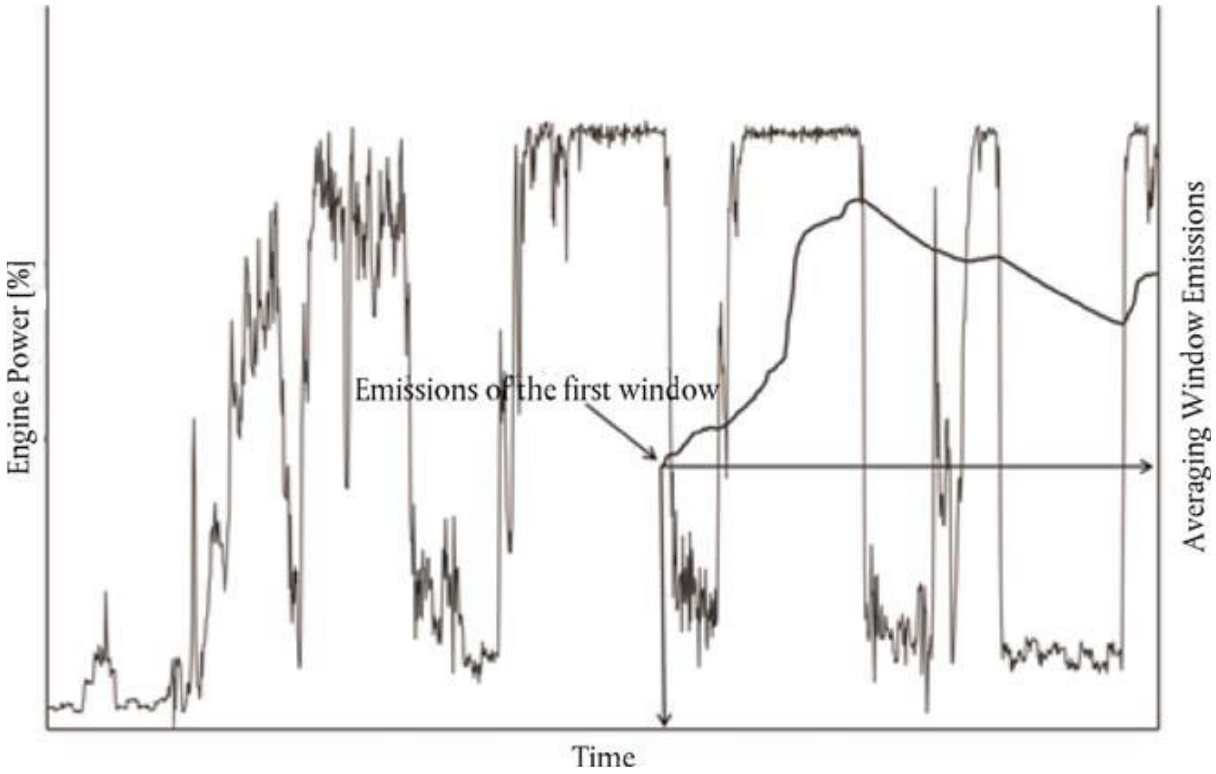
(c) the mass of the gaseous pollutant emissions for each averaging window (mg/averaging window) shall be obtained by integrating the mass of the instantaneous gaseous pollutant emissions in the averaging window;

(d) in the case of engines with an ECU that were designed with a communication interface intended to permit the collection of the engine torque and speed data as specified in Table 1 of Appendix 7, the calculations shall be conducted and results reported for both the work based method and the CO_2 mass-based method. In all other cases the calculations shall be performed, and results reported, for only the CO_2 mass-based method.

