BS ISO 8178-4:2020

BSI Standards Publication

Reciprocating internal combustion engines — Exhaust emission measurement

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

Documents
Document Sharing Hub

Full document details: BS ISO 8178-4:2020

National foreword

This British Standard is the UK implementation of ISO 8178-4:2020. It supersedes BS ISO 8178-4:2017, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MCE/14/-/3, RIC Engines - Performance and emissions.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2020
Published by BSI Standards Limited 2020

ISBN 978 0 539 06172 7

ICS 13.040.50; 27.020

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 June 2020.

Amendments/corrigenda issued since publication

Date	Text affected

Documents
Document Sharing Hub

Full document details: BS ISO 8178-4:2020

INTERNATIONAL STANDARD

ISO 8178-4

Fourth edition
2020-06

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

Reference number
ISO 8178-4:2020(E)

Documents
Document Sharing Hub

© ISO 2020

Full document details: BS ISO 8178-4:2020

COPYRIGHT PROTECTED DOCUMENT

© ISO 2020

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub

Full document details: BS ISO 8178-4:2020

Contents

Page

Foreword ... **vi**

Introduction ... **vii**

1 Scope ... **1**

2 Normative references ... **1**

3 Terms and definitions ... **1**

4 Symbols and abbreviated terms ... **11**
4.1 General symbols ... 11
4.2 Symbols and abbreviated terms for fuel composition ... 13
4.3 Symbols and abbreviated terms for chemical components ... 14
4.4 Abbreviated terms ... 14

5 Test conditions ... **15**
5.1 Engine test conditions ... 15
5.1.1 Laboratory test conditions ... 15
5.1.2 Test validity ... 16
5.2 Engine power ... 16
5.2.1 Auxiliaries to be fitted ... 16
5.2.2 Auxiliaries to be removed ... 16
5.2.3 Determination of auxiliary power ... 17
5.2.4 Engine cycle work ... 17
5.3 Engine intake air ... 17
5.3.1 General ... 17
5.3.2 Intake air restriction ... 17
5.3.3 Engines with charge air cooling ... 18
5.4 Engine exhaust system ... 18
5.4.1 General ... 18
5.4.2 Exhaust restriction ... 18
5.4.3 Engine with exhaust after-treatment system ... 18
5.5 Specific test conditions ... 19
5.5.1 Engine with exhaust after-treatment system ... 19
5.5.2 Crankcase emissions ... 22
5.6 Cooling system ... 23
5.7 Lubricating oil ... 23

6 Test fuels ... **23**

7 Test cycles ... **24**
7.1 General ... 24
7.2 Test speeds ... 24
7.2.1 Maximum test speed (MTS) ... 24
7.2.2 Rated speed ... 25
7.2.3 Intermediate speed ... 25
7.2.4 Idle speed ... 26
7.2.5 Test speed for constant-speed engines ... 26
7.3 Torque and power ... 27
7.3.1 Torque ... 27
7.3.2 Power ... 28
7.4 Engine mapping ... 28
7.4.1 Engine mapping for transient cycles ... 29
7.4.2 Engine mapping for variable-speed steady-state cycles ... 30
7.4.3 Engine mapping for constant-speed engines ... 30
7.5 Steady-state test cycles ... 31
7.5.1 Discrete mode test cycles ... 31
7.5.2 Ramped-modal test cycles ... 33
7.5.3 Cycle types and applicability ... 33

AVA Documents
Document Sharing Hub

© ISO 2020 – All rights reserved

Full document details: BS ISO 8178-4:2020

7.6 Transient cycles ... 37
7.6.1 General ... 37
7.6.2 Non-road transient cycle (NRTC) ... 37
7.6.3 Large spark-ignition non-road transient cycle ... 38
7.7 Test cycle generation ... 38
7.7.1 Generation of steady-state discrete-mode or RMC test cycles ... 38
7.7.2 Generation of NRTC and LSI-NRTC ... 39

8 Test run ... 41
8.1 General test sequence ... 41
8.2 Instrument validation for test ... 44
8.2.1 Validation of proportional flow control for batch sampling and minimum dilution ratio for PM batch sampling ... 44
8.2.2 Gas analyser range validation, drift validation and drift correction ... 45
8.2.3 PM sampling media (e.g. filters) preconditioning and tare weighing ... 45
8.3 Sample system decontamination and preconditioning ... 47
8.3.1 Verification of HC contamination ... 48
8.4 Pre-test procedures ... 49
8.4.1 Preparation of the sampling filters ... 49
8.4.2 General requirements for preconditioning the sampling system and the engine 49
8.4.3 Engine cool down (NRTC) ... 50
8.4.4 Preparation of measurement equipment for sampling ... 50
8.4.5 Calibration of gas analysers ... 51
8.4.6 Adjustment of the dilution system ... 51
8.5 Engine starting and restarting ... 51
8.5.1 Engine start ... 51
8.5.2 Engine stalling ... 51
8.6 Test cycle running procedure ... 52
8.6.1 Test sequence for discrete steady-state test cycles ... 52
8.6.2 Ramped-modal test cycles ... 53
8.6.3 Transient test cycle (NRTC and LSI-NRTC) ... 54
8.7 Post-test procedures ... 57
8.7.1 Verification of proportional sampling ... 57
8.7.2 Post-test PM conditioning and weighing ... 57
8.7.3 Analysis of gaseous batch sampling ... 58
8.7.4 Drift verification ... 59

9 Data evaluation and calculation ... 59
9.1 Gaseous emissions ... 59
9.1.1 General ... 59
9.1.2 Sampling for gaseous emissions ... 59
9.1.3 Data evaluation ... 61
9.1.4 Calculation of mass emission ... 61
9.1.5 Dry/wet correction ... 67
9.1.6 NO_x correction for humidity and temperature ... 71
9.1.7 Cycle work and specific emissions ... 71
9.1.8 NH_3 data evaluation ... 73
9.2 Particulate mass emission ... 74
9.2.1 General ... 74
9.2.2 Particulate sampling ... 74
9.2.3 Data evaluation ... 74
9.2.4 Calculation of mass emission ... 75
9.2.5 Effective weighting factor (steady-state discrete cycles only) ... 80
9.3 Adjustment for emission controls that are regenerated on an infrequent (periodic) basis ... 80
9.4 Particle number emission ... 81
9.4.1 Time alignment ... 81
9.4.2 Determination of particle numbers for transient and ramped-modal cycles (RMC) with a partial flow dilution or raw gas sampling system ... 81

© ISO 2020 – All rights reserved
AVA Documents Document Sharing Hub
Full document details: BS ISO 8178-4:2020

9.4.3 Determination of particle numbers for transient and ramped-modal cycles (RMC) with a full flow dilution system ... 82
9.4.4 Determination of particle numbers for discrete-mode cycles with partial flow dilution or raw gas sampling system ... 83
9.4.5 Determination of particle numbers for discrete-mode cycles with a full flow dilution system ... 85
9.4.6 Test result ... 85
9.4.7 Determination of particle number background ... 87
9.5 Specific requirements for dual-fuel engines ... 87
9.5.1 Emission test procedure requirements for dual-fuel engines ... 87
9.5.2 Determination of molar component ratios and u_{gas} values for dual-fuel engines 91

10 Engine control area ... 93
10.1 General remarks ... 93
10.2 Control area for engines tested to cycles C1, C2, E1 and H ... 93
10.3 Control area for engines tested to cycles D1, D2, E2, G1, G2 and G3 ... 95
10.4 Control area for engines tested to test cycle I ... 95
10.5 Control area for engines tested to E3 and E5 test cycle ... 96
10.5.1 Control area for CI marine engines ... 96
10.5.2 Control area for engines tested to the E4 test cycle ... 99
10.5.3 Control area for engines tested to the F cycle ... 100

Annex A (normative) **Steady-state discrete-mode test-cycles ... 102**

Annex B (normative) **Steady-state ramped-modal test cycles (RMCs) ... 107**

Annex C (normative) **Transient test cycles ... 113**

Annex D (informative) **Calculation of the exhaust gas mass flow and/or of the combustion air mass flow ... 171**

Annex E (informative) **Example programme for calculation of exhaust mass flows ... 192**

Annex F (informative) **Example of calculation procedure (raw/partial flow) ... 194**

Annex G (normative) **Installation requirements for equipment and auxiliaries ... 197**

Annex H (normative) **Molar based emission calculations ... 199**

Bibliography ... 239

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

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, *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.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

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.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

Documents
Document Sharing Hub

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

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

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).

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

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

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

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

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

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.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

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.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

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, $f_{\mathrm{PF\ CH4}}$, 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 $f_{\mathrm{PF\ C2H6}}$ (that is, an ethane conversion efficiency E_{C2H6} of 1). The relationship is: $f_{\mathrm{PF\ CH4}} = 1 - E_{\mathrm{CH4}}$ and $f_{\mathrm{PF\ C2H6}} = 1 - E_{\mathrm{C2H6}}$.

