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Reciprocating internal combustion engines — Exhaust emission measurement —

Part 2: Measurement of gaseous and particulate exhaust emissions under field conditions

Moteurs alternatifs à combustion interne — Mesurage des émissions de gaz d'échappement —

Partie 2: Mesurages des émissions de gaz et de particules sur site

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 8178-2 was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*, Subcommittee SC 8, *Exhaust gas emission measurement*.

This second edition cancels and replaces the first edition (ISO 8178-2:1996), which has been technically revised.

ISO 8178 consists of the following parts, under the general title *Reciprocating internal combustion engines — Exhaust emission measurement*:

— *Part 1: Test-bed measurement of gaseous and particulate exhaust emissions*

— *Part 2: Measurement of gaseous and particulate exhaust emissions under field conditions*

— *Part 3: Definitions and methods of measurement of exhaust gas smoke under steady-state conditions*

— *Part 4: Steady-state test cycles for different engine applications*

— *Part 5: Test fuels*

— *Part 6: Report of measuring results and test*

— *Part 7: Engine family determination*

— *Part 8: Engine group determination*

— *Part 9: Test cycles and test procedures for test bed measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions*

— *Part 10: Test cycles and test procedures for field measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions*

— *Part 11: Test-bed measurement of gaseous and particulate exhaust emissions from engines used in nonroad mobile machinery under transient test condition*

Reciprocating internal combustion engines — Exhaust emission measurement —

Part 2: Measurement of gaseous and particulate exhaust emissions under field conditions

1 Scope

This part of ISO 8178, together with ISO 8178-1 and ISO 8178-11, specifies the measurement and evaluation methods for gaseous and particulate exhaust emissions from reciprocating internal combustion engines (RIC engines) under steady-state and transient conditions for field testing.

This part of ISO 8178 is applied when RIC engines used in off-road vehicles, marine installations, generating sets, diesel rail traction or similar applications need to be measured under field conditions or at site in order to determine the in-use compliance, or when it is not possible to take the measurements under test-bed conditions or to use the test-bed measurement results.

Re-checking or re-certification of engines for off-road vehicles after rebuild should preferably be tested outside the vehicle on a suitable load application and measurement device such as a dynamometer or load bank, but in-use compliance testing may be done on the vehicle.

This method can be used for determining conformity or certification of new, used or rebuilt engines at site or for in-use compliance testing of off-road vehicles. Confirmation of test-bed results with respect to ISO 8178-4 can also be performed within this part of ISO 8178. However, allowances need to be made for differences in engine operating parameters from laboratory conditions and for the accuracy of emission measurement equipment used under field conditions.

For engines used in machinery covered by additional requirements (e.g. occupational health and safety regulations, regulations for powerplants), additional test conditions and special evaluation methods may apply.

NOTE This part of ISO 8178 is intended to specify special requirements for the measurement of gaseous and particulate emissions at site or under field operating conditions. In many cases, the test cycles specified in ISO 8178-4 and ISO 8178-11 cannot be reproduced at site due to constraints of load. For in-use compliance testing, actual in-use operation might be required.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3046-3:2006, *Reciprocating internal combustion engines — Performance — Part 3: Test measurements*

ISO 8178-1:2006, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 1: Test-bed measurement of gaseous and particulate exhaust emissions*

ISO 8178-4 [1)], *Reciprocating internal combustion engines — Exhaust emission measurement — Part 4: Steady-state test cycles for different engine applications*

ISO 8178-5, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 5: Test fuels*

ISO 8178-6, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 6: Report of measuring results and test*

ISO 8178-11:2006, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 11: Test-bed measurement of gaseous and particulate exhaust emissions from engines used in nonroad mobile machinery under transient test conditions*

ISO 14396, *Reciprocating internal combustion engines — Determination and method for the measurement of engine power — Additional requirements for exhaust emission tests in accordance with ISO 8178*

ISO 15550:2002, *Internal combustion engines — Determination and method for the measurement of engine power — General requirements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
particulates
material collected on a specified filter medium after diluting diesel exhaust with clean filtered air to a temperature greater than 315 K (42 °C) and less than or equal to 325 K (52 °C) as measured at a point immediately upstream of the primary filter

EXAMPLE This is primarily carbon, condensed hydrocarbons and sulphates and associated water.

NOTE 1 Particulates defined in this part of ISO 8178 are substantially different in composition and weight from particulates or dust sampled directly from the undiluted exhaust gas using a hot filter method (e.g. ISO 9096). Particulate measurement as described in this part of ISO 8178 is conclusively proven to be effective for fuel sulfur levels up to 0,8 %.

NOTE 2 The filter temperature requirement has been changed compared to ISO 8178-1 to reflect the latest U.S. environmental protection agency (EPA) and EC legal requirements. Existing systems built in compliance with the requirements of ISO 8178-1 can still be used with the agreement of the parties involved.

3.2
partial-flow dilution method
process of separating a part of the raw exhaust from total exhaust flow, then mixing in an appropriate amount of dilution air to this sample prior to the sample filter

NOTE See ISO 8178-1:2006, 17.2.1, Figures 10 to 18.

