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Reciprocating internal combustion engines — Exhaust emission measurement —

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

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

Partie 1: Mesurage des émissions de gaz et de particules au banc d'essai

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 70, *Internal combustion engines*, Subcommittee SC 8, *Exhaust emission measurement.*

This third edition cancels and replaces the second edition (ISO 8178-1:2006) which has been technically revised.

A list of all the parts in the ISO 8178- series, can be found on the ISO website.

Introduction

This document is intended for use as a measurement procedure to determine the gaseous and particulate emission levels of reciprocating internal combustion (RIC) engines for non-automotive use. Its purpose is to provide an engine's emissions characteristics which, through use of proper weighting factors and test cycles, can be used as an indication of that engine's emission levels under various applications and for different fuels. The emission results are expressed in units of grams per kilowatt-hour and represent the rate of emissions per unit of work accomplished.

Many of the procedures described in this document 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 non-road engines is more complicated than the same task for on-road engines due to the diversity of non-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. Non-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, testing at site or under appropriate conditions can be a viable alternative.

Reciprocating internal combustion engines — Exhaust emission measurement —

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

1 Scope

This document specifies the measurement methods for gaseous and particulate exhaust emissions from reciprocating internal combustion (RIC) engines 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 document is applicable to RIC engines for mobile, transportable and stationary use, excluding engines for motor vehicles primarily designed for road use. This document can be applied to engines used, for example, 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, to test in field conditions. This can only occur with the agreement of the parties involved. It should be recognized that data obtained under these circumstances may not agree completely with previous or future data obtained under the auspices of this document.

For engines used in machinery covered by additional requirements (e.g. occupational health and safety regulations, regulations for power plants), 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.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 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*

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

ISO 9000, *Quality management systems — Fundamentals and vocabulary*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/

- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
accuracy
absolute difference between the reference quantity, y_{ref}, and the arithmetic mean of the ten y_i, y values

Note 1 to entry: See the example of an accuracy calculation in Annex D.

Note 2 to entry: It is recommended that the instrument accuracy be within the specifications in Table 4.

3.2
aqueous condensation
precipitation of water-containing constituents from a gas phase to a liquid phase

Note 1 to entry: Aqueous condensation is a function of humidity, pressure, temperature, and concentrations of other constituents such as sulphuric acid. These parameters vary as a function of engine intake-air humidity, dilution-air humidity, engine air-to-fuel ratio, and fuel composition - including the amount of hydrogen and sulphur in the fuel.

3.3
atmospheric pressure
wet, absolute, atmospheric static pressure

Note 1 to entry: If the atmospheric pressure is measured in a duct, negligible pressure losses shall be ensured between the atmosphere and the measurement location, and changes in the duct's static pressure resulting from the flow shall be accounted for.

3.4
auxiliaries
equipment and devices listed in ISO 8178-4, Annex J.

3.5
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 1 to entry: See ISO 8178-4, 5.2.

3.6
calibration
process of setting a measurement system's response so that its output agrees with a range of reference signals

Note 1 to entry: Contrast with *verification* (3.57)

3.7
calibration gas
purified gas mixture used to calibrate gas analysers

Note 1 to entry: Calibration gases shall meet the specifications of 9.2.1. Note that calibration gases and span gases are qualitatively the same, but differ in terms of their primary function. Various performance verification checks for gas analysers and sample handling components might refer to either calibration gases or span gases.

3.8
certification
relating to the process of obtaining a certificate of conformity

3.9
conversion efficiency of non-methane cutter
(NMC) *E*
efficiency of the conversion of a NMC that is used for the removal of the non-methane hydrocarbons from the sample gas by oxidizing all hydrocarbons except methane

Note 1 to entry: Ideally, the conversion for methane is 0 % (E_{CH4} = 0) and for the other hydrocarbons represented by ethane is 100 % (E_{C2H6} = 100 %). For the accurate measurement of NMHC, the two efficiencies shall be determined and used for the calculation of the NMHC emission mass flow rate for methane and ethane. Contrast with *penetration fraction* (3.31);

3.10
delay time
difference in time between the change of the component to be measured at the reference point and a system response of 10 % of the final reading (t_{10}) with the sampling probe being defined as the reference point

Note 1 to entry: For the gaseous components, this is the transport time of the measured component from the sampling probe to the detector (see Figure 1).

3.11
dew point
measure of humidity stated as the equilibrium temperature at which water condenses under a given pressure from moist air with a given absolute humidity

Note 1 to entry: Dew point is specified as a temperature in °C or K, and is valid only for the pressure at which it is measured.

