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Reciprocating internal combustion engines — Exhaust emission measurement —

Part 4:
Steady-state and transient test cycles for different engine applications

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

Partie 4: Cycles d'essai à l'état stable et transitoires pour différentes applications des moteurs

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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).

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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, *Reciprocating internal combustion engines*, Subcommittee SC 8, *Exhaust gas emission measurement*.

This fourth edition cancels and replaces the third edition (ISO 8178-4:2017), which has been technically revised.

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

— amendment of the information regarding the determination of the background concentration;

— revision of particle number emission evaluation;

— addition of electrical equipment in the auxiliary table;

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

In comparison with engines for on-road applications, engines for non-road use are made in a much wider range of power output and configuration and are used in a great number of different applications.

The objective of this document is to rationalize the test procedures for non-road engines in order to simplify and make more cost effective the drafting of legislation, the development of engine specifications and the certification of engines to control gaseous and particulate emissions.

This document embraces three concepts in order to achieve the objectives.

The first principle is to group applications with similar engine operating characteristics in order to reduce the number of test cycles to a minimum, but ensure that the test cycles are representative of actual engine operation.

The second principle is to express the emissions results on the basis of brake power as defined in ISO 8178-1. This ensures that alternative engine applications do not result in a multiplicity of tests.

The third principle is the incorporation of an engine family concept in which engines with similar emission characteristics and of similar design may be represented by the highest emitting engine within the group.

Reciprocating internal combustion engines — Exhaust emission measurement —

Part 4:
Steady-state and transient test cycles for different engine applications

1 Scope

This document specifies the test cycles, the test procedures and the evaluation of gaseous and particulate exhaust emissions from reciprocating internal combustion (RIC) engines coupled to a dynamometer. With certain restrictions, this document can also be used for measurements at site. The tests are carried out under steady-state and transient operation using test cycles which are representative of given applications.

This document is applicable to RIC engines for mobile, transportable and stationary use, excluding engines for on-road transport of passengers and goods. It can be applied to engines for non-road use, e.g. for earth-moving machines, generating sets and for other applications. 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 can apply.

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 8178-1:2020, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 1: Test-bed measurement of gaseous and particulate exhaust emissions*

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

ASTM E29–06b, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

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
adjustment factors
additive (upward adjustment factor and downward adjustment factor) or multiplicative factors to be used for engines equipped with emission controls, that are regenerated on an infrequent (periodic) basis

3.2
applicable emission limit
emission limit to which an engine is subject

3.3
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.

3.4
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.

3.5
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* (3.78).

3.6
calibration gas
purified gas mixture used to calibrate gas analysers meeting the specifications of ISO 8178-1:2020, 9.2

Note 1 to entry: Calibration gases and *span gases* (3.65) are qualitatively the same, but differ in terms of their primary function. Various performance *verification* (3.78) checks for gas analysers and sample handling components might refer to either calibration gases or span gases.

3.7
certification
process of obtaining a certificate of conformity

3.8
compression ignition engine
CI engine
engine that works on the compression-ignition principle

3.9
constant-speed engine
engine whose *type approval* (3.76) or *certification* (3.7) is limited to *constant-speed operation* (3.10)

Note 1 to entry: Engines whose constant-speed *governor* (3.29) function is removed or disabled are no longer constant-speed engines.

3.10
constant-speed operation
engine operation with a *governor* (3.29) that automatically controls the *operator demand* (3.47) to maintain engine speed, even under changing load

Note 1 to entry: Governors do not always maintain speed exactly constant. Typically, speed can decrease 0,1 % to 10 % below the speed at zero load, such that the minimum speed occurs near the engine's point of *maximum power* (3.39).

3.11
continuous regeneration
regeneration (3.59) process of an *exhaust after-treatment system* (3.22) that occurs either in a sustained manner or at least once over the applicable *transient test cycle* (3.75) or ramped-modal cycle; in contrast to *infrequent (periodic) regeneration* (3.33)

3.12
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* (3.44) from the sample gas by oxidizing all *hydrocarbons* (3.30) except methane

Note 1 to entry: Ideally, the conversion for methane is 0 % (E_{CH4} = 0) and for the other hydrocarbons represented by ethane 100 % (E_{C2H6} = 100 %). For the accurate measurement of *NMHC* (3.44), 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* (3.52).

3.13
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* (3.54) 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).

3.14
deNO$_x$ system
exhaust after-treatment system (3.22) designed to reduce emissions of *oxides of nitrogen (NOx)* (3.48)

EXAMPLE Passive and active lean NO$_x$ catalysts, NO$_x$ adsorbers and selective catalytic reduction (SCR) systems.

3.15
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.

3.16
drift
difference between a zero or *calibration* (3.5) signal and the respective value reported by a measurement instrument immediately after it was used in an emission test, as long as the instrument was *zeroed* (3.79) and *spanned* (3.64) just before the test

3.17
dual-fuel engine
engine system that is designed to simultaneously operate with *liquid fuel* (3.36) and a *gaseous fuel* (3.26), both fuels being metered separately, where the consumed amount of one of the fuels relative to the other one may vary depending on the operation

3.18
emission-control system
device, system, or element of design that controls or reduces the emissions of regulated pollutants from an engine

3.19
engine family
manufacturers grouping of engines which, through their design as defined in ISO 8178-7, have similar exhaust emission characteristics

Note 1 to entry: All members of the family shall comply with the *applicable emission limit* (3.2) values.