3.3
full-flow dilution method
process of mixing dilution air with the total exhaust flow prior to separating a fraction of the diluted exhaust stream for analysis

NOTE 1 See ISO 8178-1:2006, 17.2.2, Figure 19.

NOTE 2 It is common in many full-flow dilution systems to dilute this fraction of pre-diluted exhaust a second time to obtain appropriate filter sample temperatures at the particulate filter. (See ISO 8178-1:2006, 17.3, Figures 20 and 21.)

1) To be published. (Revision of ISO 8178-4:1996)

3.4
isokinetic sampling
process of controlling the flow of the exhaust sample by maintaining the mean sample velocity at the probe equal to the exhaust stream mean velocity

3.5
non-isokinetic sampling
process of controlling the flow of the exhaust sample independent of the exhaust stream velocity

3.6
multiple-filter method
process of using one (pair of) filter(s) for each individual test mode or operating point

3.7
single-filter method
process of using one (pair of) filter(s) for all test modes or the whole in-use test sequence

3.8
specific emission
mass emissions expressed in g/kWh

3.9
brake power
observed power measured at the crankshaft or its equivalent, the engine being equipped only with the standard auxiliaries necessary for its operation on the test bed

NOTE See ISO 8178-1:2006, 5.3, and ISO 14396.

3.10
auxiliaries
equipment and devices listed in ISO 14396

NOTE 1 For many engine types within the scope of this part of ISO 8178, the auxiliaries which will be fitted to the engine in service will not be known at the time of manufacture or certification.

NOTE 2 When it is not appropriate to test the engine in the conditions defined in ISO 14396, e.g. if the engine and transmission form a single integral unit, the engine can only be tested with other auxiliaries fitted. In this case the dynamometer settings should be determined in accordance with ISO 8178-1. Where auxillary losses exceed 5 % of the maximum observed power, approval between the parties is needed prior to the test.

3.11
field conditions
conditions under which the engine under test is installed in, and coupled with, the actual equipment or vehicle, which is driven by the engine, and conditions under which the equipment or vehicle is allowed to function in normal use

4 Symbols and abbreviations

4.1 Symbols

See Table 1.

Table 1 — Symbols

Symbol	Term	Unit
α_a	Correction factor for brake power of spark ignition engines	—
b_x	Specific fuel consumption	kg/kWh
f_a	Laboratory atmospheric factor	—
H_a	Absolute humidity of the intake air	g/kg
F	Per cent torque related to the maximum torque	%
v_d	Engine speed	min^{-1}
v_t	Turbo charger speed	min^{-1}
p_b	Total barometric pressure	kPa
p_{be}	Air pressure after the charge air cooler	kPa
p_S	Dry atmospheric pressure	kPa
P	Uncorrected brake power	kW
P_{aux}	Declared total power absorbed by auxiliaries fitted for the test and not required by Annex B of ISO 8178-1:2006	kW
P_{max}	Maximum measured or declared power at the test engine speed under test conditions (see 11.5)	kW
r_{NO_x}	NO_x response factor of zirconium dioxide analyser	—
r_{NO_2}	NO_2 response factor of zirconium dioxide analyser	—
$r_{NO_2,max}$	Maximum NO_2/NO_x concentration ratio	—
s	Fuel rack position (of each cylinder, if applicable)	—
S	Dynamometer setting	kW
T_a	Absolute temperature of the intake air	K
T_{ba}	Air temperature after the charge air cooler	K
T_{ci}	Coolant temperature, inlet	K
T_{co}	Coolant temperature, outlet	K
T_{oil}	Lubricating oil temperature	K

4.2 Measured chemical components

The symbols for the measured chemical components are identical with those given in ISO 8178-1:2006, Clause 4. They are repeated in Table 2 of this part of ISO 8178 in order to facilitate comprehension.

Table 2 — Measured chemical components

Symbol	Definition
CH_4	Methane
CH_3OH	Methanol
CO	Carbon monoxide
CO_2	Carbon dioxide
(T)HC	(Total) Hydrocarbons
HCHO	Formaldehyde
H_2O	Water
NH_3	Ammonia
NMHC	Non-methane hydrocarbons
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_x	Oxides of nitrogen
N_2O	Dinitrogen Oxide
O_2	Oxygen
PT	Particulates

4.3 Abbreviations

See Table 3.

Table 3 — Abbreviations

EC	European Commission
ECE	United Nations Economic Commission for Europe
ECM	Electronic Control Module
EPA	United States Environmental Protection Agency
NTE	Not-To-Exceed
ZRDO	Zirconium dioxide (analyser)
PEMS	Portable Emissions Measurement System

5 Test conditions

5.1 General requirements

Field measurements shall be conducted only when one or more of the following requirements and conditions exist.

a) When test-bed measurement for type approval is not appropriate because site conditions cannot be duplicated.

   This test is a substitution of test-bed measurement, therefore the test should be conducted using the test cycle in ISO 8178-4.

   EXAMPLE 1 When the actual fuel used at site cannot be used because of availability or environmental restriction at test-bed location.

   EXAMPLE 2 When the ambient conditions of the test bed are not representative of the site conditions because of difference in altitude, humidity or air temperature.

