INTERNATIONAL STANDARD

ISO 8178-2

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Reciprocating internal combustion engines — Exhaust emission measurement —

Part 2:

Measurement of gaseous and particulate exhaust emissions at site

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

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

Reference number
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Contents

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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.

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.

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

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 at site*

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

— *Part 4: Test cycles for different engine applications*

— *Part 5: Test fuels*

— *Part 6: Test report*

— *Part 7: Engine family determination*

— *Part 8: Engine group determination*

— *Part 9: Test bed measurement of exhaust gas smoke emissions from engines used in non-road mobile machinery*

Annex A of this part of ISO 8178 is for information only.

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Reciprocating internal combustion engines — Exhaust emission measurement —

Part 2:
Measurement of gaseous and particulate exhaust emissions at site

1 Scope

This part of ISO 8178, together with ISO 8178-1, specifies the measurement and evaluation methods for gaseous and particulate exhaust emission from reciprocating internal combustion engines (RIC engines) under steady-state conditions at site, necessary for determining one weighted value for each exhaust gas pollutant. Various combinations of engine load and speed reflect different engine applications (see ISO 8178-4).

This part of ISO 8178 is preferably applied when RIC engines used in marine installations, generating sets, diesel electric rail traction or similar applications must be measured at site or when it is not possible to take the measurements under test-bed conditions or to use the test-bed measurement results.

It is inappropriate to apply this part of ISO 8178 to off-road vehicle engines powering vehicles such as, but not limited to, agricultural tractors and harvesters, earthmoving machines, large off-highway trucks (typically used in mining), lawn care and utility units and fork-lift trucks. Engines powering this equipment are to be certified on the test bed. If re-checking or re-certification of these engines is required after rebuild, they should preferably be tested outside the vehicle on a suitable load application and measurement device such as a dynamometer or load bank.

This method can be used for determining conformity or certification of new, used or rebuilt engines at site. Confirmation of test-bed results with respect to ISO 8178-4 can also be performed within this document. However, allowances must be made for differences in engine operating parameters from laboratory conditions. The engine must be operated at the same speed and torque measuring points as used for test-bed measurement.

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 1 This part of ISO 8178 is intended to specify special requirements for the measurement of gaseous and particulate emissions at site. Emissions can be measured and should be primarily measured on a test bed for any engine. Measurement on the test bed is much more accurate, repeatable and easy. Test-bed measurements using defined test cycles represent those of average and typical use of engines. The test cycles specified in ISO 8178-4 cannot always be reproduced at site due to constraints of load.

Site measurement is necessary only when 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.

EXAMPLES

1) when the actual fuel used at site cannot be used because of availability or environmental restriction at test-bed location;

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.

If site 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. Site measurement for this purpose must therefore be limited to those applications which can be operated under the same test cycles as those used for certification on a test bed.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 8178. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 8178 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3046-1:1995, *Reciprocating internal combustion engines — Performance — Part 1: Standard reference conditions, declarations of power, fuel and lubricating oil consumptions, and test methods.*

ISO 3046-3:1989, *Reciprocating internal combustion engines — Performance — Part 3: Test measurements.*

ISO 8178-1:1996, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 1: Test-bed measurement of gaseous and particulate exhaust emissions.*

ISO 8178-4:1996, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 4: Test cycles for different engine applications.*

ISO 8178-5:—[1], *Reciprocating internal combustion engines — Exhaust emission measurement — Part 5: Test fuels.*

3 Definitions

For the purposes of this part of ISO 8178, the following definitions apply.

3.1 particulates: Any material collected on a specified filter medium after diluting diesel exhaust with clean filtered air to a temperature of less than or equal to 325 K (52 °C) as measured at a point immediately upstream of the primary filter; this is primarily carbon, condensed hydrocarbons and sulphates and associated water.

NOTE 2 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 are conclusively proven to be effective for fuel sulfur levels up to 0,8 %.

3.2 partial-flow dilution method: The 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. (See ISO 8178-1:1996, 16.1.1, figures 10 to 18.)

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

NOTE 3 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 8178-1:1996, 16.1.2, figure 19.)

3.4 isokinetic sampling: The 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: The process of controlling the flow of the exhaust sample independent of the exhaust stream velocity.

3.6 multiple filter method: The use of one pair of filters for each of the individual test cycle modes, modal weighting factors of the test cycle modes being accounted for after sampling during the data evaluation phase of the test.

3.7 single filter method: The use of one pair of filters for all test cycle modes, modal weighting factors being accounted for during the particulate sampling phase of the test cycle.

NOTE 4 This method dictates that close attention be given to sampling duration and flow rates.

3.8 specific emission: The mass flow rate of pollutants, preferably expressed on the basis of observed brake power.

NOTE 5 Emissions are expressed in grams per kilowatt hour whenever it is possible. In those cases where it is impossible to accurately determine power, a unique expression related to fuel energy input or normalized exhaust flow volume may be used. This is only to be considered depending on specific agreement between the parties involved. When engines cannot be operated under test cycles defined in ISO 8178-4 emissions may be expressed on the basis of dry standard volume of exhaust flow rate.

When emissions are based on brake power (g/kWh)

a) if the site conditions differ from the ambient conditions on which this kind of power is based, the emissions are related to the actual power measured or calculated at site. The ambient conditions for the test shall be recorded;

1) To be published.

b) if it is not convenient to test the engine with auxiliaries removed (see ISO 8178-1:1996, 5.3); e.g. if the engine and transmission form a single integral unit, the engine can be tested with auxiliaries. In this case the power settings should be determined in accordance with ISO 8178-1:1996, 5.3 and 11.5.