Figure 4

Engine power versus time and averaging window gaseous pollutant emissions, starting from the first averaging window, versus time





2.1.2. Reference values

The reference work and reference CO_2 mass of an engine type, or for all engine types within the same engine family, shall be determined as follows:

(a) for engines in ISM groups A and C those values from the hot-start NRTC run of the type-approval test of the parent engine as specified in points 11.3.1 and 11.3.2 of the addendum to the EU type approval certificate of the engine type or the engine family, as set out in Annex IV to Implementing Regulation (EU) 2017/656;

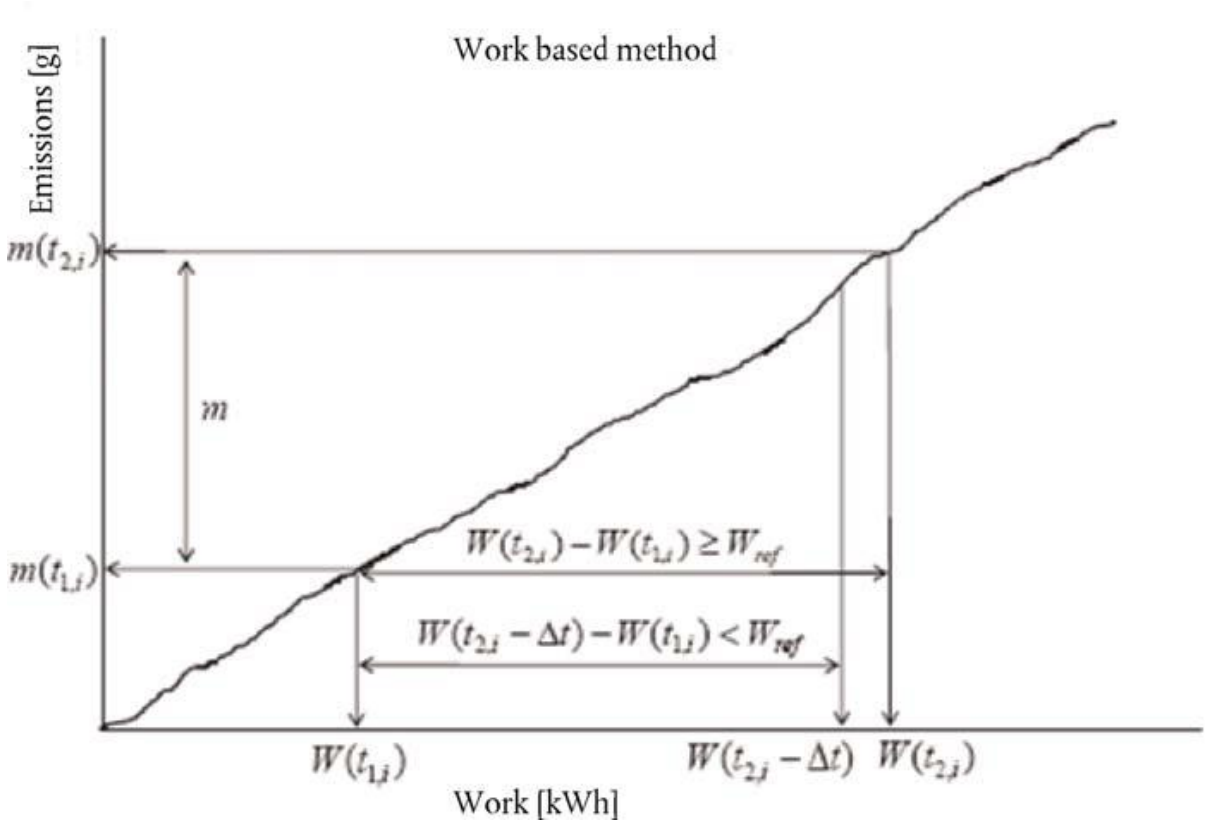
(b) for engines in ISM group H those values from the LSI-NRTC run of the type-approval test of the parent engine;

(c) for engines in ISM groups not listed in sub-points (a) or (b) those values determined from the type-approval test result of the parent engine using the method set out in Appendix 9.

2.2 Work based method

Figure 5

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 reference work determined according to point 2.1.2, 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.