   In this case, this part of ISO 8178 is only applicable to those engines which can reproduce at site measuring points specified in ISO 8178-4, such as marine engines at sea trials, initial installation of engines for driving generators and diesel electric locomotives.

b) When measurement at site is necessary to evaluate actual and local pollution.

   This should be made under actual or simulated operating conditions. Engine operation under a test cycle defined in ISO 8178-4 is not always possible, but the test procedure should be as close as possible to that procedure. Therefore, values measured in this case may not be directly comparable with test-bed results because measured values are very much dependent on test cycles.

c) When site measurement is agreed between the parties involved.

   Values obtained represent only a specific engine under specific site conditions and do not necessarily represent average or typical values. Measured values cannot be compared with test-bed results in most cases because measured values are very much dependent on test cycles.

d) When measurement at site is necessary to check the conformity of used or rebuilt engines to a standard.

e) When in-use compliance testing is required for off-road vehicles covered in ISO 8178-4:1996, 8.3 (mobile C cycle applications).

   This should be made under actual operating conditions of the vehicle. Engine operation under a test cycle defined in ISO 8178-4 or ISO 8178-11 is not possible under those conditions. Exhaust measurement shall be conducted with a portable emissions measurement system (PEMS) that shall meet the requirements of Clause 7 and be in accordance with the general provisions of ISO 8178-1 or ISO 8178-11. Values measured under those conditions are not comparable with test-bed results, and therefore other means for determining compliance of the vehicle or engine are needed, e.g. NTE.

If field measurement cannot reproduce exactly the same operating conditions as the test-bed conditions, the emission values will not be identical to the values obtained on the test bed. Therefore, specific methods shall be available for the determination of compliance. Such methods are not covered by this part of ISO 8178, but are subject to the respective legislation or to agreement between the parties involved.

5.2 Engine test conditions

5.2.1 Ambient conditions

The absolute temperature, T_a, of the engine intake air, expressed in kelvin, and the dry atmospheric pressure, p_s, expressed in kilopascal, shall be measured and recorded, and the parameter, f_a, shall be determined according to the following provisions:

— naturally aspirated and mechanically pressure-charged compression ignition engines:

$$f_a = \left(\frac{99}{p_s}\right) \times \left(\frac{T_a}{298}\right)^{0,7} \quad (1)$$

— turbocharged compression ignition engines with or without cooling of the intake air:

$$f_a = \left(\frac{99}{p_s}\right)^{0,7} \times \left(\frac{T_a}{298}\right)^{1,5} \quad (2)$$

Formulae (1) and (2) are identical with the exhaust emission legislation from ECE and EC.

For naturally aspirated and pressure-charged spark ignition engines the parameter α_a shall be determined according to the following formula:

$$\alpha_a = \left(\frac{99}{p_s}\right)^{1,2} \times \left(\frac{T_a}{298}\right)^{0,6} \quad (3)$$

The f_a and α_a values shall be stated with the results of the tests.

The following ambient parameters should be measured and recorded in the units given in Table 1.

a) absolute humidity of the intake air (H_a);

b) total barometric pressure (p_b);

5.2.2 Engines with charge air cooling

The temperature of the cooling medium and the temperature of the charge air shall be recorded (see 5.2.3).

5.2.3 Engine parameters

The following engine parameters should be measured and recorded in the units given in Table 1.

a) specific fuel consumption (b_x);

b) engine speed during the test (v_d);

c) turbo charger speed (v_t), if applicable;

d) air pressure after the charge air cooler (p_{be});

e) uncorrected brake power during the test (P);

f) fuel rack position of each cylinder (s), if applicable;

g) air temperature after the charge air cooler (T_{ba}), if applicable;

h) coolant temperature, inlet (T_{ci});

i) coolant temperature, outlet (T_{co});

j) lubricating oil temperature (T_{oil}).

5.3 Power

Terms of power are defined in ISO 14396. The basis of specific emission measurement is uncorrected brake power when g/kWh is used. Power, engine speed and torque values may differ at field compared to the test-bed conditions. Therefore, the emission values expressed in g/kWh differ at field compared to those under test-bed conditions. If the 100 % load of the test-bed measurement cannot be reached, the maximum power output to be measured is limited by maximum allowed engine speed and maximum allowed torque.

In cases where a direct measurement of torque is not possible, the power output shall be calculated based on other available data including signals from the engine ECM. The method of calculation and estimation shall be agreed between parties involved.

The appropriate engine power output, as measured with provisions existing at field, shall be recorded for each operating condition.

5.4 Engine air intake system

The engine shall be equipped with an air intake system presenting an air inlet restriction within the limit specified by the manufacturer for the engine operating conditions which results in maximum full load air flow.

5.5 Engine exhaust system

The test engine shall be equipped with an exhaust system presenting an exhaust back pressure within the limit specified by the manufacturer for the engine operating conditions which results in maximum full load air flow.

5.6 Cooling system

An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures prescribed by the manufacturer, in order to meet the range of ambient conditions and site load requirements, shall be used.

5.7 Lubricating oil

Specifications of the lubricating oil used for the test shall be recorded and presented with the results of the test.