3.12
discrete-mode
relating to a type of steady-state test, as described in ISO 8178-4, 7.5.1 and Annex A;

3.13
engine type
category of engines which do not differ in essential engine characteristics

3.14
exhaust after-treatment system
catalyst, particulate filter, deNO_x system, combined deNO_x particulate filter or any other emission-reducing device that is installed downstream of the engine

Note 1 to entry: This definition excludes exhaust gas recirculation (EGR) and turbochargers, which are considered an integral part of the engine.

3.15
full flow dilution method
process of mixing the total exhaust flow with dilution air prior to separating a fraction of the diluted exhaust stream for analysis

3.16
good engineering judgement
judgement made consistent with generally accepted scientific and engineering principles and available relevant information

3.17
HEPA filter
high-efficiency particulate air filters that are rated to achieve a minimum initial particle-removal efficiency of 99,97 % using ASTM F 1471–93 or equivalent standard

3.18
hydrocarbon
HC
THC, NMHC as applicable

Note 1 to entry: Hydrocarbon generally means the hydrocarbon group on which the emission standards are based for each type of fuel and engine.

3.19
internationally traceable recognized standard
international standard which includes but is not limited to the list quoted in the following table:

Table 1 — Internationally traceable recognized standard

Internationally recognized standard:	Where copies of the documents may be purchased:
American Society for Testing and Materials (ASTM)	American Society for Testing and Materials, 100 Barr Harbour Dr., P.O. Box C700, West Conshohocken, PA 19428 or *www.astm.com*
International Organization for Standardization (ISO)	International Organization for Standardization, Case Postale 56, CH-1211 Geneva 20, Switzerland or *www.iso.org*
National Institute of Standards and Technology (NIST)	Government Printing Office, Washington, DC 20402 or download them free from the Internet at *www.nist.gov*
Society of Automotive Engineering (SAE)	Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096 or *www.sae.org*
Institute of Petroleum	Energy Institute, 61 New Cavendish Street, London, W1G 7AR, UK, +44 (0)20 7467 7100 or *www.energyinst.org.uk*
The National Metrology Institute of Japan (NMIJ)	AIST Tsukuba Headquarters, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8568, Japan or *www.nmij.jp/english/info/*
Japanese Industrial Standards (JIS)	Japanese Standards Association (JSA), 4-1-12 Akasaka, Minato-ku, 107-8440, Japan or *www.jsa.org.jp/default_english.asp*

3.20
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

3.21
linearity
degree to which measured values agree with respective reference values

Note 1 to entry: Linearity is quantified using a linear regression of pairs of measured values and reference values over a range of values expected or observed during testing.

3.22
multiple-filter method
process of using one filter for each of the individual test cycle modes

Note 1 to entry: The modal weighting factors are accounted for after sampling during the data evaluation phase of the test.

3.23
noise
two times the root-mean-square of the ten standard deviations (that is, noise = 2 $\times rms_{\sigma}$) when the reference signal is a zero-quantity signal

Note 1 to entry: See the example of a root-mean-square calculation in Annex D. It is recommended that the instrument noise be within the specifications in Table 4.

3.24
non-isokinetic sampling
process of controlling the flow of the exhaust sample independently of the exhaust stream velocity

3.25
non-methane hydrocarbons
NMHC
sum of all hydrocarbon species except methane

3.26
operator demand
engine operator's input to control engine output

Note 1 to entry: The "operator" may be a person (i.e., manual), or a governor (i.e., automatic) that mechanically or electronically signals an input that demands engine output. Input may be from an accelerator pedal or signal, a throttle-control lever or signal, a fuel lever or signal, a speed lever or signal, or a governor setpoint or signal. Output means engine power, P, which is the product of engine speed, n, and engine torque, T.

3.27
oxides of nitrogen
compounds containing only nitrogen and oxygen as measured by the procedures specified in this document

Note 1 to entry: Oxides of nitrogen are expressed quantitatively as if the NO is in the form of NO_2, such that an effective molar mass is used for all oxides of nitrogen equivalent to that of NO_2.

3.28
partial pressure
pressure, p, attributable to a single gas in a gas mixture

Note 1 to entry: For an ideal gas, the partial pressure divided by the total pressure is equal to the constituent's molar concentration, x.

3.29
partial flow dilution method
process of separating a part from the total exhaust flow, then mixing it with an appropriate amount of dilution air prior to the particulate sampling filter.