2.2.1. Calculations of the brake specific gaseous pollutant emissions

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

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

Where:

– m_i is the mass emission of the gaseous pollutant during the i[th] averaging window, g/averaging window,

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

2.2.2. Selection of valid averaging windows

The valid averaging windows are the averaging windows whose average power exceeds the power threshold of 20 % of the reference power, as defined in Article 3, point (26), of Regulation (EU) 2016/1628 and listed in Annex I to that

Regulation for each engine (sub-)category, for the engine type subject to ISM test, except for engines of category ATS where the reference power is the power at intermediate speed as defined in Section 5.2.5.4, point (f) of Annex VI to Delegated Regulation (EU) 2017/654. The percentage of valid averaging windows shall be equal or greater than 50 %.

2.2.2.1. 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 from 20 % in steps of 1 % until the percentage of valid windows is equal to or greater than 50 %.

2.2.2.2. In any case, the lower power threshold shall not be lower than 10 %.

2.2.2.3. The test shall be considered void if the percentage of valid averaging windows is less than 50 % at a power threshold of 10 %.

2.2.3. Calculations of the conformity factors

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

$$CF = \frac{e_{gas}}{L}$$

Where:

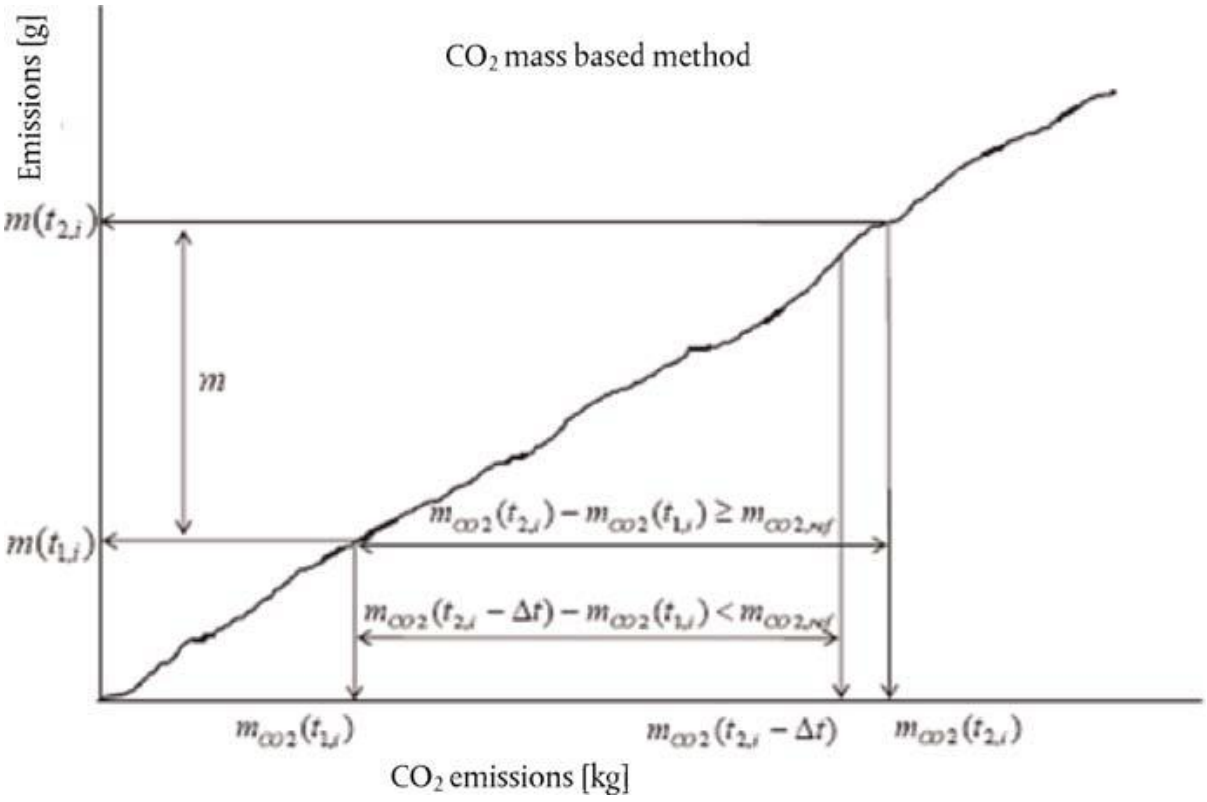
– e_{gas} is the brake-specific emission of the gaseous pollutant, g/kWh;

– L is the applicable limit, g/kWh.

