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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

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.

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

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

This fourth edition cancels and replaces the third edition (ISO 8178-1:2017), which has been technically revised.

The main changes compared to the previous edition are as follows:

— addition of provision to use alternative systems for ammonia analysis;

— improvement of weighing chamber and analytical balance specifications;

— insertion of general section on measurement instruments;

— revision of particle number measurement system requirements;

— addition concentration and expiration date for analytical gases;

— revision of the annex on carbon flow check;

— addition of the 1980 international gravity formula.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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.

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.

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.

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 8178-4:2020, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 4: Test cycles for different engine applications*

ASTM F1471–93, *Standard Test Method for Air Cleaning Performance of a High-Efficiency Particulate Air-Filter System*

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:

— ISO Online browsing platform: available at https://www.iso.org/obp

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

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 5.

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
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* (3.51).

3.5
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* (3.37) are qualitatively the same, but differ in terms of their primary function. Various performance *verification* (3.51) checks for gas analysers and sample handling components might refer to either calibration gases or span gases.

3.6
certification
process of obtaining a certificate of conformity

3.7
conversion efficiency of non-methane cutter
conversion efficiency of NMC
E
efficiency of the conversion of an NMC that is used for the removal of the *non-methane hydrocarbons* (3.21) 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* (3.21), 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* (3.27).

3.8
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* (3.28) 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).

3.9
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.

3.10
drift
difference between a zero or *calibration* (3.4) signal and the respective value reported by a measurement instrument immediately after it was used in an emission test

3.11
exhaust aftertreatment 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.

3.12
full flow dilution
method of mixing the exhaust gas flow with dilution air prior to separating a fraction of the diluted exhaust gas flow for analysis

3.13
good engineering judgement
judgement made consistent with generally accepted scientific and engineering principles and available relevant information

3.14
HEPA filter
high-efficiency particulate air filter that is rated to achieve a minimum initial particle-removal efficiency of 99,97 % using ASTM F1471–93 or an equivalent standard

3.15
hydrocarbon
HC
hydrocarbon group on which the emission standards are based for each type of fuel and engine

EXAMPLE *THC* (3.47), *NMHC* (3.21) as applicable.

3.16
internationally recognized-traceable standard
international standard which includes but is not limited to the list quoted in Table 1

Table 1 — Internationally recognized-traceable 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

Table 1 *(continued)*

Internationally recognized standard	Where copies of the documents may be purchased
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

3.17
isokinetic sampling
process of controlling the flow of the exhaust sample by maintaining the mean sample velocity at the *probe* (3.28) equal to the exhaust stream mean velocity

3.18
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.

3.19
multiple-filter method
process of using one filter for each of the individual *test cycle* (3.44) modes

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

3.20
noise
two times the root-mean-square of the ten standard deviations (that is, $N = 2 \times y_{RMS(\sigma)}$) 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 5.

3.21
non-methane hydrocarbons
NMHC
sum of all *hydrocarbon* (3.15) species except methane

3.22
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*.

3.23
oxides of nitrogen
NO_x
compounds containing only nitrogen and oxygen as measured by the *procedures* (3.29) 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.

3.24
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*.

3.25
partial flow dilution
method of analysing the exhaust gas whereby a part of the total exhaust gas flow is separated and then mixed with an appropriate amount of dilution air prior to reaching the particulate sampling filter

3.26
particulate matter
PM
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* (3.15), and sulphates with associated water

3.27
penetration fraction
PF
deviation from ideal functioning of a non-methane cutter

Note 1 to entry: See *conversion efficiency of non-methane cutter* (NMC), *E* (3.7).

Note 2 to entry: An ideal non-methane cutter would have a methane penetration factor, $f_{PF\ CH4}$, of 1,000 (that is, a methane conversion efficiency E_{CH4} of 0), and the penetration fraction for all other *hydrocarbons* (3.15) would be 0,000, as represented by $f_{PF\ C2H6}$ (that is, an ethane conversion efficiency E_{C2H6} of 1). The relationship is: $f_{PF\ CH4} = 1 - E_{CH4}$ and $f_{PF\ C2H6} = 1 - E_{C2H6}$.

3.28
probe
first section of the transfer tube which transfers the sample to next component in the sampling system

3.29
procedures
all aspects of engine testing, including the equipment specifications, *calibrations* (3.4), calculations and other protocols and specifications needed to measure emissions, unless otherwise specified

3.30
ramped-modal test
test cycle (3.44) 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

3.31
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 8178-4:2020, 5.5.1.2.1) and infrequent (periodic) regeneration (see ISO 8178-4:2020, 5.5.1.2.2);

3.32
repeatability
two times the standard deviation of the ten errors, i.e. $r = 2\sigma_{\varepsilon}$

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 5.

3.33
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* (3.28) 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 s

Note 1 to entry: The system response time consists of the *delay time* (3.8) to the system and of the *rise time* (3.34) of the system.

3.34
rise time
difference in time of the 10 % and 90 % response of the final reading ($t_{90} - t_{10}$)

3.35
single-filter method
process of using one filter for all *test cycle* (3.44) 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.

3.36
span, verb
adjust an instrument so that it gives a proper response to a *calibration* (3.4) standard that represents between 75 % and 100 % of the maximum value in the instrument range or expected range of use

3.37
span gas
purified gas mixture used to *span* (3.36) gas analysers

Note 1 to entry: Span gases shall meet the specifications of 9.2.1. Note that *calibration gases* (3.5) and span gases are qualitatively the same, but differ in terms of their primary function. Various performance *verification* (3.51) checks for gas analysers and sample handling components might refer to either calibration gases or span gases.

3.38
span response
mean response, including *noise* (3.20), to a *span gas* (3.37) during a 30 s time interval

3.39
specific emissions
mass emissions expressed in g/kWh

3.40
stand-alone
having no dependencies

3.41
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 (3.30).

3.42
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

3.43
storage medium
particulate filter, sample bag, or any other storage device used for batch sampling