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Reciprocating internal combustion engines — Exhaust emission measurement —

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

[Revision of first edition (ISO 8178-1:1996)]

Moteurs alternatifs à combustion interne — Mesurage des émissions de gaz d'échappement —
Partie1: Mesurage des émissions de gaz et de particules au banc d'essai

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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 3.

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.

This International Standard has been prepared by ISO/TC 70 *Internal combustion engines*, SC 8 *Exhaust 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: Report of measuring results and tests*

— *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*

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

Annex A forms an integral part of this standard. Annexes B, C, D and E are for information only.

Reciprocating internal combustion engines – Exhaust emission measurement – Part 1: Test-bed measurement of gaseous and particulate exhaust emissions

1 Scope

This part of ISO 8178 specifies the measurement and evaluation methods for gaseous and particulate exhaust emission from reciprocating internal combustion engines (RIC engines) under steady-state conditions on a test bed, 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 applicable to RIC engines for mobile, transportable and stationary use, excluding engines for motor vehicles primarily designed for road use. This part of ISO 8178 may be applied to engines used e.g. for earth-moving machines, generating sets and for other applications.

In limited instances, the engine can be tested on the test bed in accordance with ISO 8178-2, the field test document. This can only occur with the agreement of the parties involved. It should be recognised that data obtained under these circumstances may not agree completely with previous or future data obtained under the auspices of this part of ISO 8178. Therefore, it is recommended that this option be exercised only with engines built in very limited quantities such as very large marine or generating set engines.

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.

Where it is not possible to use a test bed or where information is required on the actual emissions produced by an in-service engine, the site test procedures and calculation methods specified in ISO 8178-2 are appropriate.

NOTE This part of ISO 8178 is intended for use as a measurement procedure to determine the gaseous and particulate emission levels of RIC engines for non-automotive use. Its purpose is to provide a map of an engine's emissions characteristics which, through use of the proper weighting factors, can be used as an indication of that engine's emission levels under various applications. The emission results are expressed in units of grams per kilowatt hour and represent the mass rate of emissions per unit of work accomplished.

Although this part of ISO 8178 is designed for non-automotive engines, it shares many principles with particulate and gaseous emission measurements that have been in use for many years for on-road engines. One test procedure that shares many of these principles is the full dilution method as presently specified for certification of 1985 and later heavy duty truck engines in the USA. Another is the procedure for direct measurement of the gaseous emissions in the undiluted exhaust gas, as presently specified for the certification of heavy duty truck engines in Japan and Europe.

Many of the procedures described below are detailed accounts of laboratory methods, since determining an emissions value requires performing a complex set of individual measurements, rather than obtaining a single measured value. Thus, the results obtained depend as much on the process of performing the measurements as they depend on the engine and test method.

Evaluating emissions from off-road engines is more complicated than the same task for on-road engines due to the diversity of off-road applications. For example, on-road applications primarily consist of moving a load from one point to another on a paved roadway. The constraints of the paved roadways, maximum acceptable pavement loads and maximum allowable grades of fuel, narrow the scope of on-road vehicle and engine sizes. Off-road engines and vehicles include a wider range of size, including the engines that power the equipment. Many of the engines are large enough to preclude the application of test equipment and methods that were acceptable for on-

road purposes. In cases where the application of dynamometers is not possible the tests must be made at site or under appropriate conditions.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard 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:—[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 (Satellite standard)*

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

ISO 5167-1:1991, *Measurement of fluid flow by means of pressure differential devices – Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full*

ISO 5167-1 AMD 1:1998, *Measurement of fluid flow by means of pressure differential devices – Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full, Amendment 1*

ISO 5167-1: —[2], *Measurement of fluid flow in circular cross-section conduits running full using pressure differential devices – Part 1: General (Revision of ISO 5167-1 :1991)*

ISO 5167-2:—[3], *Measurement of fluid flow in circular cross-section conduits running full using pressure differential devices – Part 2: Orifice plates*

ISO 5167-3: —[4], *Measurement of fluid flow in circular cross-section conduits running full using pressure differential devices – Part 3: Nozzles and Venturi nozzles*

ISO 5167-4: —[5], *Measurement of fluid flow in circular cross-section conduits running full using pressure differential devices – Part 4: Venturi tubes*

ISO 5725-1:1994, *Accuracy (trueness and precision) of measurement methods and results - Part 1: General principles and definitions*

ISO 5725-1:Technical Corrigendum 1 :1998, *Accuracy (trueness and precision) of measurement methods and results - Part 1: General principles and definitions, Technical Corrigendum 1*

ISO 5725-2:1994, *Accuracy (trueness and precision) of measurement methods and results – Part 2: A basic method for the determination of repeatability and reproducibility of a standard measurement method*

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

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1) To be published.