2.3. CO_2 mass-based method

Figure 6

CO_2 mass-based method



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

$$m_{CO_2}(t_{2,i}) - m_{CO_2}(t_{1,i}) \geq m_{CO_2,ref}$$

Where:

– $m_{CO_2}(t_{1,i})$ is the CO_2 mass measured between the test start and time $t_{j,i}$, g;

– $m_{CO_2,ref}$ is the reference CO_2 mass determined in Grams (g) in accordance with point 2.1.2,

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

$$m_{CO_2}(t_{2,i} - \Delta t) - m_{CO_2}(t_{1,i}) < m_{CO_2,ref} \leq m_{CO_2}(t_{2,i}) - m_{CO_2}(t_{1,i})$$

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

The CO_2 masses are calculated in the averaging windows by integrating the instantaneous gaseous pollutant emissions calculated in accordance with the requirements introduced in point 1.

2.3.1. Selection of valid averaging windows

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

$$D_{max} = 3\,600 \cdot \frac{W_{ref}}{0{,}2 \cdot P_{max}}$$

Where:

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

— P_{max} is the reference power, as defined in Article 3, point (26), of Regulation (EU) 2016/1628, kW, and listed in Annex I to that Regulation for each engine (sub-)category, for the engine type subject to ISM test, except for engines of category ATS where the reference power is the power at intermediate speed as defined in Section 5.2.5.4., point (f), of Annex VI to Delegated Regulation (EU) 2017/654.

The percentage of valid averaging windows shall be equal or greater than 50 %.

2.3.1.1. If the percentage of valid windows is less than 50 %, the data evaluation shall be repeated using longer window durations. This is achieved by decreasing the value of 0,2 in the formula given in point 2.3.1 by steps of 0,01 until the percentage of valid windows is equal to or greater than 50 %.

2.3.1.2. In any case, the lowest value in the above formula shall not be lower than 0,10.

2.3.1.3. The test shall be void if the percentage of valid windows is less than 50 % at a maximum window duration calculated in accordance with points 2.3.1., 2.3.1.1. and 2.3.1.2.

2.3.2. Calculations of the conformity factors

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

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

With

$$CF_I = \frac{m_i}{m_{CO_2}(t_{2,i}) - m_{CO_2}(t_{1,i})}$$ (in service ratio) and

$$CF_C = \frac{m_L}{m_{CO_2,ref}}$$ (certification ratio)

Where:

— m_i is the mass emission of the gaseous pollutant during the i[th] averaging window, g/averaging window,

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

—$m_{CO_2,ref}$ is the reference engine CO_2 mass determined in accordance with point 2.1.2, sub-point (g),

— m_L is the mass emission of gaseous pollutant corresponding to the applicable limit on the reference test cycle, g.

m_L is determined as follows:

$$m_L = L \cdot W_{ref}$$

Where:

— L is the applicable limit, g/kWh

— W_{ref} is the engine reference work determined in accordance with point 2.1.2, kWh.';

(24) In Appendix 6, point 2, is replaced by the following:

'**2. Impossibility to check the conformity of the ECU torque signal**

When the manufacturer demonstrates to the approval authority that it is not possible to check the ECU torque signal during the in-service monitoring test, the verification performed in accordance with the requirements of Appendix 3 of Annex VI to Delegated Regulation (EU) 2017/654 during the tests required for EU type- approval and stated in the EU type-approval certificate shall be accepted by the approval authority.