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.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

3.59
regeneration
event during which emissions levels change while the after treatment performance is being restored by design

Note 1 to entry: Two types of regeneration can occur: *continuous regeneration* (3.11) (see 5.5.1.2.1) and *infrequent (periodic) regeneration* (3.33) (see 5.5.1.2.2).

3.60
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* (3.54) 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* (3.13) to the system and of the *rise time* (3.61) of the system.

3.61
rise time
difference in time of the 10 % and 90 % response of the final reading ($t_{90} - t_{10}$)

3.62
shared atmospheric pressure meter
atmospheric pressure (3.4) meter whose output is used as the atmospheric pressure for an entire test facility that has more than one dynamometer test cell

3.63
shared humidity measurement
humidity measurement that is used as the humidity for an entire test facility that has more than one dynamometer test cell

3.64
span, verb
adjust an instrument so that it gives a proper response to a *calibration* (3.5) standard that represents between 75 % and 100 % of the maximum value in the instrument range or expected range of use

3.65
span gas
purified gas mixture used to *span* (3.64) gas analysers meeting the specifications of ISO 8178-1:2020, 9.2

Note 1 to entry: *Calibration gases* (3.6) and span gases 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.

3.66
spark-ignition engine
SI engine
engine that works on the spark-ignition principle

3.67
specific emissions
mass emissions expressed in g/kWh; particulate Number (PN) emissions expressed in #/kWh

3.68
steady-state test
emission test 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.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

3.69
stoichiometric
particular ratio of air and fuel such that if the fuel were fully oxidized, there would be no remaining fuel or oxygen

3.70
test cycle
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 Annexes A, B and C. A single duty cycle may consist of one or more test intervals (3.71).

3.71
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* (3.70), the standard may specify additional calculations that weigh and combine results to arrive at composite values for comparison against the *applicable emission limits* (3.2).

3.72
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 only due to measurement variability

Note 1 to entry: The specified recording frequencies and time intervals shall be used to determine if a quantity is within the applicable tolerance. For parameters not subject to measurement variability, tolerance means an absolute allowable range.

3.73
total hydrocarbon
THC
combined mass of organic compounds measured by the specified procedure for measuring total hydrocarbon

Note 1 to entry: Total hydrocarbon is expressed as a *hydrocarbon* (3.30) with a hydrogen-to-carbon mass ratio of 1,85:1 (Diesel), 1,93 (petrol (E10)), 2,525 (LPG), 4,0 (NG/biomethane) or 2,74 (ethanol (E85)).

3.74
transformation time
difference in time between the change of the component to be measured at the reference point and a system response of 50 % of the final reading (t_{50}) with the sampling *probe* (3.54) being defined as the reference point

Note 1 to entry: The transformation time is used for the signal alignment of different measurement instruments (see Figure 1).

3.75
transient test cycle
test cycle (3.70) with a sequence of *normalized speed and torque* (3.45) values that vary relatively quickly with time (NRTC)

3.76
type approval
approval of an *engine type* (3.21) with regard to its emissions measured in accordance with the *procedures* (3.55) specified in this document

3.77
variable-speed engine
engine that is not a *constant-speed engine* (3.9)

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

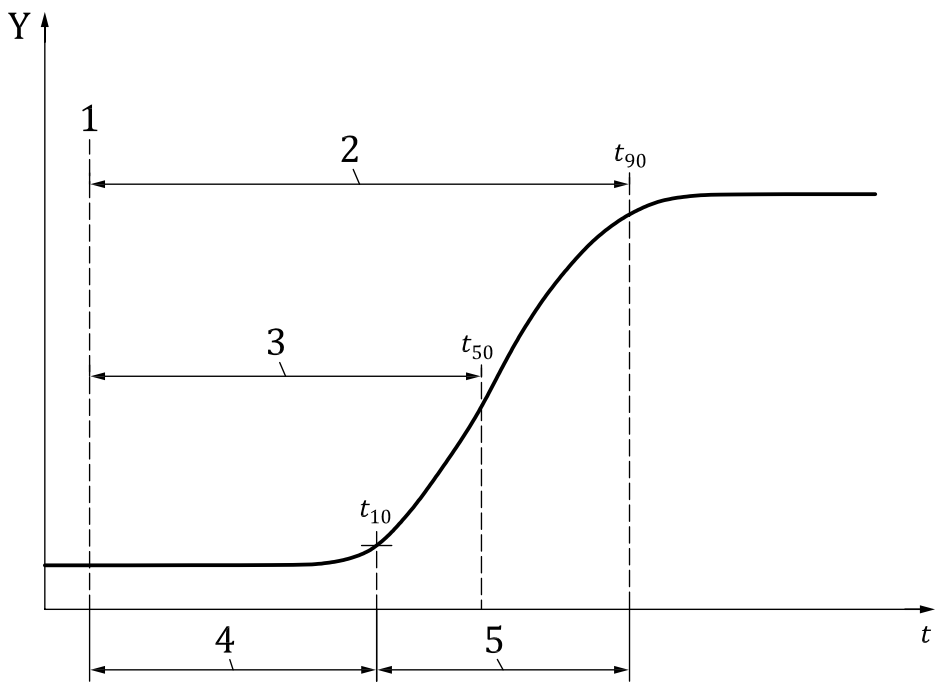
3.78
verification
evaluation of whether or not a measurement system's outputs agree with a range of applied reference signals to within one or more predetermined thresholds for acceptance

Note 1 to entry: Contrast with *calibration* (3.5).

3.79
zero, verb
adjust an instrument so it gives a zero response to a zero *calibration* (3.5) standard, such as purified nitrogen or purified air for measuring concentrations of emission constituents

3.80
zero gas
gas that yields a zero response in an analyser

Note 1 to entry: This may either be purified nitrogen, purified air, a combination of purified air and purified nitrogen.



Key

1 step input time
2 *response time* (3.60)
3 *transformation time* (3.74)
4 *delay time* (3.13)
5 *rise time* (3.61)
t time
Y response

Figure 1 — Definitions of system response: delay time, response time, rise time and transformation time

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

4 Symbols and abbreviated terms

4.1 General symbols

For the purposes of this document, the general symbols given in Table 1 apply.

Table 1 — General symbols

Symbol	Term	Unit
A	Relative atomic mass	g/mol
A/F_{st}	Stoichiometric air to fuel ratio	—
a_0	y intercept of the regression line	—
a_1	Slope of the regression line	—
C_d	CFV discharge coefficient [–]	—
c_d	Concentration in the dilution air	% (V/V)
D	Dilution factor	—
d	Diameter	m
E	Conversion efficiency	%
e_{gas}	Specific emission of gaseous components	g/kWh
e_{PM}	Specific emission of particulates	g/kWh
e_{PN}	Number of particles emitted	#/kWh
e_w	Weighted specific emission	g/kWh
F_S	stoichiometric factor	—
f	Data sampling rate	Hz
f_a	Laboratory atmospheric factor	—
f_c	Carbon factor	—
f_{fd}	Fuel specific factor for exhaust flow calculation on dry basis	—
f_{fh}	Fuel specific factor used for the calculations of wet concentrations from dry concentrations	—
f_{fw}	Fuel specific factor for exhaust flow calculation on wet basis	—
f_{PF}	Penetration fraction	%
f_{RF}	Response factor	—
f_{WF}	Weighting factor	—
H_a	Absolute humidity of the intake air (g water/kg dry air)	g/kg
H_d	Absolute humidity of the dilution air (g water/kg dry air)	g/kg
i	Subscript denoting an individual mode	—
i	Subscript denoting an instantaneous measurement (e.g. - Hz)	—
k_{Dr}	Additive downward adjustment factor	—
k_f	Fuel specific factor	—
$k_{h,D}$	Humidity correction factor for NO_x for CI engines	—
$k_{h,G}$	Humidity correction factor for NO_x for SI engines	
k_{MDr}	Multiplicative downward adjustment factor	—
k_{MUr}	Multiplicative upward adjustment factor	—
k_r	Multiplicative regeneration factor	—
k_{Ur}	Additive upward adjustment factor	—
k_w	Dry to wet correction factor for the raw exhaust gas	—
$k_{w,d}$	Dry to wet correction factor for the dilution air	—
$k_{w,e}$	Dry to wet correction factor for the diluted exhaust gas	—