2) To be published.

3) To be published.

4) To be published.

5) To be published.

ISO 8178-2:1996 *Reciprocating internal combustion engines – Exhaust emission measurement – Part 2: Measurement of gaseous and particulate exhaust emissions at site*

ISO 8178-3:1994 *Reciprocating internal combustion engines – Exhaust emission measurement – Part 3: Definitions and methods of measurement of exhaust gas smoke under steady-state conditions*

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

ISO 8178-5 :1998, *Reciprocating internal combustion engines – Exhaust emission measurement – Part 5: Specification of test fuels*

ISO 8178-6:2000, *Reciprocating internal combustion engines – Exhaust emission measurement – Part 6: Test report*

ISO 8178-7:1996, *Reciprocating internal combustion engines – Exhaust emission measurement – Part 7 : Engine family determination*

ISO 8178-8:1996, *Reciprocating internal combustion engines – Exhaust emission measurement – Part 8: Engine group determination*

ISO 8178-9:2000, *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*

ISO 8178-10:2000, *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*

ISO 9000: —[2], *Quality management systems - Fundamentals and vocabulary*

ISO 9000-1:1994, *Quality management and quality assurance standards – Part 1 : Guidelines for selection and use*

ISO 9000-2:1997, *Quality management and quality assurance standards – Part 2 : Generic guidelines for the application of ISO 9001, ISO 9002 and ISO 9003*

ISO 9000-3:1997, *Quality management and quality assurance standards – Part 3 : Guidelines for the application of ISO 9001 :1994 to the development, supply, installation and maintenance of computer software*

ISO 9000-4:1993, *Quality management and quality assurance standards – Part 4 : Guide to dependability programme management*

ISO 9096:1992, *Stationary source emissions - Determination of concentration and mass flow rate of particulate material in gas-carrying ducts - Manual gravimetric method*

ISO 14396:—[2], *Reciprocating internal combustion engines – Determination and method for the measurement of engine power – Additional requirements for exhaust amission tests according to ISO 8178 (Satellite standard)*

SAE J 1151:1991, *Methane measurement using gas chromatography*

SAE J 1936:1995, *Chemical methods for the measurement of nonregulated diesel emissions*

SAE J 1937:1995, *Engine testing with low-temperature charge air-cooler systems in a dynamometer test cell*

3 Definitions

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

3.1
particulatesAny material collected on a specified filter medium after diluting exhaust gases with clean, filtered air at a 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 sulfates and associated water.

NOTE 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). Particulates measurement as described in this part if ISO 8178 is conclusively proven to be effective for fuel sulphur levels up to 0,8 %.

3.2
partial flow dilution method
The process of separating a part of the raw exhaust from the total exhaust flow, then mixing with an appropriate amount of dilution air prior to passing through the particulate sampling filter (see 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 It is common in many full flow dilution systems to dilute this fraction of pre-diluted exhaust a second time to obtain appropriate sample temperatures at the particulate filter (see 16.2.2, 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 process of using one pair of filters for each of the individual test cycle modes. The modal weighting factors are accounted for after sampling during the data evaluation phase of the test.

3.7
single filter method
The process of using one pair of filters for all test cycle modes. Modal weighting factors must be accounted for during the particulate sampling phase of the test cycle by adjusting sample flow rate and/or sampling time. This method dictates that particular attention be given to sampling duration and flow rates.

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

3.8
specific emissions
mass emissions expressed in g/kW h

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

When it is not appropriate to test the engine in the conditions as defined in Annex B, 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 5.3 and 11.5. The auxiliary losses should not exceed 5 % of the maximum observed power. Losses exceeding 5 % must be approved by the parties involved prior to the test.