For engines in ISM groups other than A, C and H, the approval authority may accept a separate demonstration conducted in accordance with the requirements of Appendix 3 of Annex VI to Delegated Regulation (EU) 2017/654 but using the following mapping procedures of that Annex:

(a) for engines in ISM group I, and variable speed engines in ISM groups E, F, G, J, K, L, M and N, Section 7.6.1;

(b) for all other engines, Section 7.6.3.

Where mapping is performed at constant speed in accordance with sub-point (b), it shall be sufficient to measure and compare the readings of the torque measured by the dynamometer and the torque broadcast by the ECU at the single point of rated net power.';

(25) In Appendix 7, points 1 to 1.3 are replaced by the following:

'**1. Data to be provided**

1.1 Where an ECU is used to provide engine torque, speed or coolant temperature that data at a minimum shall be provided in accordance with Table 1.

Table 1

Measurement data

Parameter	Unit [1]
Engine torque [2]	Nm
Engine speed	rpm
Engine coolant temperature	K

[1] Where the available data stream uses different units to those required by the table, that data stream shall be transformed into the required units during the data pre-processing set out in Appendix 3.

[2] The provided value shall be either (a) the net brake engine torque or (b) the net brake engine torque calculated from other appropriate torque values as defined in the corresponding protocol standard set out in point 2.1.1. The basis for the net torque shall be uncorrected net torque delivered by the engine inclusive of the equipment and auxiliaries to be included for an emissions test in accordance with Appendix 2 of Annex VI to Delegated Regulation (EU) 2017/654.

1.2. Where either ambient pressure or ambient temperature are not measured by external sensors, they shall be provided by the ECU in accordance with Table 2.

Table 2

Additional measurement data

Parameter	Unit [1]
Ambient temperature [2]	K
Ambient pressure	kPa
Engine fuel flow	g/s

[1] Where the available data stream uses different units to those required by the table, that data stream shall be transformed into the required units during the data pre-processing set out in Appendix 3.

[2] Use of an intake air temperature sensor shall comply with the requirements set out in the second paragraph of point 5.1 of Appendix 2.

1.3. Where exhaust mass flow is not measured directly, the engine fuel flow shall be provided in accordance with the Table of Appendix 2';

(26) Appendix 8 is amended as follows:

(a) data entries 2 to 2.20 are replaced by the following:

'**2. Engine information**

2.1. ISM Group

2.2. Category and sub-category of the engine type/engine family

2.3. Type approval number

2.4. Commercial name(s) (if applicable)

2.5 Engine family designation (if member of a family)

2.6 Reference work [kWh]

2.7 Reference CO_2 mass [g]

2.8 Engine type designation

2.9. Engine identification number

2.10. Engine production year and month

2.11. Engine rebuilt (yes/no)

2.12. Engine total swept volume [cm^3]

2.13. Number of cylinders

2.14. Engine declared rated net power/rated speed [kW/rpm]

2.15. Engine maximum net power/power speed [kW/rpm]

2.16. Engine declared maximum torque/torque speed [kW/rpm]

2.17. Idle speed [rpm]

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

2.19. Manufacturer supplied full-load torque curve reference number

2.20. Installed $DeNO_x$ system (e.g., EGR, SCR)

2.21. Installed type of catalytic converter

2.22. Installed type of particulate after-treatment

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

2.24. Installed ECU information (Software calibration number)';

(b) data entries 9 to 9.11 are replaced by the following:

'9. Averaging window [1] conformity factors (determined in accordance with Appendices 3 to 5)

(Minimum, maximum and 90th cumulative percentile)

9.1. Work averaging window THC conformity factor [-] [2]

9.2. Work averaging window CO conformity factor [-]

9.3. Work averaging window NOx conformity factor [-] [3]

9.4. Work averaging window THC + NOx conformity factor [-] [4]

9.5. CO_2 mass averaging window THC conformity factor [-] [5]

9.6. CO_2 mass averaging window CO conformity factor [-]

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1 Averaging window is the sub-set of the complete calculated data set during the in-service monitoring test whose CO_2 mass or work is equal to the engine reference CO_2 mass or work measured over the applicable parent engine reference laboratory NRTC or NRSC

2 Only applicable for engine (sub-)categories which have separate limits for HC and NOx in accordance with [*Please make change to all similar footnotes*] Annex II of Regulation (EU) 2016/1628.