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

Table 1 *(continued)*

Symbol	Term	Unit
$k_{w,r}$	Dry to wet correction factor for the raw exhaust gas	—
L	%torque	—
λ	Excess air ratio	—
M	Molar mass	g/mol
M_{gas}	Molar mass of gaseous components	g/mol
m	Mass	kg
m_d	Mass of the dilution air sample passed through the particulate sampling filters	kg
m_{edf}	Mass of equivalent diluted exhaust gas over the cycle	kg
m_f	Particulate sample mass collected	mg
m_{ed}	mass of diluted exhaust gas over the cycle	kg
$m_{f,d}$	Particulate sample mass of the dilution air collected	mg
m_{gas}	Mass of gaseous emissions over the test cycle	g
m_{PM}	Mass of particulate emissions over the test cycle	g
m_{se}	Exhaust sample mass over the cycle	kg
m_{sed}	Mass of diluted exhaust gas passing the dilution tunnel	kg
m_{sep}	Mass of the diluted exhaust sample passed through the particulate sampling filters	kg
μ	Dynamic viscosity of exhaust gas	Pa*s
n	Engine speed	min^{-1}
n_{hi}	High engine speed	min^{-1}
n_{lo}	Low engine speed	min^{-1}
P	Power	kW
P_{AUX}	Declared total power absorbed by auxiliaries fitted for the test and not required by ISO –4396	kW
P_{max}	Maximum observed or declared power at the test speed under the test conditions (specified by the manufacturer)	kW
p	Pressure	kPa
p_a	Saturation vapour pressure of the intake air	kPa
p_b	Total atmospheric pressure	kPa
p_d	Saturation vapour pressure of the dilution air	kPa
p_r	Water vapor pressure after cooling bath	kPa
p_s	Dry atmospheric pressure	kPa
q_{mad}	Dry intake air flow rate	kg/s
q_{maw}	Intake air mass flow rate on wet basis	kg/s
q_{mdew}	Diluted exhaust gas mass flow rate on wet basis	kg/s
q_{mdw}	Dilution air mass flow rate on wet basis	kg/s
q_{medf}	Equivalent diluted exhaust gas mass flow rate on wet basis	kg/s
q_{mew}	Exhaust gas mass flow rate on wet basis	kg/s
q_{mf}	Fuel mass flow rate	kg/s
q_{mgas}	Emission mass flow rate of individual gas	g/h
q_{mp}	Sample flow of exhaust gas into partial flow dilution system	kg/s
q_{sw}	mass flow rate fed back into dilution tunnel to compensate for particle number sample extraction	kg/s
q_V	Volume flow rate	m^3/s
q_{Vt}	Tracer gas flow rate	cm^3/min

© ISO 2020 – All rights reserved
AVA Documents Document Sharing Hub
Full document details: BS ISO 8178-4:2020

Table 1 *(continued)*

Symbol	Term	Unit
R	molar gas constant	J/(mol K)
r^2	Coefficient of determination	—
r_d	Dilution ratio	—
r_s	Average sample ratio	—
ρ	Density	kg/m3
S	Dynamometer setting	kW
S_{EE}	Standard error of estimate of y on x	—
T	Temperature	°C
T	Engine torque	Nm
T_a	Absolute temperature of the intake air	K
T_{dew}	Absolute dewpoint temperature	K
T_{ref}	Absolute reference temperature (of combustion air: 298 K)	K
t	Time	s
t_{10}	Time between step input and 10 % of final reading	s
t_{50}	Time between step input and 50 % of final reading	s
t_{90}	Time between step input and 90 % of final reading	s
u_{gas}	Ratio between densities of gas component and exhaust gas	—
V	Volume	m^3
V_m	Molar volume	l/mol
W	Work	kWh
W_{act}	Actual cycle work of the respective test cycle	kWh
x	Concentration	µmol/mol or %
$\bar{y}$	Arithmetic mean	

4.2 Symbols and abbreviated terms for fuel composition

w_H hydrogen content of fuel, % mass

w_C carbon content of fuel, % mass

w_S sulfur content of fuel, % mass

w_N nitrogen content of fuel, % mass

w_O oxygen content of fuel, % mass

α molar hydrogen-to-carbon ratio (H/C)

β molar carbon-to-carbon ratio (C/C)

γ molar sulphur-to-carbon ratio (S/C)

δ molar nitrogen-to-carbon ratio (N/C)

ε molar oxygen-to-carbon ratio (O/C)

EXAMPLE Referring to a fuel: $C_\beta H_\alpha O_\varepsilon N_\delta S_\gamma$.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

4.3 Symbols and abbreviated terms for chemical components

Ar	Argon
C_1	Carbon 1 equivalent hydrocarbon
C_2H_6	Ethane
C_2H_5OH	Ethanol
C_3H_8	Propane
CH_3OH	Methanol
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
H	Atomic hydrogen
H_2	Molecular hydrogen
H_2O	Water
HCHO	Formaldehyde
He	Helium
N_2	Molecular nitrogen
N_2O	Nitrous oxide
NH_3	Ammonia
NO	Nitric oxide
NO_2	Nitrogen dioxide
O_2	Oxygen
RME	Rapeseed oil methylester
S	Sulphur
SO_2	Sulphur dioxide

4.4 Abbreviated terms

ASTM	American Society for Testing and Materials
CFV	Critical flow venturi
CI	Compression-ignition
CNG	Compressed natural gas
CVS	Constant volume sampling
deNOx	NO_x after-treatment system

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

EGR	Exhaust-gas recirculation
FID	Flame ionization detector
FS	Full scale
G_R, G_{23}, G_{25}	Gaseous EU reference fuels according to ISO 8178-5
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
NMC	Non-methane cutter
NRMM	Non-road mobile machinery
NRTC	Non road transient cycle
PDP	Positive displacement pump
PFS	Partial flow system
PTFE	Polytetrafluoroethylene (commonly known as Teflon®)[a]
RIC	Reciprocating internal combustion (engines)
RMC	Ramped-modal cycle
SAE	Society of Automotive Engineers
SSV	Subsonic venture

[a] Teflon® is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

5 Test conditions

5.1 Engine test conditions

5.1.1 Laboratory test conditions

The absolute temperature (T_a) of the engine air at the inlet to the engine 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. In multi-cylinder engines having distinct groups of intake manifolds, such as in a "V" engine configuration, the average temperature of the distinct groups shall be taken. The parameter f_a shall be reported with the test results.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

Naturally aspirated and mechanically supercharged engines:

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

Turbocharged engines with or without cooling of the intake air:

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

5.1.2 Test validity

a) For the test to be considered valid both the following conditions shall be met:

   1) f_a shall be within the range $0,93 \leq f_a \leq 1,07$ except as permitted by b) and d);

   2) the temperature of intake air shall be maintained to (25 ± 5) °C, as measured upstream of any engine component, except as permitted by c) and d).

b) Where the altitude of the laboratory in which the engine is being tested exceeds [600] m, with the agreement of the manufacturer f_a may exceed 1,07 on the condition that p_s shall not be less than 80 kPa.

c) Where the power of the engine being tested is greater than 560 kW, with the agreement of the manufacturer the maximum value of intake air temperature may exceed 30 °C on the condition that it shall not exceed 35 °C.

d) Where the altitude of the laboratory in which the engine is being tested exceeds [300] m and the power of the engine being tested is greater than 560 kW, with the agreement of the manufacturer f_a may exceed 1,07 on the condition that p_s shall not be less than 80 kPa and the maximum value of intake air temperature may exceed 30 °C on the condition that it shall not exceed 35 °C.

The following is allowed:

a) a shared atmospheric pressure meter as long as the equipment for handling intake air maintains ambient pressure, where the engine is tested, within ±1 kPa of the shared atmospheric pressure;

b) a shared humidity measurement for intake air as long as the equipment for handling intake air maintains dew point, where the engine is tested, within ±0,5 °C of the shared humidity measurement.

5.2 Engine power

The basis of specific emissions measurement is uncorrected brake power as defined in ISO 14396. The engine shall be submitted for testing with the auxiliaries needed for operating the engine.

5.2.1 Auxiliaries to be fitted

During the test, the auxiliaries necessary for the engine operation shall be installed on the test bench according to the requirements of Annex G.

Where the necessary auxiliaries cannot be fitted for the test, the power they absorb shall be determined and subtracted from the measured engine power.

5.2.2 Auxiliaries to be removed

Certain auxiliaries whose definition is linked with the operation of the machine and which may be mounted on the engine shall be removed for the test.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

Where auxiliaries cannot be removed, the power they absorb in the unloaded condition may be determined and added to the measured engine power (see Table G.1, footnote h). If this value is greater than 3 % of the maximum power at the test speed it may be verified by the parties involved. The power absorbed by auxiliaries shall be used to adjust the set values and to calculate the work produced by the engine over the test cycle.

5.2.3 Determination of auxiliary power

The power absorbed by the auxiliaries/equipment needs only be determined, if:

a) auxiliaries/equipment required according to Annex G are not fitted to the engine; and/or

b) auxiliaries/equipment not required according to Annex G are fitted to the engine.

The values of auxiliary power and the measurement/calculation method for determining auxiliary power shall be submitted by the engine manufacturer for the whole operating area of the applicable test cycles, and approved by the parties involved.

5.2.4 Engine cycle work

The calculation of reference and actual cycle work (see 8.6.3.5) shall be based upon engine power according to 5.2. In this case, P_f and P_r of Formula (3) are zero, and P equals P_m.