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 Annexe B)

3.10
auxiliaries
equipment and devices listed in Annexe B

4 Symbols and abbreviations

4.1 Symbols and subscripts

Symbols		Term	Unit
According to EC regulations[e)]	SI		
A_P	A_p	Cross sectional area of the isokinetic sampling probe	m^2
A_T	A_x	Cross sectional area of the exhaust pipe	m^2
$conc_c$	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
λ	—	Excess air factor ([kg dry air] / ([kg fuel] [M_{STOI}]))	1
λ_{Ref}	—	Excess air factor at reference conditions	1
f_a	F_a	Laboratory atmospheric factor	1
F_{FCB}	F_{cb}	Fuel specific factor for the carbon balance calculation	1
F_{FD}	F_d	Fuel specific factor for exhaust flow calculation on dry basis	1
F_{FH}	F_h	Fuel specific factor used for the calculations of wet concentrations from dry concentrations	1
F_{FW}	F_w	Fuel specific factor for exhaust flow calculation on wet basis	1
G_{AIRD}	q_{mad}	Intake air mass flow rate on dry basis	kg/h
G_{AIRW}	q_{maw}	Intake air mass flow rate on wet basis	kg/h
G_{DILW}	q_{mdw}	Dilution air mass flow rate on wet basis	kg/h
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_{FUEL}	q_{mf}	Fuel mass flow rate	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)	g/kW h
H_a	H_a	Absolute humidity of the intake air	g/kg
H_d	H_d	Absolute humidity of the dilution air	g/kg
H_{REF}	H_{ref}	Reference value of absolute humidity[b)]	g/kg
$HTCRAT$	HC	Hydrogen-to-carbon ratio	mol/mol
i	i	Subscript denoting an individual mode	1
K_{HDIES}	K_{hd}	Humidity correction factor for NO_x for diesel engines	1
K_{HPET}	K_{hp}	Humidity correction factor for NO_x for gasoline (petrol) engines	1
K_P	K_p	Humidity correction factor for particulates	1
K_{Wa}	K_{wa}	Dry to wet correction factor for the intake air	1
K_{Wd}	K_{wd}	Dry to wet correction factor for the dilution air	1
K_{We}	K_{we}	Dry to wet correction factor for the diluted exhaust gas	1

K_{Wr}	K_{wr}	Dry to wet correction factor for the raw exhaust gas	1
L	M	Percent torque related to the maximum torque for the test engine speed	%
$mass$	q_{mPT}	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_{GASi}	m_{gasi}	Mass of individual gas	g/h
M_{STOI}	m_{stoi}	Stoichiometric air fuel ratio	1
M_{SAM}	m_{sam}	Mass of the diluted exhaust sample passed through the particulate sampling filters	kg
p_a	p_a	Saturation vapour pressure of the engine intake air[c)]	kPa
p_B	p_b	Total barometric pressure[c)]	kPa
p_d	p_d	Saturation vapour pressure of the dilution air	kPa
p_{REST}	p_{REST}	Water vapour pressure after cooler	kPa
p_s	p_s	Dry atmospheric pressure	kPa
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	kW
P_m	P_m	Maximum measured or declared power at the test engine speed under test conditions (see 11.5)	kW
PT	e_{PT}	Particulate emission	g/kW h
PT_{mass}	q_{mPT}	Particle mass flow rate	g/h
q	r_{dil}	Dilution ratio	1
r	r_a	Ratio of cross sectional areas of isokinetic probe and exhaust pipe	1
R_a	R_a	Relative humidity of the intake air	%
R_d	R_d	Relative humidity of the dilution air	%
R_f	r_f	FID response factor	1
R_{fM}	r_m	FID response factor for methanol	1
ρ	ρ	Density	kg/m^3
S	S	Dynamometer setting	kW
T_a	T_a	Absolute temperature of the intake air	K
T_{Dd}	T_d	Absolute dewpoint temperature	K
T_{ref}	T_{ref}	Absolute reference temperature (of combustion air: 298 K)	K
T_{SC}	T_c	Absolute temperature of the intercooled air	K
T_{SCRef}	T_{cref}	Absolute intercooled air reference temperature	K
W_F	W_f	Weighting factor	1
W_{FE}	W_{fe}	Effective weighting factor	1

a) According to ISO 31 on Quantities an units.

b) 10,71 g/kg; for calculation of NO_x and particulate humidity correction factors.

c) Corresponds to p_{sy} or PSY (test ambient conditions) as defined in ISO 3046-1.

d) Correspond to px or PX (site total pressure in ambient conditions); py or PY (test total pressure in ambient conditions) as defined in ISO 3046-1.

e) For the purposes of this part of ISO 8178 the symbols according to EC regulations are used.