3 Only applicable for engine (sub-)categories which have separate limits for HC and NOx according to Annex II of Regulation (EU) 2016/1628.

4 Only applicable for engine (sub-)categories which have a combined emission limit for HC + NOx according to Annex II of Regulation (EU) 2016/1628.

5 Only applicable for engine (sub-)categories which have separate limits for HC and NOx according to Annex II of Regulation (EU) 2016/1628.

9.7. CO_2 mass averaging window NOx conformity factor [-] (6)

9.8. CO_2 mass averaging window THC+NOx conformity factor [-] (7)

9.9. Work averaging window: minimum and maximum averaging window power [%]

9.10. CO_2 mass averaging window: minimum and maximum averaging window duration [s]

9.11. Work averaging window: percentage of valid averaging windows

9.12 CO_2 mass averaging window: percentage of valid averaging windows';

(c) data entries 10 to 10.8 are replaced by the following:

'10. Averaging window conformity factors (determined in accordance with Appendices 3 and 5 without the determination of working and non-working events in accordance with Appendix 4 and without the exclusion of invalid windows as set out in points 2.2.2 and 2.3.1 of Appendix 5)

(Minimum, maximum and 90th cumulative percentile)

10.1. Work averaging window THC conformity factor [-] (8)

10.2. Work averaging window CO conformity factor [-]

10.3. Work averaging window NO_x conformity factor [-] (9)

10.4. Work averaging window THC+NO_x conformity factor [-] (10)

10.5. CO_2 mass averaging window THC conformity factor [-] (11)

10.6. CO_2 mass averaging window CO conformity factor [-]

10.7. CO_2 mass averaging window NO_x conformity factor [-] (12)

10.8. CO_2 mass averaging window THC+NO_x conformity factor [-] (13)

10.9. Work averaging window: minimum and maximum averaging window power [%]

10.10. CO_2 mass averaging window: minimum and maximum averaging window duration [s]';

(d) data entries I-2 to I-2.20. are replaced by the following:

I-2. Instantaneous calculated data

I-2.1. THC mass [g/s]

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6 Only applicable for engine (sub-)categories which have separate limits for HC and NOx according to Annex II of Regulation (EU) 2016/1628.

7 Only applicable for engine (sub-)categories which have a combined emission limit for HC + NOx according to Annex II of Regulation (EU) 2016/1628.

8 Only applicable for engine (sub-)categories which have separate limits for HC and NOx according to Annex II of Regulation (EU) 2016/1628.

9 Only applicable for engine (sub-)categories which have separate limits for HC and NOx according to Annex II of Regulation (EU) 2016/1628.

10 Only applicable for engine (sub-)categories which have a combined emission limit for HC + NOx according to Annex II of Regulation (EU) 2016/1628.

11 Only applicable for engine (sub-)categories which have separate limits for HC and NOx according to Annex II of Regulation (EU) 2016/1628.

12 Only applicable for engine (sub-)categories which have separate limits for HC and NOx according to Annex II of Regulation (EU) 2016/1628.

13 Only applicable for engine (sub-)categories which have a combined emission limit for HC + NOx according to Annex II of Regulation (EU) 2016/1628.