5.8 Installation of sampling probes and equipment

Provisions to be taken for the proper installation of the sampling probes and measuring equipment are described in ISO 8178-1:2006, 7.5 and 7.6. Modifications to suit field installation conditions are permitted under the following conditions:

a) The space available for the necessary instrumentation shall be large enough to meet the requirements for safety and working ambient conditions.

b) The engine exhaust shall be routed using short connectors, preferably flexible, at the end of the engine's exhaust pipe downstream of any aftertreatment device, if used.

c) Flexible connectors that do not exceed a length of three times their largest inside diameter may be used to enlarge or reduce the exhaust-pipe diameter to match that of the test equipment.

d) Rigid stainless steel raw exhaust tubing shall be used to connect between flexible connectors. The tubing may be straight or bent to accommodate equipment geometry. “T” or “Y” stainless steel fittings may be used to join exhaust from multiple tailpipes.

e) Connectors and tubing shall not increase back pressure so much that it exceeds the manufacturer's maximum specified exhaust restriction.

6 Test fuels

Fuel characteristics influence the engine exhaust gas emission. Therefore, in all cases, the characteristics of the fuel used for the test shall be verified as required, recorded and declared with the results of the test. The characteristics to be recorded shall be those listed in the appropriate universal data sheet in ISO 8178-5.

Unless otherwise agreed, the test fuel shall be either the appropriate reference fuel given in ISO 8178-5 or the typical fuel for the engine in its field application.

The fuel temperature shall be measured at the inlet to the fuel injection pump or as specified by the manufacturer, and the location of measurement recorded.

The fuel temperature shall be in accordance with the manufacturer's recommendations.

7 Measurement equipment and data to be measured

7.1 General

The emission of gaseous and particulate pollutants by the engine submitted for testing shall be measured

a) for steady-state testing by the methods described in ISO 8178-1:2006, Clauses 16 and 17,

b) for transient testing by the methods described in ISO 8178-11:2006, Clauses 11 and 12.

These clauses describe the analytical systems for the gaseous pollutants and the particulate dilution and sampling systems used in the test cell. The same principles shall also be applied to field measurement systems including portable emissions measurement system (PEMS). Field analytical systems shall be minimally affected by ambient conditions such as temperature, pressure, humidity, physical orientation, mechanical shock and vibration, electromagnetic radiation, and ambient hydrocarbons.

The types of systems to be used for testing shall be declared prior to the test and shall be agreed upon by the parties involved.

7.1.1 Alternative measurement procedures

Other systems or analysers may be accepted, if it is found that they yield equivalent results or if parties involved agree to the use of such a system or analyser.

The determination of system equivalency shall be based on a seven-sample pair (or larger) correlation study between the system under consideration and one of the accepted systems of this part of ISO 8178. This testing shall be done under laboratory conditions. “Results” refers to the specific cycle-weighted emissions value. The correlation testing is to be performed at the same laboratory and test cell, and on the same engine, and is preferably run concurrently. The test cycle to be used shall be the appropriate cycle as found in ISO 8178-4 or in ISO 8178-11. The equivalency of the sample pair averages shall be determined by F-test and t-test statistics in accordance with ISO 8178-1:2006, Annex D, under the laboratory conditions and engine conditions described above.

The systems to be used for correlation testing shall be declared prior to the test and shall be agreed upon by the parties involved.

7.1.2 Zirconium dioxide (ZRDO) NO_x analyser

A zirconium dioxide (ZRDO) NO_x analyser may be used for the measurement of NO_x emissions from IC engines, if the exhaust does not contain NH_3, and if the NO_x response factor is not less than 0,9.

The NO_x response factor shall be calculated as follows:

$$r_{NO_x} = 1 - \left(1 - r_{NO_2}\right) \times r_{NO_{2,max}} \quad (4)$$

where

r_{NO_x} is the NO_x response factor;

r_{NO_2} is the NO_2 response factor of the ZRDO NO_x analyser, which shall be provided by the instrument manufacturer;

$r_{NO_{2,max}}$ is the maximum NO_2/NO_x concentration ratio expected during the test run.

Measurement results by ZRDO analyser shall be corrected for r_{NO_x} with the following formula:

$$c_{NO_x} = c_{NO_x,m} / r_{NO_x} \quad (5)$$

where

c_{NO_x} is the corrected NO_x concentration, in ppm;

$c_{NO_x,m}$ is the measured NO_x concentration, in ppm;

r_{NO_x} is the NO_x response factor.

A ZRDO NO_x analyser may be applied for engines with an aftertreatment device that emits NH_3, if the parties involved agree.

7.2 Torque and speed

The engine shall be operated with the torque and speed sequence applied according to the typical field conditions or, if applicable, to the relevant test cycles described in ISO 8178-4. In cases where the relevant test cycle is not possible, e.g. due to the characteristic of the load or because of the torsional vibration of the plant, the required test point shall be replaced by a point as close as possible, by agreement with all parties involved.

The instrumentation for torque and speed measurement shall enable the measurement of the shaft power to be within the given limits. Additional calculations and comparison with test-bed measurement results may be necessary (see also 5.3).