If auxiliaries/equipment are installed according to 5.2.1 and/or 5.2.2, the power absorbed by them shall be used to correct each instantaneous cycle power value $P_{m,i}$, as follows:

$$P_i = P_{m,i} + P_{AUX} \tag{3}$$

where

$P_{m,i}$ is the measured engine power, kW;

P_{AUX} $= P_{r,i} - P_{f,i}$;

$P_{f,i}$ is the power absorbed by auxiliaries/equipment to be fitted for the test but that were not installed, kW;

$P_{r,i}$ is the power absorbed by auxiliaries/equipment to be removed for the test but that were installed, kW.

5.3 Engine intake air

5.3.1 General

The intake-air system installed on the engine or one that represents a typical in-use configuration shall be used. This includes the charge-air cooling and exhaust-gas recirculation systems.

5.3.2 Intake air restriction

An engine air intake system or a test laboratory system shall be used presenting an air intake restriction within ± 300 Pa of the maximum value specified by the manufacturer for a clean air cleaner at the rated speed and full load. Where this is not possible due to the design of the test laboratory air supply system a restriction not exceeding the value specified by the manufacturer for a dirty filter shall be permitted subject to prior approval of the parties involved. The static differential pressure of the restriction shall be measured at the location specified by the manufacturer. If the manufacturer does not specify a location, this pressure shall be measured upstream of any turbocharger or exhaust-gas recirculation system connection to the intake air system.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

When the maximum test speed (MTS) defined in 3.40 is being used in place of rated speed to run the test cycle then this speed may be used in place of rated speed when setting the intake air restriction.

5.3.3 Engines with charge air cooling

A charge-air cooling system with a total intake-air capacity that represents the production engine's in-use installation shall be used. Any laboratory charge-air cooling system shall be designed to minimize accumulation of condensate. Any accumulated condensate shall be drained and all drains shall be completely closed before emission testing. The drains shall be kept closed during the emission test. Coolant conditions shall be maintained as follows:

a) A coolant temperature of at least 20 °C shall be maintained at the inlet to the charge-air cooler throughout testing.

b) At the rated speed and full load, the coolant flow rate shall be set to achieve an air temperature within ±5 °C of the value designed by the manufacturer after the charge-air cooler's outlet. The air-outlet temperature shall be measured at the location specified by the manufacturer. This coolant flow rate set point shall be used throughout testing.

c) If the engine manufacturer specifies pressure-drop limits across the charge-air cooling system, it shall be ensured that the pressure drop across the charge-air cooling system at engine conditions specified by the manufacturer is within the manufacturer's specified limit(s). The pressure drop shall be measured at the manufacturer's specified locations.

When the maximum test speed (MTS) defined in 3.40 is being used in place of rated speed to run the test cycle then this speed may be used in place of rated speed when setting the charge air temperature.

The objective is to produce emission results that are representative of in-use operation. If good engineering judgment indicates that the specifications in this clause would result in unrepresentative testing (such as overcooling of the intake air), with the prior agreement of the parties involved more sophisticated set points and controls of charge-air pressure drop, coolant temperature, and flow rate may be used to achieve more representative results.

5.4 Engine exhaust system

5.4.1 General

The exhaust system installed with the engine or one that represents a typical in-use configuration shall be used. The exhaust system shall conform to the requirements for exhaust gas sampling, as set out in ISO 8178-1:2020, 5.2.1.

5.4.2 Exhaust restriction

An engine exhaust system or a test laboratory system shall be used presenting a static exhaust backpressure within 80 % to 100 % of the maximum exhaust restriction specified by the manufacturer at the rated speed and full load. The restriction may be set using a valve. If the maximum restriction is 5 kPa or less, the set point shall not be more than 1,0 kPa from the maximum.

When the maximum test speed (MTS) defined in 3.40 is being used in place of rated speed to run the test cycle then this speed may be used in place of rated speed when setting the exhaust restriction.

5.4.3 Engine with exhaust after-treatment system

If the engine is equipped with an exhaust after-treatment system, the exhaust pipe shall have the same diameter as found in-use, or as specified by the manufacturer, for at least four pipe diameters upstream of the expansion section containing the after-treatment device. The distance from the exhaust manifold flange or turbocharger outlet to the exhaust after-treatment system shall be the same as in the in-use configuration or within the distance specifications of the manufacturer. Where other installation requirements are specified by the manufacturer these shall also be respected for the test configuration.

© ISO 2020 – All rights reserved
AVA Documents Document Sharing Hub
Full document details: BS ISO 8178-4:2020

The exhaust restriction shall be set according to 5.4.2. For variable-restriction after-treatment devices, the maximum exhaust restriction used in 5.4.2 is defined at the after-treatment condition (degreening/ageing and regeneration/loading level) specified by the manufacturer. The after-treatment container may be removed during dummy tests and during engine mapping, and replaced with an equivalent container having an inactive catalyst support.

5.5 Specific test conditions

5.5.1 Engine with exhaust after-treatment system

The emissions measured on the test cycle shall be representative of the emissions in the field.

5.5.1.1 Use of reagent

In the case of an engine equipped with an exhaust after-treatment system that requires the consumption of a reagent, the reagent used for all tests shall be declared by the manufacturer.

5.5.1.2 Regeneration

For engines equipped with exhaust after-treatment systems that are regenerated on an infrequent (periodic) basis, as described in 5.5.1.2.2, emission results shall be adjusted to account for regeneration events. In this case, the average emission depends on the frequency of the regeneration event in terms of fraction of tests during which the regeneration occurs. After-treatment systems with continuous regeneration according to 5.5.1.2.1 do not require a special test procedure.

If the exhaust aftertreatment has a security mode that works on an infrequent (periodic) regeneration mode, it shall be checked according to 5.5.1.2.2. For that specific case, the applicable emission limits could be exceeded and the measured emissions would not be weighted.

5.5.1.2.1 Continuous regeneration

For an exhaust aftertreatment system based on a continuous regeneration process, the emissions shall be measured on an aftertreatment system that has been stabilized so as to result in repeatable emissions behaviour. The regeneration process shall occur at least once during the NRTC hot start test, LSI-NRTC or NRSC test, and the manufacturer shall declare the normal conditions under which regeneration occurs (soot load, temperature, exhaust back-pressure, etc.). In order to demonstrate that the regeneration process is continuous, at least three NRTC hot start tests, LSI-NRTC or NRSC tests shall be conducted. In case of NRTC hot start test, the engine shall be warmed up in accordance with 8.4.2, the engine shall be soaked according to 8.6.3 and the first NRTC hot start test run. The subsequent NRTC hot start tests shall be started after soaking according to 8.6.3. During the tests, exhaust temperatures and pressures shall be recorded (temperature before and after the after-treatment system, exhaust back pressure, etc.). The aftertreatment system is considered to be satisfactory if the conditions declared by the manufacturer occur during the test during a sufficient time and the emission results do not scatter by more than ±25 % from the mean value or 0,005 g/kWh, whichever is greater. PN emissions do not need to meet the specified scatter requirement if gaseous and PM emissions meet this requirement. If the exhaust aftertreatment has a security mode that shifts to an infrequent (periodic) regeneration mode, it shall be checked according to 5.5.1.2.2. For that specific case, the applicable emission limits could be exceeded and would not be weighted.

5.5.1.2.2 Infrequent (periodic) regeneration

This provision only applies for engines equipped with emission controls that are regenerated on a periodic basis.

Testing and development of adjustment factors is only required for one applicable transient (NRTC or LSI-NRTC) or RMC test cycle. The factors that have been developed may be applied to results from the other applicable test cycles including discrete-mode NRSC.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

In case that no suitable adjustment factors are available from testing using transient or RMC test cycles then adjustment factors shall be established using an applicable discrete-mode test. Factors developed using a discrete-mode test cycle shall only be applied to discrete-mode test cycles.

It shall not be required to conduct testing and develop adjustment factors on both RMC and discrete-mode NRSCs.

5.5.1.2.2.1 Requirement for establishing adjustment factors using NRTC, LSI-NRTC or RMC NRSC testing

The emissions shall be measured on at least three NRTC hot start tests, LSI-NRTC or ramped-modal cycle (RMC) NRSC tests, one with and two without a regeneration event on a stabilized aftertreatment system. The regeneration process shall occur at least once during the NRTC, LSI-NRTC or RMC NRSC test with a regeneration event. If regeneration takes longer than one NRTC, LSI-NRTC or RMC NRSC test, consecutive NRTC, LSI-NRTC or RMC NRSC tests shall be run and emissions continued to be measured without shutting the engine off until regeneration is completed and the average of the tests shall be calculated. If regeneration is completed during any test, the test shall be continued over its entire length.

An appropriate adjustment factor shall be determined for the entire applicable cycle using Formulae (5) to (8).

5.5.1.2.2.2 Requirement for establishing adjustment factors using discrete-mode NRSC testing

Starting with a stabilized after-treatment system the emissions shall be measured on at least three runs of each test mode of the applicable discrete-mode NRSC on which the conditions for regeneration can be met, one with and two without a regeneration event. The measurement of PM shall be conducted using the multiple filter method. If regeneration has started but is not complete at the end of the sampling period for a specific test mode extend the sampling period until regeneration is complete. Where there are multiple runs for the same mode an average result shall be calculated. The process shall be repeated for each test mode.