3.30
particulate matter
PM
any material collected on a specified filter medium after diluting exhaust with clean filtered air to a temperature and a point as specified in 8.1.4, primarily carbon, condensed hydrocarbons, and sulphates with associated water

3.31
penetration fraction
PF
deviation from ideal functioning of a non-methane cutter (see *conversion efficiency of non-methane cutter* (NMC) E (3.9)

Note 1 to entry: An ideal non-methane cutter would have a methane penetration factor, PF_{CH4}, of 1,000 (that is, a methane conversion efficiency E_{CH4} of 0), and the penetration fraction for all other hydrocarbons would be 0,000, as represented by PF_{C2H6} (that is, an ethane conversion efficiency E_{C2H6} of 1). The relationship is: $PF_{CH4} = 1 - E_{CH4}$ and $PF_{C2H6} = 1 - E_{C2H6}$.

3.32
probe
first section of the transfer tube which transfers the sample to next component in the sampling system

3.33
procedures
all aspects of engine testing, including the equipment specifications, calibrations, calculations and other protocols and specifications needed to measure emissions, unless otherwise specified

3.34
ramped modal steady state test cycle
test cycle with a sequence of steady state engine test modes with defined speed and torque criteria at each mode and defined speed and torque ramps between these modes

3.35
regeneration
event during which emissions levels change while the aftertreatment performance is being restored by design

Note 1 to entry: Two types of regeneration can occur: continuous regeneration (see ISO 8178-4, 5.5.1.2.1) and infrequent (periodic) regeneration (see ISO 8178-4, 5.5.1.2.2);

3.36
repeatability
two times the standard deviation of the ten errors, i.e. repeatability = $2\zeta\varepsilon$

Note 1 to entry: See the example of a standard-deviation calculation in Annex D. It is recommended that the instrument repeatability be within the specifications shown in Table 4.

3.37
response time

difference in time between the change of the component to be measured at the reference point and a system response of 90 % of the final reading (t_{90}) with the sampling probe being defined as the reference point, whereby the change of the measured component is at least 60 % full scale (FS) and the devices for gas switching shall be specified to perform the gas switching in less than 0,1 second

Note 1 to entry: The system response time consists of the delay time to the system and of the rise time of the system.

3.38
rise time
difference in time of the 10 % and 90 % response of the final reading ($t_{90} - t_{10}$)

3.39
shared humidity measurement
humidity measurement that is used as the humidity for an entire test facility that has more than one dynamometer test cell

3.40
single-filter method
process of using one filter for all test cycle modes

Note 1 to entry: Modal weighting factors shall 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.

3.41
span (verb)
adjust an instrument so that it gives a proper response to a calibration standard that represents between 75 % and 100 % of the maximum value in the instrument range or expected range of use

3.42
span gas
purified gas mixture used to span gas analysers

Note 1 to entry: Span gases shall meet the specifications of 9.2.1. Note that calibration gases and span gases are qualitatively the same, but differ in terms of their primary function. Various performance verification checks for gas analysers and sample handling components might refer to either calibration gases or span gases.

3.43
span response
mean response, including noise, to a span gas during a 30 s time interval

3.44
specific emissions
mass emissions expressed in g/kWh

3.45
stand-alone
something that has no dependencies that can "stand alone"

3.46
steady-state
relating to emission tests in which engine speed and load are held at a finite set of nominally constant values

Note 1 to entry: Steady-state tests are either discrete-mode tests or ramped-modal tests.

3.47
stoichiometric
relating to the particular ratio of air and fuel such that if the fuel were fully oxidized, there would be no remaining fuel or oxygen

3.48
storage medium
particulate filter, sample bag, or any other storage device used for batch sampling

3.49
test (or duty) cycle
sequence of test points each with a defined speed and torque to be followed by the engine under steady state or transient operating conditions

Note 1 to entry: Duty cycles are specified in ISO 8178-4, Annexes A to C. A single duty cycle may consist of one or more test intervals.

3.50
test interval
duration of time over which brake-specific emissions are determined

Note 1 to entry: In cases where multiple test intervals occur over a duty cycle, the regulation may specify additional calculations that weigh and combine results to arrive at composite values for comparison against the applicable emission limits.

3.51
tolerance
interval in which 95 % of a set of recorded values of a certain quantity shall lie, with the remaining 5 % of the recorded values deviating from the tolerance interval, using the specified recording frequencies and time intervals to determine if a quantity is within the applicable tolerance