3.20
engine governed speed
engine operating speed when it is controlled by the installed *governor* (3.29)

3.21
engine type
category of engines which do not differ in essential engine characteristics

3.22
exhaust after-treatment system
catalyst, particulate filter, *deNOx system* (3.14), 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)* (3.23) and turbochargers, which are considered an integral part of the engine.

3.23
exhaust-gas recirculation
EGR
technology that reduces emissions by routing exhaust gases that had been exhausted from the combustion chamber(s) back into the engine to be mixed with incoming air before or during combustion

Note 1 to entry: The use of valve timing to increase the amount of residual exhaust gas in the combustion chamber(s) that is mixed with incoming air before or during combustion is not considered exhaust-gas recirculation for the purposes of this document.

3.24
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

3.25
gas energy ratio
GER
value of the energy content (for a *dual-fuel engine* (3.17)) of the *gaseous fuel* (3.26) divided by the energy content of both fuels (liquid and gaseous), the energy content of the fuels being defined as the lower heating value

3.26
gaseous fuel
fuel which is wholly gaseous at standard ambient conditions

Note 1 to entry: Ambient temperature 298 K (25 °C), absolute ambient pressure 101,3 kPa.

3.27
gaseous pollutants
exhaust gas emissions of carbon monoxide, *NOx* (3.48), expressed in NO_2 equivalent, *hydrocarbons* (3.30)

Note 1 to entry: They are total hydrocarbons, *non-methane hydrocarbons* (3.44) and methane.

3.28
good engineering judgement
judgement made consistent with generally accepted scientific and engineering principles and available relevant information

3.29
governor
device or control strategy that automatically controls engine speed or load that is not an over-speed limiter

3.30
hydrocarbon
HC
hydrocarbon group on which the emission standards are based for each type of fuel and engine

EXAMPLE *THC* (3.73), *NMHC* (3.44) as applicable

3.31
high speed
n_{hi}
highest engine speed where 70 % of the *maximum power* (3.39) occurs

3.32
idle speed
engine speed declared by the manufacturer that conforms to the requirements of 7.2.4

3.33
infrequent regeneration
periodic regeneration
regeneration (3.59) process of an *exhaust after-treatment system* (3.22) that occurs periodically in typically less than 100 hours of normal engine operation

Note 1 to entry: During cycles where regeneration occurs, emission standards may be exceeded.

3.34
intermediate speed
engine speed declared by the manufacturer that conforms to the requirements of 7.2.3

3.35
linearity
degree to which measured values agree with respective reference values quantified using a linear regression of pairs of measured values and reference values over a range of values expected or observed during testing

3.36
liquid fuel
fuel which exists in the liquid state under standard ambient conditions (298 K, absolute ambient pressure 101,3 kPa)

3.37
low speed
n_{lo}
lowest engine speed where 50 % of the *maximum power* (3.39) occurs

3.38
maximum no load speed
engine speed at which an engine *governor* (3.29) function controls engine speed with *operator demand* (3.47) at maximum and with zero load applied

3.39
maximum power
maximum power as designed by the manufacturer

Note 1 to entry: It is expressed in kW.

3.40
maximum test speed
engine speed determined from the curve of engine speed versus power according to 7.2.1

3.41
maximum torque speed
engine speed at which the maximum torque is obtained from the engine, as designed by the manufacturer

3.42
mode
engine operating point characterized by a speed and a torque (or a power output)

3.43
mode length
time between leaving the speed and/or torque of the previous *mode* (3.42) or the preconditioning phase and the beginning of the following mode

Note 1 to entry: It includes the time during which speed and/or torque is being changed and the stabilization at the beginning of each mode.

3.44
non-methane hydrocarbons
NMHC
sum of all *hydrocarbon* (3.30) species except methane

3.45
normalized speed and torque
speed and torque values expressed as a percentage of a maximum value

3.46
open crankcase emissions
flow from an engine's crankcase that is emitted directly into the environment

Note 1 to entry: Crankcase emissions are not "open crankcase emissions" if the engine is designed to always route all crankcase emissions back into the engine (for example, through the intake system or an aftertreatment system) such that all the crankcase emissions, or their products, are emitted into the environment only through the engine exhaust system.

3.47
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* (3.29) (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.

3.48
oxides of nitrogen
NO_x
compounds containing only nitrogen and oxygen as measured by the *procedures* (3.55) 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.

3.49
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*.

3.50
partial flow dilution
method of analysing the exhaust gas whereby a part of the total exhaust gas flow is separated, then mixed with an appropriate amount of dilution air prior to reaching the particulate sampling filter

3.51
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 ISO 8178-1:2020, 8.1.4, primarily carbon, condensed *hydrocarbons* (3.30), and sulphates with associated water

3.52
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*, (3.12).

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* (3.30) 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 $f_{PF\ C2H6} = 1 - E_{C2H6}$.

3.53
per cent load
fraction of the maximum available torque at an engine speed

3.54
probe
first section of the transfer line which transfers the sample to the next component in the sampling system

3.55
procedures
all aspects of engine testing, including the equipment specifications, *calibrations* (3.5), calculations and other protocols and specifications needed to measure emissions, unless otherwise specified

3.56
ramped-modal steady-state test cycle
test cycle (3.70) with a sequence of steady-state engine test *modes* (3.42) with defined speed and torque criteria at each mode and defined speed and torque ramps between these modes

3.57
rated power
value of the power, declared by the manufacturer, which an engine will deliver under the specified test conditions

Note 1 to entry: For details see ISO 14396.

3.58
rated speed
engine speed at which, according to the statement of the engine manufacturer, and conforming to the requirements of 7.2.2, the *rated power* (3.57) is delivered

Note 1 to entry: For details see ISO 14396.