An appropriate adjustment factor shall be determined using Formulae (5) to (8) for those modes of the applicable cycle for which regeneration occurs.

5.5.1.2.2.3 General procedure for developing infrequent regeneration adjustment factors (IRAFs)

The engine may be equipped with a switch capable of preventing or permitting the regeneration process provided this operation has no effect on the original engine calibration.

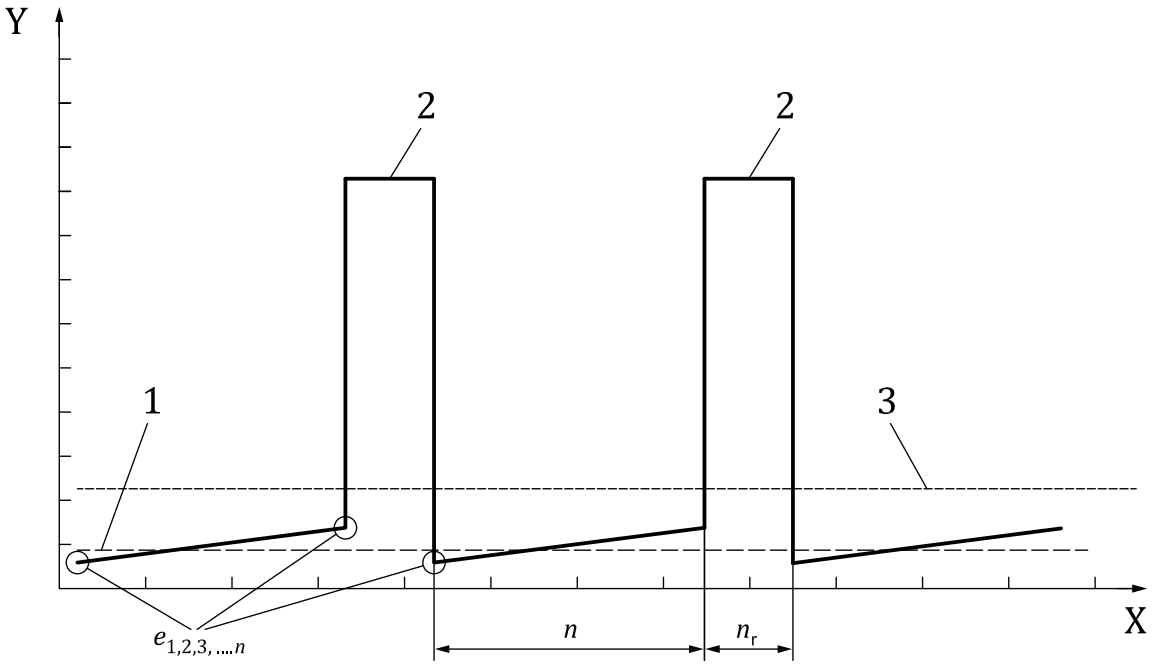
The manufacturer shall declare the normal parameter conditions under which the regeneration process occurs (soot load, temperature, exhaust back pressure, etc.). The manufacturer shall also provide the frequency of the regeneration event in terms of number of tests during which the regeneration occurs. The exact procedure to determine this frequency shall be agreed by the parties involved based upon good engineering judgement.

For a regeneration test, the manufacturer shall provide an aftertreatment system that has been loaded. Regeneration shall not occur during this engine conditioning phase. As an option, the manufacturer may run consecutive tests of the applicable cycle until the aftertreatment system is loaded. Emissions measurement is not required on all tests.

Average emissions between regeneration phases shall be determined from the arithmetic mean of several approximately equidistant tests of the applicable cycle. As a minimum, at least one applicable cycle as close as possible prior to a regeneration test and one applicable cycle immediately after a regeneration test shall be conducted.

During the regeneration test, all the data needed to detect regeneration shall be recorded (CO or NO_x emissions, temperature before and after the after-treatment system, exhaust back pressure, etc.). During the regeneration process, the applicable emission limits may be exceeded. The test procedure is schematically shown in Figure 2.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020



Key

X number of test cycles

Y emissions (g/kWh or #/kWh)

1 mean emissions during sampling $e_{1,2,3,...n}$

2 emissions during regeneration e_r

3 weighted emissions of sampling and regeneration e_w

n number of tests cycles in which regeneration does not occur

n_r number of tests cycles in which regeneration occurs (minimum one test)

Figure 2 — Scheme of infrequent (periodic) regeneration with n number of measurements and n_r number of measurements during regeneration

The average specific emission rate related to the test runs conducted according to 5.5.1.2.2.1 or 5.5.1.2.2.2 [g/kWh or #/kWh] shall be weighted as follows (see Figure 2):

$$\bar{e}_w = \frac{n \cdot \bar{e} + n_r \cdot \bar{e}_r}{n + n_r} \tag{4}$$

where

n is the number of tests in which regeneration does not occur;

n_r is the number of tests in which regeneration occurs (minimum one test);

$\bar{e}_w$ is the average specific emission from a test in which the regeneration does not occur [g/kWh or #/kWh];

$\bar{e}_r$ is the average specific emission from a test in which the regeneration occurs [g/kWh or #/kWh].

At the choice of the manufacturer and based on upon good engineering analysis, the regeneration adjustment factor k_r, expressing the average emission rate, may be calculated either multiplicative or additive for all gaseous pollutants, and, where there is an applicable limit for PM and PN, as follows:

— **Multiplicative**

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

$$k_{\mathrm{MUr}} = \frac{\bar{e}_{\mathrm{w}}}{\bar{e}} \text{ (upward adjustment factor)} \tag{5}$$

$$k_{\mathrm{MDr}} = \frac{\bar{e}_{\mathrm{w}}}{\bar{e}_{\mathrm{r}}} \text{ (downward adjustment factor)} \tag{6}$$

— **Additive**

$$k_{\mathrm{Ur}} = \bar{e}_{\mathrm{w}} - \bar{e} \text{ (upward adjustment factor)} \tag{7}$$

$$k_{\mathrm{Dr}} = \bar{e}_{\mathrm{w}} - \bar{e}_{\mathrm{r}} \text{ (downward adjustment factor)} \tag{8}$$

Upward adjustment factors are multiplied with or added to measured emission rates for all tests in which the regeneration does not occur. Downward adjustment factors are multiplied with or added to measured emission rates for all tests in which the regeneration occurs. The occurrence of the regeneration shall be identified in a manner that is readily apparent during all testing. Where no regeneration is identified, the upward adjustment factor shall be applied.

With reference to Clause 9 and Annex H on brake specific emission calculations, the regeneration adjustment factor:

a) When established for an entire weighted cycle, shall be applied to the results of the applicable weighted NRTC, LSI-NRTC and NRSC tests;

b) When established specifically for the individual modes of the applicable discrete-mode cycle, shall be applied to the results of those modes of the applicable discrete-mode NRSC cycle for which regeneration occurs prior to calculating the cycle weighted emission result. In this case the multiple filter method shall be used for PM measurement;

c) May be extended to other members of the same engine family;

d) May be extended to other engine families within the same engine aftertreatment system family with the prior approval of the parties involved based on technical evidence to be supplied by the manufacturer that the emissions are similar.

The following options shall be considered:

a) A manufacturer may elect to omit adjustment factors for one or more of its engine families (or configurations) because the effect of the regeneration is small, or because it is not practical to identify when regenerations occur. In these cases, no adjustment factor shall be used, and the manufacturer is liable for compliance with the emission limits for all tests, without regard to whether a regeneration occurs.

b) Upon request by the manufacturer, the parties involved may account for regeneration events differently than is provided in a). However, this option only applies for events that occur extremely infrequently, and which cannot be practically addressed using the adjustment factors described in a).

5.5.2 Crankcase emissions

Where the parties involved require crankcase emissions that are normally discharged to ambient atmosphere to be included, the emissions shall be added to the exhaust emissions during all emission testing either

a) physically, or

b) mathematically.

When using method a), manufacturers shall install the engines on the test-bed in a manner that all crankcase emissions are routed into the exhaust system as described in this clause. For the

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

purpose of this clause, crankcase emissions that are routed into the exhaust upstream of exhaust after-treatment during all operation are not considered to be discharged directly into the ambient atmosphere.

Open crankcase emissions shall be routed into the exhaust system for emission measurement, as follows:

c) The tubing materials shall be smooth-walled, electrically conductive, and not reactive with crankcase emissions. Tube lengths shall be minimized as far as possible. The tube may optionally be heated or thin-walled or insulated with an air-gap to minimize temperature differences between the wall and the crankcase emissions constituents.

d) The number of bends in the laboratory crankcase tubing shall be minimized, and the radius of any unavoidable bend shall be maximized.

e) The laboratory crankcase exhaust tubing shall meet the engine manufacturer's specifications for crankcase back pressure.

f) The crankcase exhaust tubing shall connect into the raw exhaust downstream of any aftertreatment system, downstream of any installed exhaust restriction, and sufficiently upstream of any sample probes to ensure complete mixing with the engine's exhaust before sampling. The crankcase exhaust tube shall extend into the free stream of exhaust to avoid boundary-layer effects and to promote mixing. The crankcase exhaust tube's outlet may orient in any direction relative to the raw exhaust flow.