Signals from the engine's ECM may be used in place of values measured by individual instruments, provided the signals are correctly filtered and time-aligned with the emissions signals from the instrument in accordance with ISO 8178-11:2006, 9.3.3. Any combination of ECM signals, with or without other measurements, may be used to estimate engine speed and torque for use in brake-specific emission calculations, provided the overall performance of any speed or torque estimator meets the performance specifications in Table 1.

7.3 Exhaust gas flow

The principal methods applicable for determining the exhaust gas flow are described in ISO 8178-1:2006, 7.3. For the accuracy required, see 7.4 of this part of ISO 8178.

7.4 Accuracy of the data to be measured

7.4.1 Exhaust gas analyser

The analyser shall not deviate from the nominal calibration point by more than ± 4 % of the reading or ± 0,5 % of full scale, whichever is larger. The accuracy shall be determined according to the calibration requirements laid down in ISO 8178-1:2006, 8.5.

7.4.2 Other measuring equipment

The accuracy of the measuring equipment shall be such that the permissible deviations given in Tables 4 and 5 are not exceeded. The deviations given in Table 4 and Table 5 refer to the final recorded value, which is inclusive of the data acquisition system. The calibration of all measuring instruments shall be traceable to national (international) standards. The instruments shall be calibrated as required by internal audit procedures, by the instrument manufacturer or in accordance with ISO 9000 requirements.

Table 4 — Permissible deviations of instruments for engine-related parameters

No.	Item	Permissible deviation based on maximum engine values
1	Engine speed	± 2 %
2	Torque	± 5 %
3	Power	± 5 %
4	Fuel consumption	diesel fuel: ± 4 % residual fuel oil: ± 6 %
5	Air consumption	± 5 %
6	Exhaust gas flow	± 5 % calculated

Because of limited total tolerances for the exhaust emission calculation, the permissible values for some items, used in the appropriate equations, shall be smaller than the permissible deviations given in ISO 15550:2002, Table 4.

In practical cases it is often impossible to measure the fuel consumption at site. In such cases, especially those concerning heavy fuel, an estimation with a corresponding estimated error has to be made.

The consequences of such an error on the final emissions shall be calculated and reported with the results of the emission measurement.

Table 5 — Permissible deviations of instruments for other essential parameters

No.	Item	Permissible deviation from absolute values "of reading"
1	Coolant temperature	± 2 K
2	Lubricating oil temperature	± 2 K
3	Exhaust gas pressure	± 5 % of max.
4	Inlet manifold depressions	± 5 % of max.
5	Exhaust gas temperature	± 15 K
6	Air intake temperature (combustion air)	± 2 K
7	Atmospheric pressure	± 0,5 % of reading
8	Intake air humidity (relative)	± 3 %
9	Fuel temperature	± 2 K
10	Dilution tunnel temperatures	± 1,5 K
11	Dilution air humidity (relative)	± 3 %
12	Diluted exhaust gas flow	± 2 % of reading

7.4.3 Estimated accuracy and precision of the test results

Field measurements are typically less precise and less accurate than measurements on the test bed due to environmental and operational impacts. Precision and accuracy also depend on the measuring units, e.g. volume concentration (ppm), mass concentration (µg/m^3) or brake-specific emission (g/kWh). From the accuracies as specified in ISO 8178-1, 7.5.1.2 and 9.2, and in Table 4 of this part of ISO 8178, the expected accuracy and precision of the measurement results are calculated and are given in Table 6.

Table 6 — Estimated accuracy and precision of measuring values

Component	Unit	Accuracy	Precision
Gaseous emissions	ppm	± 5 % of reading	± 1 % of reading
	µg/m^3	± 7 %	± 5,1 %
	g/kWh	± 9 %	± 7,4 %
Particulate emissions	µg/m^3	± 6,5 %	± 6,5 %
	g/kWh	± 8,5 %	± 8,5 %
NOTE The given values are only valid under ideal testing conditions. In practice these conditions do not always exist, especially if the engine operating modes deviate from the test cycles as specified in ISO 8178-4 and ISO 8178-11.			

7.5 Determination of the gaseous components

The analytical measuring equipment and the methods are described in ISO 8178-1:2005, 7.5 and Clause 16. For field measurements, the non-methane hydrocarbon analysis according to ISO 8178-1:2006, 7.5.3.6, is not applicable in most cases, as this method needs laboratory equipment (e.g. gas chromatographic equipment).

For the measurement of non-methane hydrocarbons, the hydrocarbon cutter method of ISO 8178-1:2006, 7.5.3.6.3, should preferably be applied. Alternatively, a factor of 0,98 THC may be used for diesel engines.

7.6 Determination of the particulates

The determination of particulates and the equipment needed shall be as specified in ISO 8178-1:2006, 7.6 and Clause 17. However, the reference filter weighing time may be exceeded.

Field particulate sampling systems are not required to achieve the filter face velocity criteria required for laboratory systems in ISO 8178-1 and ISO 8178-11. The average filter face velocity shall be calculated and declared with the test results. However, the 25 kPa maximum pressure differential increase shall still be observed.

For reasons of practicability, partial flow dilution systems are recommended for at site and field measurements.

The weighing chamber conditions according to ISO 8178-1:2006, 7.6.3, also apply to the measurement at site and under field conditions. In cases where the weighing chamber is not located near the measurement site, it shall be ensured that the loading of the filter does not change during the transport to the weighing chamber (see also 11.1 of this part of ISO 8178).