When emissions are based on dry standard volume of exhaust flow rate, expressed in g/m^3, measured results should be corrected into figures at a required O_2 concentration.

3.9 brake power: The 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 (see 5.3 and table B.1 of ISO 8178-1:1996).

3.10 auxiliaries: The equipment and devices of which a list is given in table B.1 of ISO 8178-1:1996.

3.11 site conditions: Conditions under which the engine under test is installed in and coupled with the actual equipment which is driven by the engine and those under which the equipment is allowed to function normally.

4 Symbols and abbreviations

4.1 Symbols and subscripts

Symbol		Term	Unit
According to EEC regulations	SI[1)]		
b_x	b_x	Specific fuel consumption	kg/kWh
$conc_c$	c_{corr}	Background corrected concentration	ppm, % (*V/V*)
$conc_d$	c_{dil}	Concentration of the dilution air	ppm, % (*V/V*)
$conc_x$	c_x	Concentration (with suffix of the component nominating)	ppm, % (*V/V*)
DF	D	Dilution factor	1
f_a	f_a	Laboratory atmospheric factor	1
G_{EDFW}	q_{mdx}^*	Equivalent diluted exhaust gas mass flow rate on wet basis	kg/h
G_{EXHW}	q_{mxw}	Exhaust gas mass flow rate on wet basis	kg/h
G_{TOTW}	q_{mdx}	Diluted exhaust gas mass flow rate on wet basis	kg/h
GAS_x	e_x	Gas emission (with subscript denoting compound)	kg/kWh
H_a	H_a	Absolute humidity of the intake air	g/kg
i	i	Subscript denoting an individual mode	1
L	M	Percent torque related to the maximum torque for the test engine speed	%
$mass$	q_m	Emissions mass flow rate	g/h
M_d	m_d	Particulate sample mass of the dilution air collected	mg
M_{DIL}	m_{dil}	Mass of the dilution air sample passed through the particulate sampling filters	kg
M_f	m_f	Particulate sample mass collected	mg
M_{GAS}	m_{gas}	Mass of gas	kg
M_{SAM}	m_{sam}	Mass of the diluted exhaust sample passed through the particulate sampling filters	kg
n_d	n_d	Engine speed	min^{-1}
n_{turb}	n_t	Turbo charger speed	min^{-1}
p_B	p_B	Total barometric pressure[2)]	kPa
p_{be}	p_{ba}	Air pressure after the charge air cooler	kPa
p_s	p_s	Dry atmospheric pressure	kPa

Symbol		Term	Unit
According to EEC regulations	SI[1]		
P	P	Uncorrected brake power	kW
P_{AUX}	P_{aux}	Declared total power absorbed by auxiliaries fitted for the test and not required by annex B of ISO 8178-1:1996	kW
P_m	P_m	Maximum measured or declared power at the test engine speed under test conditions (see 11.5)	kW
PT_{mass}	q_{mPT}	Particulate mass flow rate	kg/h
PT_x	e_x	Particulate emission (with subscript denoting compound)	kg/kWh
q	r_{dil}	Dilution ratio	1
s	s	Fuel rack position (of each cylinder, if applicable)	—
S	S	Dynamometer setting	kW
T_a	T_a	Absolute temperature of the intake air[3]	K
T_{ba}	T_{ba}	Air temperature after the charge air cooler	K
T_{clin}	T_{ci}	Coolant temperature, inlet	K
T_{clout}	T_{co}	Coolant temperature, outlet	K
T_{oil}	T_{oil}	Lubricating oil temperature	K
V_{DIL}	V_{dil}	Volume of the dilution air sample passed through the particulate sampling filters	m^3
V_{EDFW}	q^*_{Vdx}	Equivalent diluted exhaust gas volume flow rate on wet basis	m^3/h
V_{EXHD}	q_{Vxd}	Exhaust gas volume flow rate on dry basis	m^3/h
V_{EXHW}	q_{Vxwi}	Exhaust gas volume flow rate on wet basis	m^3/h
V_{SAM}	V_{sam}	Volume of the diluted exhaust sample passed through the particulate sampling filters	m^3
V_{TOTW}	q_{Vdx}	Diluted exhaust gas volume flow rate on wet basis	m^3/h
W_F	W_f	Weighting factor	1
W_{FE}	W_{fe}	Effective weighting factor	1
α_a	α_a	Correction factor for brake power in spark ignition engines	1
ρ_{GAS}	ρ_{gas}	Gas mass concentration	g/m^3

1) According to ISO 31 on Quantities and units.

2) Corresponds to p_x or PX (site total pressure in ambient conditions), p_y or PY (test total pressure in ambient conditions) as defined in ISO 3046-1.

3) Corresponds to T_y or TTY (ambient air thermodynamic temperature during test), as defined in ISO 3046-1.

4.2 Symbols and abbreviations for the measured emission components

CH_4	Methane
CH_3OH	Methanol
CO	Carbon monoxide
CO_2	Carbon dioxide
HC	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

CVS	Constant volume sampling
GC	Gas chromatograph
HPLC	High pressure liquid chromatograph
NMC	Non-methane cutter

5 Test conditions

5.1 General requirements

All volumes and volumetric flow rates shall be related to 273 K and 101,3 kPa.

5.2 Engine test conditions

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

Naturally aspirated and mechanically pressure charged compression ignition engines:

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

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

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

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

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

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

and shall be between 0,93 and 1,07.

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

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 kPa, shall be measured, and recorded (see 5.2.3).