Method b) is permitted with the prior approval of the parties involved.

5.6 Cooling system

An engine cooling system with sufficient capacity to maintain the engine, with its intake-air, oil, coolant, block and head temperatures, at normal operating temperatures prescribed by the manufacturer shall be used. Laboratory auxiliary coolers and fans may be used.

5.7 Lubricating oil

The lubricating oil shall be specified by the manufacturer and be representative of lubricating oil available in the market; the specifications of the lubricating oil used for the test shall be recorded and presented with the results of the test.

6 Test fuels

Fuel characteristics influence the engine exhaust gas emission. Therefore, the characteristics of the fuel used for the test should be determined, recorded and presented with the results of the test. Where fuels designated in ISO 8178-5 as reference fuels are used, the reference code and the analysis of the fuel shall be provided. For all other fuels the characteristics to be recorded are those listed in the appropriate universal data sheets in ISO 8178-5. See Table 2.

Table 2 — Selection of fuel

Test purpose	Interested parties	Fuel selection
Type approval (Certification)	1. Certification body 2. Manufacturer or supplier	Reference fuel, if one is defined Commercial fuel if no reference fuel is defined
Acceptance test	1. Manufacturer or supplier 2. Customer or inspector	Commercial fuel as specified by the manufacturer[a]
[a] Customers and inspectors should note that the emission tests carried out using commercial fuel will not necessarily comply with limits specified when using reference fuels.		

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

Table 2 *(continued)*

Test purpose	Interested parties	Fuel selection
Research/development	One or more of: Manufacturer, research organization, fuel and lubricant supplier, etc.	To suit the purpose of the test
[a] Customers and inspectors should note that the emission tests carried out using commercial fuel will not necessarily comply with limits specified when using reference fuels.		

7 Test cycles

7.1 General

The following duty cycles are described in this clause: discrete mode steady-state cycles, ramped-modal steady-state cycles and transient cycle. The cycles and their applicability are described in 7.5 (steady-state) and 7.6 (transient), while the method to determine the appropriate test points (speed, torque, power) are described in 7.2 to 7.4. The tabulated cycles are contained in Annex A to Annex C.

7.2 Test speeds

Test speeds shall be determined according to the test cycle(s) to be used. In certain cases a rated speed will be used to represent 100 % speed, as declared by the manufacturer according to 3.58. In other cases the MTS (maximum test speed) will be used to represent 100 % speed, as determined from the curve of engine speed versus power according to 7.2.1. Where applicable, an intermediate speed will be determined according to 3.34. Where intermediate speed is not used the other speeds will be determined as a percentage of the rated speed or MTS.

For constant-speed engines the 100 % speed shall be determined according to 7.2.5.

7.2.1 Maximum test speed (MTS)

For engines that are tested with a transient cycle the MTS shall be determined according to this clause. In this case the 100 % test speed is equal to the MTS. For engines that are tested with both a steady state cycle (discrete- or ramped- modal) and also a transient cycle, the MTS shall also be used in place of the rated speed for operating the steady state cycle.

7.2.1.1 Calculation of MTS

In order to calculate the MTS for variable-speed engines the transient mapping procedure shall be performed according to 7.4. The MTS is then determined from the mapped values of engine speed versus power. For the calculation of the MTS one of the following formulations shall be used:

a) $$n_{MTS} = n_{lo} + 0{,}95 \cdot (n_{hi} - n_{lo}) \quad (9)$$

where

n_{hi} is high speed (see 3.31);

n_{lo} is low speed (see 3.37).

b) $n_{MTS} = n_i$ at the average of the lowest and highest speeds at which $(n^2_{normi} + P^2_{normi})$ is equal to 98 % of the maximum value of $(n^2_{normi} + P^2_{normi})$. If there is only one speed at which the value of $(n^2_{normi} + P^2_{normi})$ is equal to 98 % of the maximum value of $(n^2_{normi} + P^2_{normi})$ then MTS = ni at which the maximum value of $(n^2_{normi} + P^2_{normi})$ occurs. (10)

© ISO 2020 – All rights reserved
Documents Document Sharing Hub
Full document details: BS ISO 8178-4:2020

where

n is engine speed;

i is an indexing variable that represents one recorded value of an engine map;

$n_{\text{norm}i}$ is an engine speed normalized by dividing it by $n_{P\text{max}}$;

$P_{\text{norm}i}$ is an engine power normalized by dividing it by P_{max};

$n_{P\text{max}}$ is the average of the lowest and highest speeds at which power is equal to 98 % of P_{max}. Linear interpolation shall be used between the mapped values to determine the speeds where power is equal to 98 % of P_{max}. If there is only one speed at which power is equal to 98 % of P_{max} then $n_{P\text{max}}$ shall be the speed at P_{max}.

Linear interpolation shall be used between the mapped values to determine the speeds where $(n^2_{\text{norm}i} + P^2_{\text{norm}i})$ is equal to 98 % of the maximum value of $(n^2_{\text{norm}i} + P^2_{\text{norm}i})$.

7.2.1.2 Use of a declared MTS

If the MTS calculated according to 7.2.1.1 is within ±3 % of the MTS declared by the manufacturer, the declared MTS may be used for the emissions test. If the tolerance is exceeded, the calculated MTS shall be used for the emissions test.

7.2.1.3 Use of an adjusted MTS for correct driving of the NRTC

If the falling part of the full load curve has a very steep edge, this may cause problems to drive the 105 % speeds of the NRTC test cycle correctly. In this case it is allowed, with prior agreement of the parties involved, to use an alternative value of MTS determined using one of the following methods:

a) Reduce the MTS slightly (maximum 3 %) in order to make correct driving of the NRTC possible.

b) Calculate an alternative MTS using the following formulation:

$$n_{\text{MTS}} = (n_{\text{max}} - n_{\text{idle}})/1{,}05 + n_{\text{idle}} \tag{11}$$

where

n_{max} is maximum no load speed;

n_{idle} is idle speed.

7.2.2 Rated speed

The rated speed is defined in 3.58 and will normally be the maximum full load speed allowed by the governor, as designed by the manufacturer, or, if such a governor is not present, the speed at which the maximum power is obtained from the engine, as designed by the manufacturer.

For variable-speed engines that are not tested with a transient cycle the 100 % test speed is equal to the rated speed.

At manufacturers' discretion, maximum test speed may be used instead of rated speed for any steady state test cycle.

7.2.3 Intermediate speed

The maximum torque speed used for the determination of intermediate speed shall be obtained from the maximum torque curve established from the engine mapping conducted according to one of the procedures in 7.4.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

The maximum torque speed is either:

a) the speed at which the highest torque was recorded; or

b) the average of the lowest and highest speeds at which the torque is equal to 98 % of the maximum torque. Where necessary, linear interpolation shall be used to determine the speeds at which the torque is equal to 98 % of the maximum.

If the maximum torque speed determined from the maximum torque curve is within ±4 % of the maximum torque speed declared by the manufacturer for SI engines <56 kW, or ±2,5 % of the maximum torque speed declared by the manufacturer for all other engines, the declared value may be used. If the tolerance is exceeded, the maximum torque speed determined from the maximum torque curve shall be used.

The intermediate speed shall meet one of the following requirements:

a) For engines that are designed to operate over a speed range on a full load torque curve, the intermediate speed shall be the maximum torque speed if it occurs between 60 % and 75 % of rated speed.

b) If the maximum torque speed is less than 60 % of rated speed, then the intermediate speed shall be 60 % of the rated speed.

c) If the maximum torque speed is greater than 75 % of the rated speed then the intermediate speed shall be 75 % of rated speed. Where the engine is only capable of operation at speeds higher than 75 % of rated speed the intermediate speed shall be the lowest speed at which the engine can be operated.

d) For engines that are not designed to operate over a speed range on a full-load torque curve at steady-state conditions, the intermediate speed will typically be between 60 % and 70 % of the rated speed.

e) For engines to be tested on cycle G1, the intermediate speed shall be 85 % of the rated speed.

In the case that the maximum test speed (MTS) is used in place of rated speed for the 100 % test speed, MTS shall also replace rated speed when determining the intermediate speed.

7.2.4 Idle speed

The idle speed is the lowest engine speed with minimum load (greater than or equal to zero load), where an engine governor function controls engine speed. For engines without a governor function that controls idle speed, idle speed means the manufacturer-declared value for lowest engine speed possible with minimum load. Note that warm idle speed is the idle speed of a warmed-up engine.