Particulate mass measurement might prove difficult under field conditions, especially on board ships, locomotives and off-road vehicles. It is therefore acceptable to use alternative particulate sample media or measurement procedures, if their equivalency is proven in accordance with 7.1.1, including non-filtering techniques. This includes PT deposition on an inert substrate using electrostatic, thermophoresis, inertia, diffusion, or some other deposition mechanism.

8 Calibration of the analytical instruments

The definitions and requirements given in ISO 8178-1:2006, Clause 8, and ISO 8178-11:2005, 11.3, apply with the exception of the calibration points, which shall not differ from the least-squares best-fit line by more than ± 4 % of reading or ± 0,5 % of full scale, whichever is larger.

The calibration shall be done in a laboratory. The interference checks shall be repeated after each instrument repair.

9 Calibration of the particulate sampling system

The definitions and requirements given in ISO 8178-1:2006, Clause 9, and ISO 8178-11:2006, 12.3, apply with the exception of the sample flow proportionality error through the particulate filter, which shall be within ± 4 % of reading.

10 Running conditions

10.1 Test cycles

Testing in the field should be representative of actual engine operation. If test cycles can be run in the field, they should preferably conform to ISO 8178-4. In most cases, however, it is not possible to use the same measuring points as in ISO 8178-4 in the field. Furthermore, the number of measuring points may be limited under field conditions. If the number of measuring points for field measurement is different from that of the test cycles as defined in ISO 8178-4, the weighting factors in ISO 8178-4 cannot be used, and the emission values can be different from the values obtained under the test-bed conditions.

Measuring points and weighting factors shall be agreed between parties involved, prior to the test, when it is not possible to use ISO 8178-4.

For in-use compliance testing of off-road vehicles, test cycles do not apply, since the vehicle is run under real operating conditions. The measurement values shall be summed up over testing time and divided by the work delivered by the engine over that time period.

10.2 Preparation of the engine

Prior to testing, the engine, including auxiliary equipment and the exhaust system, shall be conditioned according to the engine manufacturer's and/or user's recommendations in order to clean up the system and to achieve reliable test results. This preconditioning is important for engines with long exhaust stacks and engines with silencers and exhaust aftertreatment systems in place, as well as infrequently operated engines.

11 Test run

11.1 Preparation of the sampling filters (if needed)

At least one hour before the test, each filter (pair) shall be placed in a closed, but unsealed Petri dish and placed in a weighing chamber (see ISO 8178-1:2006, 7.6.3) for stabilization. At the end of the stabilization period, each filter (pair) shall be weighed and the tare weight shall be recorded. The filter (pair) shall then be stored in a closed Petri dish or in a sealed filter holder until needed for testing.

After testing, the Petri dish shall be appropriately sealed until it is returned to the weighing chamber, where it shall be conditioned for at least one hour, but not more than 80 hours, and then weighed. The gross weight of the filters shall be recorded and the tare weight subtracted.

If transportation of the filters between the weighing chamber and the test location is necessary, precautions are required to avoid changes in filter loading [e.g. caused by mechanical vibrations, evaporation at temperatures above 325 K (52 °C)]. It is permissible to collect and store particulate samples from several tests before transporting them to the weighing chamber, but this storage time should be reduced to the maximum possible extent.

If alternative PT methods are used, they shall be conditioned for testing in accordance with the instrument manufacturer's requirements and as conditioned during the alternative approval procedure according to 7.1.1.

11.2 Installation of the measuring equipment

The instrumentation and sample probes shall be installed as required. When using a full-flow dilution system for exhaust gas dilution (see ISO 8178-1:2006, Figure 19), the tailpipe shall be connected to the system.

11.3 Starting the dilution system and engine

The dilution system and engine shall be started. Depending on the specific test conditions, engine and dilution system may be warmed up until all temperatures and pressures have stabilized at the maximum achievable load point (for stabilization criteria, see ISO 15550:2002, 6.2.4.3.2).

Where possible, the dilution air temperature limits set forth in ISO 8178-1:2006, 17.2, should be followed. A dilution air temperature of less than 288 K is permitted if the ambient air temperature is below 288 K or if the parties involved agree.

11.4 Adjustment of the dilution ratio

All procedures shall be carried out according to those given in ISO 8178-1:2006, 12.4.

11.5 Determination of test points (steady-state testing only)

If applicable, the maximum power values at the specified test speeds shall be declared by the manufacturer in order to calculate the power values for the specified test modes. The engine setting for each test mode shall be calculated using the formula:

$$S = \left[\left(P_{\text{max}} + P_{\text{aux}} \right) \frac{F}{100} \right] - P_{\text{aux}} \qquad (6)$$

where

S is the engine dynamometer setting, in kilowatts;

P_{max} is the maximum observed or declared power at the test engine speed under the test conditions (specified by the manufacturer), in kilowatts;

P_{aux} is the declared total power absorbed by auxiliaries fitted for the test, and not required by ISO 15550:2002, Table 1, in kilowatts;

F is the per cent torque related to the maximum torque for the test engine speed.