I-2.2. CO mass [g/s]

I-2.3. NOx mass [g/s]

I-2.4. CO_2 mass [g/s]

I-2.5. THC cumulated mass [g]

I-2.6. CO cumulated mass [g]

I-2.7. NOx cumulated mass [g]

I-2.8. CO_2 cumulated mass [g]

I-2.9. Calculated fuel rate [g/s]

I-2.10. Engine power [kW]

I-2.11. Engine work [kWh]

I-2.12. Work averaging window duration [s]

I-2.13. Work averaging window average engine power [%]

I-2.14. Work averaging window THC conformity factor [-] (14)

I-2.15. Work averaging window CO conformity factor [-]

I-2.16. Work averaging window NOx conformity factor [-] (15)

I-2.17. Work averaging window THC+NOx conformity factor [-] (16)

I-2.18. CO_2 mass averaging window duration [s]

I-2.19. CO_2 mass averaging window THC conformity factor [-] (17)

I-2.20. CO_2 mass averaging window CO conformity factor [-]

I-2.21. CO_2 mass averaging window NOx conformity factor [-] (18)

I-2.22. CO_2 mass averaging window THC+NOx conformity factor [-] (19)';

(27) The following Appendices 9 and 10 are added:

'*Appendix 9*

Determination of reference work and reference CO_2 mass for engine types for which the applicable type-approval test cycle is solely a Non-Road Steady-State Cycle (NRSC)

1. **General**

14 Only applicable for engine (sub-)categories which have separate limits for HC and NOx in accordance with [*Please make change throughout footnotes*.] Annex II of Regulation (EU) 2016/1628.

15 Only applicable for engine (sub-)categories which have separate limits for HC and NOx according to Annex II of Regulation (EU) 2016/1628.

16 Only applicable for engine (sub-)categories which have a combined emission limit for HC + NOx according to Annex II of Regulation (EU) 2016/1628.

17 Only applicable for engine (sub-)categories which have separate limits for HC and NOx according to Annex II of Regulation (EU) 2016/1628.

18 Only applicable for engine (sub-)categories which have separate limits for HC and NOx according to Annex II of Regulation (EU) 2016/1628

19 Only applicable for engine (sub-)categories which have a combined emission limit for HC + NOx according to Annex II of Regulation (EU) 2016/1628.

The reference work and reference mass of CO_2 for ISM groups A and C are taken from hot-start NRTC run of the type-approval test of the parent engine, and for ISM group H from the LSI-NRTC type-approval test of the parent engine, as set out in point 2.1.2 of Appendix 5. This Appendix defines how to determine the reference work and reference mass of CO_2 for engine types in all ISM groups except A, C and H.

For the purpose of this Appendix the applicable laboratory test cycle shall be the discrete-mode NRSC or RMC NRSC for the corresponding engine (sub-)category set out in tables IV-1 and IV-2, and tables IV-5 to IV-10 of Annex IV to Regulation (EU) 2016/1628.

2. **Determination of W_{ref} and $m_{CO_2,ref}$ from RMC NRSC**

2.1. The reference work W_{ref} ,kWh, is equal to the actual work W_{act} ,kWh, as given by Section 2.4.1.1 of Annex VII to Delegated Regulation (EU) 2017/654 on technical and general requirements.

2.2 The reference mass of CO_2 , $m_{CO_2,ref}$, g, is equal to the mass of CO_2 for the laboratory test cycle m_{CO_2}, g, calculated in accordance with one of Sections 2.1.2, 2.2.1, 3.5.1 or 3.6.1 of Annex VII to Delegated Regulation (EU) 2017/654 on technical and general requirements according to whether raw or dilute gaseous sampling is used and whether mass-based or molar-based calculation is applied.

3. **Determination of W_{ref} and $m_{CO_2,ref}$ from discrete-mode NRSC**

3.1. The reference work W_{ref} , kWh shall be calculated using equation 9-1.

$$W_{ref} = \sum_{i=1}^{N_{mode}} (P_i \cdot WF_i) \cdot \frac{t_{ref}}{3600} \qquad (9\text{-}1)$$

Where:

P_i is the engine power for mode *i*, kW, with $P_i = P_{m,i} + P_{AUX}$ (see Sections 6.3 and 7.7.1.3 of Annex VI to Delegated Regulation (EU) 2017/654 on technical and general requirements);

WF_i is the weighting factor for the mode i [-];

t_{ref} is the reference time, s, (see table);

W_{ref} is the reference cycle work emitted by the parent engine on the reference laboratory test cycle, kWh;

i is the mode number;

N_{mode} is the total number of modes in the test cycle.