7.2.5 Test speed for constant-speed engines

The governors of constant-speed engines may 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. The test speed for constant-speed engines may be commanded by using the governor installed on the engine or using a test-bed speed demand where this represents the engine governor.

Where the governor installed on the engine is used the 100 % speed shall be the engine governed speed.

Where a test-bed speed demand signal is used to simulate the governor, the 100 % speed at zero load shall be the no load speed specified by the manufacturer for that governor setting and the 100 % speed at full load shall be the rated speed for that governor setting. Interpolation shall be used to determine the speed for the other test modes.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

In the case that the governor has an isochronous operation setting, or the nominal rated speed and no-load speed declared by the manufacturer differ by no more than 3 %, a single value declared by the manufacturer may be used for the 100 % speed at all load points.

7.3 Torque and power

7.3.1 Torque

The torque figures given in the test cycles are percentage values that represent, for a given test mode, one of the following:

a) The ratio of the required torque to the maximum possible torque at the specified test speed (all cycles except D1, D2, E2, E4).

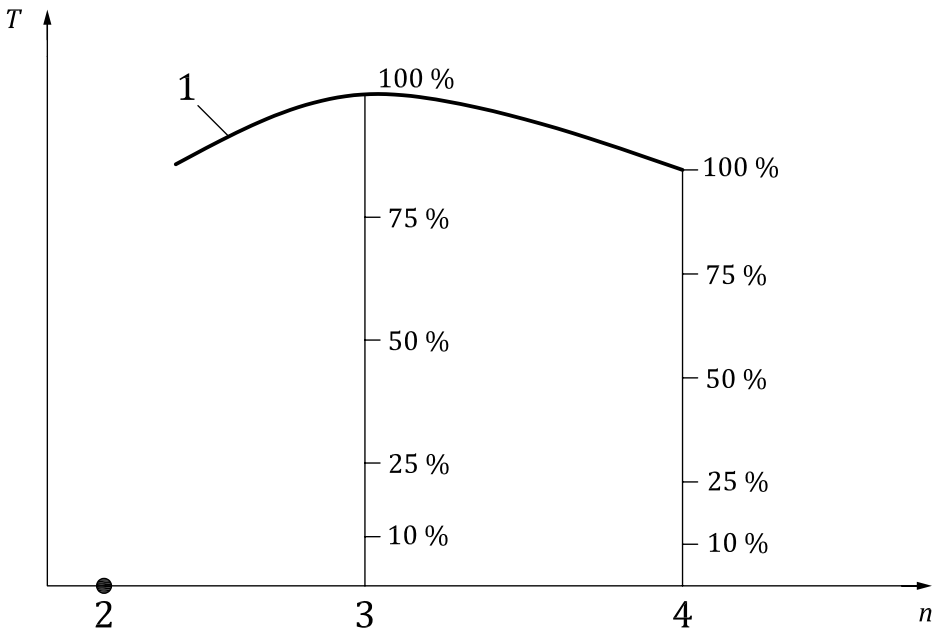
b) The ratio of the required torque to the torque corresponding to the continuous rated power (cycle D1) declared by the manufacturer as defined in ISO 8528-1.

c) The ratio of the required torque to the torque corresponding to the rated power declared by the manufacturer as defined in ISO 8528-1 (cycle D2).

d) For cycle E2 % torque is relative to the torque corresponding to the rated power declared by the manufacturer.

e) For the test cycle E4 the torque figures are percentage values of the torque at rated power. This cycle is based on the theoretical propeller characteristic curve representing typical pleasure craft spark-ignition engine operation.

Figure 3 shows torque scales for engines operating on a non-propeller curve.



Key

T torque

n engine speed

1 full-load torque curve

2 low idle

3 intermediate speed

4 100 % speed

Figure 3 — Torque scales: Percentage of full-load torque at each engine speed

© ISO 2020 – All rights reserved

AVA Documents Document Sharing Hub
Full document details: BS ISO 8178-4:2020

7.3.2 Power

The power figures given in the test cycles are percentage values that represent, for a given test mode, one of the following:

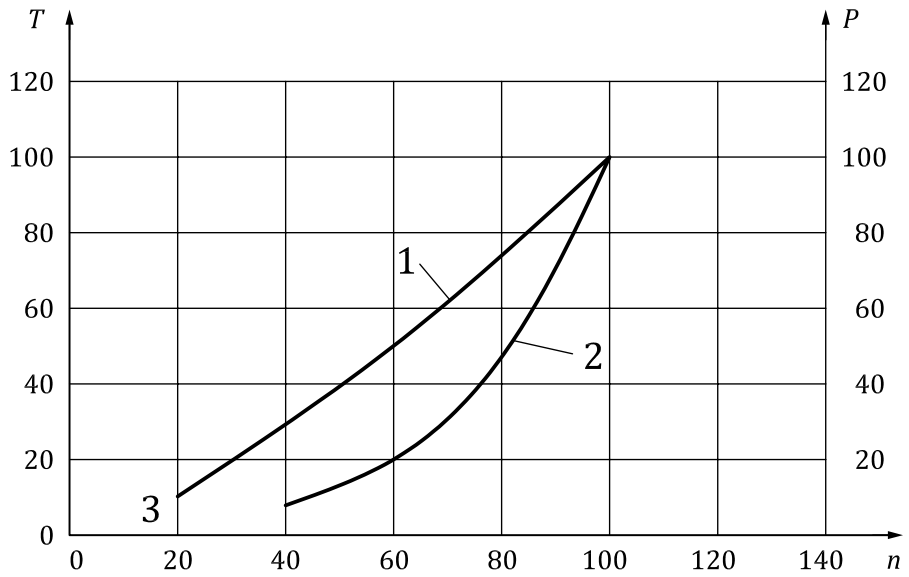
a) For the test cycle E3 the power figures are percentage values of the maximum rated power at the 100 % speed as this cycle is based on a theoretical propeller characteristic curve for vessels driven by heavy-duty engines without limitation of length.

b) For the test cycle E5 the power figures are percentage values of the maximum rated power at the 100 % speed as this cycle is based on a theoretical propeller characteristic curve for vessels of less than 24 m in length driven by diesel engines.

c) For the test cycle F the power figures are percentage values of the maximum power at the given test speed, except for idle speed where it is a percentage of the maximum rated power at the 100 % speed.

Figure 4 shows an example of two representative propeller curves.

NOTE Other propeller characteristic curves exist.



Key

T torque

n engine speed

P power

1 torque E4

2 power E3

3 idling

NOTE The values of n, T and P are expressed in % of rated speed, maximum torque and maximum power respectively.

Figure 4 — Examples of torque and power scales for propeller curves

7.4 Engine mapping

Before starting the engine mapping, the engine shall be warmed up and towards the end of the warm up it shall be operated for at least 10 min at maximum power or according to the recommendation of the manufacturer and good engineering judgement in order to stabilize the engine coolant and lube oil temperatures. When the engine is stabilized, the engine mapping shall be performed.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

Except constant-speed engines, engine mapping shall be performed with fully open fuel lever or governor using discrete speeds in ascending order. The minimum and maximum mapping speeds are defined as follows:

— Minimum mapping speed = warm idle speed;

— Maximum mapping speed = n_{hi} × 1,02 or speed where max torque drops off to zero, whichever is smaller.

where n_{hi} is high speed (see 3.31).

If the highest speed is unsafe or unrepresentative (e.g. for ungoverned engines), good engineering judgement shall be used to map up to the maximum safe speed or the maximum representative one.

7.4.1 Engine mapping for transient cycles

The engine mapping shall be performed according to the following procedure:

a) The engine shall be unloaded and operated at idle speed.

   1) For engines with a low-speed governor, the operator demand shall be set to the minimum, the dynamometer or another loading device shall be used to target a torque of zero on the engine's primary output shaft and the engine shall be allowed to govern the speed. This warm idle speed shall be measured.

   2) For engines without a low-speed governor, the dynamometer shall be set to target a torque of zero on the engine's primary output shaft, and the operator demand shall be set to control the speed to the manufacturer-declared lowest engine speed possible with minimum load (also known as manufacturer-declared warm idle speed).