11.6 Checking the analysers

The emission analysers shall be set to zero and spanned.

11.7 Test sequence

11.7.1 General

The engine shall be operated according to 10.1.

If for steady-state testing measuring points different from those given in ISO 8178-4 are used, measurement shall be conducted in order of decreasing power or torque, and a minimum of 10 min is necessary for each point. A longer time may be required for reasons of stabilization and the sufficient collection of particulates.

If applicable, during each mode of the test cycle after the initial change period, the specified speed shall be held to within $\pm$ 1 % of rated speed or $\pm$ 3 min^{-1}, whichever is greater, except for low idle which shall be within the tolerances declared by the manufacturer.

If applicable, the specified torque shall be held so that the average over the period during which the measurements are being taken is within $\pm$ 2 % of the maximum torque at the test speed. If it is not possible to maintain speed and torque within the above limits, the limit shall be agreed between parties involved, prior to test. If, in practice, tolerances cannot be held during a mode of a cycle, the application of a mean value is not excluded.

For in-use compliance testing with off-road vehicles, the vehicle shall be operated under its normal working conditions. Those conditions may be transient and/or steady state without a pre-defined running order of test points.

The fuel temperature shall be in accordance with Clause 6.

11.7.2 Analyser response

The output of the analysers shall be recorded on a strip chart recorder or measured with an equivalent data acquisition system with the exhaust gas flowing through the analysers

— at least during the last three minutes of each mode for steady-state testing,

— continuously over the test period for transient testing or in-use compliance testing.

If bag sampling is applied for the diluted CO and CO_2 measurement (see ISO 8178-1:2006, 7.5.4), a sample shall be bagged

— for steady-state testing, during the last three minutes of each mode,

— for transient testing or in-use compliance testing, over the total test period,

and the bag sample analysed and recorded.

11.7.3 Particulate sampling (if applicable)

The particulate sampling can be done either with the single-filter method or the multiple-filter method. For details, see ISO 8178-1:2006, 7.6.

Since the results of the methods may differ slightly, the method used shall be declared with the results.

For the single-filter method, the modal weighting factors, as specified in the test cycle procedure or as agreed by the parties involved, shall be taken into account during sampling by adjusting sample flow rate and/or sampling time accordingly.

For steady-state testing over a test cycle as specified in ISO 8178-4, sampling shall be conducted as late as possible within each mode. The sampling time per mode shall be at least 20 s for the single filter method and at least 60 s for the multiple-filter method. For additional information on test mode duration see ISO 8178-4. For systems without by-pass capability, the sampling time per mode shall be at least 60 s for single- and multiple-filter methods.

For transient testing or steady-state testing over a non-specified test cycle, the particulate sampling system shall be switched from by-pass to collecting particulates at the start of the engine or test sequence. The sample pump(s) shall be adjusted so that the flow rate through the particulate sample probe or transfer tube is maintained proportional to the exhaust mass flow rate.

11.7.4 Engine conditions

The engine speed and load, intake air temperature, exhaust back pressure, fuel flow and air or exhaust gas flow shall be recorded

— for steady-state testing, within the final 80 % at each mode once the engine has been stabilized,

— for transient testing or in-use compliance testing, over the complete test sequence.

The values may be averaged over the considered time.

If the measurement of the exhaust gas flow or the measurement of combustion air and fuel consumption is not possible, they may be calculated using the total carbon and oxygen balance method (see ISO 8178-1:2006, 7.3.4 and Annex A).

Any additional data required for calculation shall be recorded (see Clause 12).

11.8 Re-checking the analysers

The zero and span settings of the emission analysers shall be checked and adjusted, as required, at least at the end of the test. The test shall be considered satisfactory if the adjustment necessary after the test does not exceed the accuracy of the analysers specified in 7.4.1.

11.9 Test report

11.9.1 General

The test report shall be in accordance with ISO 8178-6.

11.9.2 General guidelines

The report shall be clear concerning what has been measured and how, and what has been calculated and/or corrected and how. An assessment of accuracy and reasons for choice of test options shall be included where applicable.

11.9.3 Measuring equipment

A record shall be made of the measuring equipment which has been used, including span gases indications, the ambient conditions at air inlet including humidity and the engine performance data and fuel characteristics, which indicate how the values of those characteristics have been obtained.

11.9.4 Engine parameter

A description of engine parts shall not include those parts which, due to standardization, can be easily traced later on, but indications concerning injection timing, injector setting, injection nozzle holes and turbocharger specification shall be given. In the case of spark ignition engines, the ignition setting and the spark plug characteristics shall be given.

12 Emissions evaluation and calculation

12.1 General guidelines

The emissions evaluation and calculation shall be performed in accordance with

a) ISO 8178-1:2006, Clauses 13 and 14, for gaseous components under steady-state conditions.

b) ISO 8178-1:2006, Clause 13 and 15, for particulates under steady-state conditions.

c) ISO 8178-11:2006, Clause 9, for gaseous components and particulates under transient conditions using raw exhaust and partial flow dilution.

d) ISO 8178-11:2006, Clause 10, for gaseous components and particulates under transient conditions using full flow dilution.

