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Reciprocating internal combustion engines — Exhaust emission measurement —

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

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

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

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Contents

Page

iTeh STANDARD PREVIEW
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ISO 8178-2:2008
https://standards.iteh.ai/catalog/standards/sist/da3f214d-cc3d-4e0d-9073-04f31b3421f9/iso-8178-2-2008

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Foreword

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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*.

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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*:

ISO 8178-2:2008
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— *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*

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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.

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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.

ISO 8178-2:2008
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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*

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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

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ISO 8178-2:2008
https://standards.iteh.ai/catalog/standards/sist/da5124fd-e05d-40dd-9075-04f31b3421f9/iso-8178-2-2008

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)

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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

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

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3.10
auxiliaries
equipment and devices listed in ISO 14396

ISO 8178-2:2008
https://standards.iteh.ai/catalog/standards/sist/da3f214d-cc3d-4e0d-9073-04f31b3421f9/iso-8178-2-2008

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

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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

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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

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ISO 8178-2:2008
https://standards.iteh.ai/catalog/standards/sist/da3f214d-ee3d-4e0d-9073-04f31b3421f9/iso-8178-2-2008

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

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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.

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ISO 8178-2:2008
https://standards.iteh.ai/catalog/standards/sist/da9f214d-cc3d-4e0d-9073-04f31b3421f9/iso-8178-2-2008

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.

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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:

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

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

ISO 8178-2:2008
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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;

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