3.2 The reference mass of CO_2 $m_{CO_2,ref}$, kg, shall be determined from the mean CO_2 mass flow rate $q_{mCO2,i}$, g/h, for each mode *i* calculated in according with Sections 2 or 3 of Annex VII to Delegated Regulation (EU) 2017/654 on technical and general requirements using equation 9-2.

$$m_{CO_2,ref} = \sum_{i=1}^{N_{mode}} \left(q_{mCO_2,i} \cdot WF_i\right) \cdot \frac{t_{ref}}{3600}$$

(9-2)

Where:

$q_{mCO_2,i}$ is the mean CO_2 mass flow rate for mode *i*, g/h;

WF_i is the weighting factor for the mode *i* [-];

t_{ref} is the reference time, s, (see table);

$m_{CO_2,ref}$ is the reference mass of CO_2 emitted by the parent engine on the reference laboratory test cycle, g;

i is the mode number;

N_{mode} is the total number of modes in the test cycle

3.3 Reference time t_{ref} is the total duration of the equivalent Ramped Modal Cycle (RMC) set out in Appendix 2 to Annex XVII to Delegated Regulation (EU) 2017/654 on technical and general requirements. Those values are set out in table.

Table

Reference time t_{ref} for each discrete-mode NRSC

NRSC	**t_{ref} [s]**
C1	1800
C2	1800
D2	1200
E2	1200
E3	1200
F	1200
G1	1800
G2	1800
H	1200

Appendix 10

Determination of the instantaneous proxy power from CO_2 mass flow

1. **General**

'Proxy power' means a value obtained by simple linear interpolation for the sole purpose of the determination of valid events during in-service monitoring as described in Appendix 4. This methodology is for engines designed without a communication interface capable to provide torque and speed data in accordance with Table 1 of Appendix 7. The calculation is based upon the assumption that, for all engine types within an engine family:

(a) the ratio of work and CO_2 mass on the reference laboratory test cycle are similar;

(b) there is a linear relationship between power and CO_2 mass flow rate; and,

(c) an operating engine that produces no net power emits no CO_2.

2. **Calculation of the instantaneous proxy power**

2.1. For the sole purpose of the calculations in Appendix 4, an instantaneous power for the engine under ISM test shall be computed from the measured CO_2 mass flow at a time increment equal to the data sampling period. For this calculation a simplified engine-family-specific CO_2 ('Veline') constant shall be used.

2.2 The Veline constant shall be calculated from the applicable reference values set out in point 2.1.2 of Appendix 5.

The Veline constant, $K_{veline,}$ is computed from the reference mass of CO_2 emitted by the parent engine at type-approval divided by the work performed by the parent engine at type-approval using equation 10-1.

$$K_{veline} = \frac{m_{CO_2,ref}}{W_{ref}} \quad (10\text{-}1)$$

Where:

K_{veline} is the "Veline" constant, g/kWh;

$m_{CO_2,ref}$ is the reference mass of CO_2 emitted by the parent engine in the reference laboratory test cycle, g;

W_{ref} is the reference work performed by the parent engine in the reference laboratory test cycle, kWh.

2.3 The instantaneous proxy power of the engine under ISM test is calculated from the instantaneous CO_2 mass flow using equation 10-2

$$P_{i,proxy} = 3600 \cdot \frac{\dot{m}_{CO_2,i}}{K_{veline}} \quad (10\text{-}2)$$

Where:

$P_{i,proxy}$ is the instantaneous proxy power, kW;

$\dot{m}_{CO_2,i}$ is the instantaneous mass flow of CO_2 emitted by the engine under test, g/s.'.