12.2 Specific requirements for in-use compliance testing of off-road vehicles

In-use compliance testing of off-road vehicles is not based on a specified test cycle, but on running the vehicle under its actual operating conditions in the field. In most cases, such in operation will be transient by nature, and therefore the calculation procedures of ISO 8178-11 apply. The duty cycle characteristics and length shall be agreed upon by the parties involved prior to the start of the in-use compliance test.

The vehicle shall be started as described in the owner's manual. Depending on the agreement of the parties involved, emissions measurement may start directly at vehicle start or at a later point, when the engine is warmed up. All data shall be recorded and integrated throughout the complete in-use duty cycle. At the end of the in-use duty cycle, emissions sampling shall be stopped after the system response time has elapsed.

For determining the brake-specific emissions, ECM values of engine speed, torque or fuel consumption may be used. Discontinuous or irrational ECM data shall be replaced with linearly interpolated values from adjacent data. ECM signals shall be time-aligned with other data using the transformation time in accordance with ISO 8178-11:2006, 3.15.

In case of a non-electronic engine, the determination of engine work shall be agreed upon by the parties involved.

Bibliography

[1] ISO 1585, *Road vehicles — Engine test code — Net power*

[2] ISO 2534, *Road vehicles — Engine test code — Gross power*

[3] ISO 2710-1, *Reciprocating internal combustion engines — Vocabulary — Part 1: Terms for engine design and operation*

[4] ISO 2710-2, *Reciprocating internal combustion engines — Vocabulary — Part 2: Terms for engine maintenance*

[5] ISO 3046-1, *Reciprocating internal combustion engines — Performance — Part 1: Declarations of power, fuel and lubricating oil consumptions, and test methods — Additional requirements for engines for general use*

[6] ISO/TR 3313, *Measurement of fluid flow in closed conduits — Guidelines on the effects of flow pulsations on flow-measurement instruments*

[7] ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

[8] ISO 5168, *Measurement of fluid flow — Procedures for the evaluation of uncertainties*

[9] ISO 5725-1, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions*

[10] ISO 5725-2, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

[11] ISO 5725-3, *Accuracy (trueness and precision) of measurement methods and results — Part 3: Intermediate measures of the precision of a standard measurement method*

[12] ISO 5725-4, *Accuracy (trueness and precision) of measurement methods and results — Part 4: Basic methods for the determination of the trueness of a standard measurement method*

[13] ISO 5725-6, *Accuracy (trueness and precision) of measurement methods and results — Part 6: Use in practice of accuracy values*

[14] ISO/TR 7066-1, *Assessment of uncertainty in calibration and use of flow measurement devices — Part 1: Linear calibration relationships*

[15] ISO 7066-2, *Assessment of uncertainty in the calibration and use of flow measurement devices — Part 2: Non-linear calibration relationships*

[16] ISO 8178-3, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 3: Definitions and methods of measurement of exhaust gas smoke under steady-state conditions*

[17] ISO 8178-7, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 7: Engine family determination*

[18] ISO 8178-8, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 8: Engine group determination*

[19] ISO 8178-9, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 9: Test cycles and test procedures for test bed measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions*

[20] ISO 8178-10, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 10: Test cycles and test procedures for field measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions*

[21] ISO 8216-1, *Petroleum products — Fuels (class F) classification — Part 1: Categories of marine fuels*

[22] ISO 8217, *Petroleum products — Fuels (class F) — Specifications of marine fuels*

[23] ISO 8665, *Small craft — Marine propulsion reciprocating internal combustion engines — Power measurements and declarations*

[24] ISO 9096, *Stationary source emissions — Manual determination of mass concentration of particulate matter*

[25] ISO 9249, *Earth-moving machinery — Engine test code — Net power*

[26] ISO 10054, *Internal combustion compression-ignition engines — Measurement apparatus for smoke from engines operating under steady-state conditions — Filter-type smokemeter*

[27] UN-ECE R24, *Uniform provisions concerning the approval of - diesel engines with regard to the emission of visible pollutants - motor vehicles with regard to the installation of diesel engines of an approved type - vehicles equipped with diesel engines with regard to the emission of visible pollutants by the engine - method of measuring the power of compression ignition engines*

[28] UN-ECE R49, *Uniform provisions concerning the approval of diesel engines with regard to the emission of gaseous pollutants*

[29] 88/77/EEC:1988, *Council directive in the approximation of the laws of the member states relating to the measures to be taken against the emission of gaseous polluants from diesel engines for use in vehicles*

[30] SAE J177, *Measurement of Carbon Dioxide, Carbon Monoxide and Oxides of Nitrogen in Diesel Exhaust*

[31] SAE J244, *Measurement of Intake Air or Exhaust Gas Flow of Diesel Engines*

[32] SAE J1003, *Diesel Engine Emission Measurement Procedure*

[33] SAE J1088, *Test Procedure for the Measurement of Gaseous Exhaust Emissions from Small Utility Engines*

[34] SAE J1151, *Methane Measurement Using Gas Chromatography*

[35] SAE J1936, *Chemical Methods for the Measurement of Non-regulated Diesel Emissions*

[36] ICOMIA Standard 34-88, *Test Procedure for the Measurement of Exhaust Emissions from Marine Engines*

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