   3) The manufacturer declared idle torque may be used for all variable-speed engines (with or without a low-speed governor), if a nonzero idle torque is representative of in-use operation.

b) Operator demand shall be set to maximum and engine speed shall be controlled to between warm idle and 95 % of its warm idle speed. For engines with reference duty cycles, which lowest speed is greater than warm idle speed, the mapping may be started at between the lowest reference speed and 95 % of the lowest reference speed.

c) The engine speed shall be increased at an average rate of (8 ± 1) min^{-1}/s or the engine shall be mapped by using a continuous sweep of speed at a constant rate such that it takes 4 min to 6 min to sweep from minimum to maximum mapping speed. The mapping speed range shall be started between warm idle and 95 % of warm idle and ended at the highest speed above maximum power at which less than 70 % of maximum power occurs. If this highest speed is unsafe or unrepresentative (e.g. for ungoverned engines), good engineering judgment shall be used to map up to the maximum safe speed or the maximum representative speed. Engine speed and torque points shall be recorded at a sample rate of at least 1 Hz.

d) If a manufacturer believes that the above mapping techniques are unsafe or unrepresentative for any given engine, alternate mapping techniques may be used. These alternate techniques shall satisfy the intent of the specified mapping procedures to determine the maximum available torque at all engine speeds achieved during the test cycles. Deviations from the mapping techniques specified in this clause for reasons of safety or representativeness shall be approved by the parties involved along with the justification for their use. In no case, however, the torque curve shall be run by descending engine speeds for governed or turbocharged engines.

e) An engine need not be mapped before each and every test cycle. An engine shall be remapped if:

   1) an unreasonable amount of time has transpired since the last map, as determined by good engineering judgement; or

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

2) physical changes or recalibrations have been made to the engine which potentially affect engine performance; or

3) the atmospheric pressure near the engine's air inlet is not within ±5 kPa of the value recorded at the time of the last engine map.

7.4.2 Engine mapping for variable-speed steady-state cycles

In the case of engine mapping for a steady-state cycle (only for engines which have not to run a transient cycle), good engineering judgment shall be used to select a sufficient number of evenly spaced set-points. At each set-point, speed shall be stabilized and torque allowed to stabilize for at least 15 s. The mean speed and torque shall be recorded at each set-point. Where feasible the mean speed and torque should be calculated using the recorded data from the last 4 s to 6 s. Linear interpolation shall be used to determine the steady-state test speeds and torques if needed.

Except as set-out in 7.2, if the derived test speeds and torques do not deviate for more than ±3 % from the speeds and torques indicated by the manufacturer, the manufacturer defined speeds and torques shall be applied. When engines are additionally required to run a transient cycle, then the transient mapping curve shall be used to determine steady-state test speeds and torques.

At the choice of the manufacturer the engine mapping may alternatively be conducted according to the procedure in 7.4.1.

7.4.3 Engine mapping for constant-speed engines

The engine may be operated with a production constant-speed governor or a constant-speed governor maybe simulated by controlling engine speed with an operator demand control system. Either isochronous or speed-droop governor operation shall be used, as appropriate.

The following mapping procedure shall be applied:

a) With the governor or simulated governor controlling speed using operator demand, the engine shall be operated at no-load governed speed (at high speed, not low idle) for at least 15 s, unless the specific engine is unable to perform this task.

b) The dynamometer shall be used to increase torque at a constant rate. The map shall be conducted such that it takes no less than 2 min to sweep from no-load governed speed to the torque corresponding to rated power for engines to be tested on cycle D1, D2 or E2 or to maximum torque in the case of other constant-speed test cycles. During the engine mapping actual speed and torque shall be recorded with at least 1 Hz;

c) In case of a constant-speed engine with a governor that can be reset to alternative speeds, the engine shall be tested at each applicable constant speed.

d) For constant-speed engines good engineering judgment shall be used to apply other methods to record torque corresponding to rated power at the defined operating speed(s). Other suitable methods shall include but not be limited to the following:

   1) For constant-speed engines subject only to steady-state testing, an engine map may be performed by using a series of discrete torques. At least five evenly spaced torque setpoints from no-load to 80 % of the manufacturer-declared test torque or to a torque derived from the published maximum power level shall be selected if the declared test torque is not available. Starting at the 80 % torque point, setpoints in 2,5 % or smaller intervals are selected, stopping at the endpoint torque. The endpoint torque is defined as the first discrete mapped torque value greater than the torque at maximum observed power where the engine outputs 90 % of the maximum observed power; or the torque when engine stall has been determined. Torque and speed shall be allowed to stabilize at each setpoint and the mean feedback speed and torque at each setpoint shall be recorded. Mapping at higher torque setpoints may be carried out if desired. From this series of mean feedback speed and torque values, intermediate values are

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

determined by using linear interpolation. These series of mean speeds and torques are used to generate the power map.

2) For any constant-speed engine, an engine map may be performed with a continuous torque sweep by continuing to record the mean feedback speed and torque at 1 Hz or higher frequency. The reference torque shall be increased by the dynamometer at a constant rate from no-load to the endpoint torque. The torque sweep rate is targeted to be equal to the manufacturer-declared test torque (or a torque derived from the published power level) divided by 180 s. It shall be verified, that the average torque sweep rate over the entire map is within ±7 % of the target torque sweep rate. From this series of mean feedback speed and torque values, intermediate values are determined by using linear interpolation. These series of mean speeds and torques are used to generate the power map.

3) For any isochronous governed (0 % speed droop) constant-speed engine, the engine may be mapped with two points. After stabilizing at the no-load governed speed, the mean feedback speed and torque is recorded.

The engine shall be operated with the governor or simulated governor controlling engine speed using operator demand, and the dynamometer shall be used to target a speed of 99,5 % of the recorded mean no-load governed speed. Torque and speed shall be allowed to stabilize at each setpoint. The mean feedback speed and torque at each setpoint and the target speed shall be recorded.

The absolute value of the speed error (the mean feedback speed minus the target speed) must be no greater than 0,1 % of the recorded mean no-load governed speed. From this series of mean feedback speed and torque values, intermediate values are determined by using linear interpolation. These series of two mean feedback speeds and torques are used to generate the power map. Note that the measured maximum test torque will be the mean feedback torque recorded on the second point.

For engines tested on cycles other than D1, D2 or E2, when both measured and declared values are available for the maximum torque, the declared value may be used instead of the measured value if it is within 95 to 100 % of the measured value.

7.5 Steady-state test cycles

Steady-state test cycles are specified as a list of discrete modes (operating points), where each operating point has one value of speed and one value of torque. A steady-state test cycle shall be measured with a warmed up and running engine according to manufacturer's specification.

At the choice of the manufacturer, a steady-state test cycle may be run as a discrete-mode cycle or a ramped-modal cycle (RMC), as explained in 7.5.1 and 7.5.2.

Performing an RMC emission test according to 7.5.2 shall be optional. There may be technical reasons why an engine may not be able to operate according to the test cycles in 7.5.2. It shall not be required to conduct an emission test according to both 7.5.1 and 7.5.2.

7.5.1 Discrete mode test cycles

7.5.1.1 General remarks

The exhaust emission measurement and evaluation shall be carried out using the appropriate test cycle for the application as described in general in 7.5.3. The corresponding test cycles are tabulated in Annex A.

The particulate emission may be measured by either the multiple filter or the single filter method according to ISO 8178-1:2020, 8.6.1.2. To evaluate the particulate emission by the multiple filter method, it is necessary to measure the particulate concentration and the particulate mass emission of each test mode at stabilized engine operation. The time needed for stabilization of the engine depends on engine size and ambient conditions.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

7.5.1.2 Requirements for conduct of test using discrete mode cycle

7.5.1.2.1 Test sequence

Each test shall be performed with a warmed-up and running engine in the given sequence of the test modes for a particular test cycle.

7.5.1.2.2 Mode length

The minimum test mode length is 10 min, which is the standard, except when testing spark-ignition engines using cycles "G". If necessary the mode length may be extended e.g. to collect sufficient particulate sample mass or to achieve stabilization with large engines.

For spark-ignition engines when only gaseous emissions are measured using cycles "G", each mode time shall be at least 3 min.

The mode length shall be recorded and reported.

7.5.1.2.3 Emission measurement

Except when testing spark-ignition engines using test cycles "G", the gaseous exhaust emission concentration values shall be measured and recorded for at least 3 min anywhere in the mode if the engine is stabilized and meets the speed and torque requirements of the respective mode.

For spark-ignition engines when only gaseous emissions are measured using cycles "G", the gaseous exhaust emission concentration values shall be measured and recorded for the last 2 min of the respective test mode.

Only the last 60 s of the measurement period shall be used for emission calculation in accordance with Clause 9 or Annex H.

Particulate sampling shall not commence before engine stabilization, as defined by the manufacturer, has been achieved, and shall preferably be conducted at the same time as gaseous emissions are measured. For the single filter method, the completion of particulate sampling shall be within ±5 s of the completion of the gaseous emission measurement.

7.5.1.2.4 Repeat measurements

For the multiple filter method only, particulate sampling and gaseous emissions measurement may be repeated during the mode until a valid sample is obtained as long as the speed and torque requirements are met.

Test modes may be repeated, as long as the engine is pre-conditioned by running the previous or current mode. In the case of the first mode of any cycle, the engine shall be preconditioned according to 8.4.2.

7.5.1.2.5 Validation criteria

During each mode of the given steady-state test cycle after the initial transition period, the measured speed shall not deviate from the reference speed for more than ±1 % of rated speed or ±3 min^{-1}, whichever is greater except for idle which shall be within the tolerances declared by the manufacturer. The measured torque shall not deviate from the reference torque for more than ±2 % of the maximum torque at the test speed.

7.5.1.2.6 Equipment malfunction

If at any time during a test mode, the test equipment malfunctions or the engine speed and load do not meet the requirements of 7.5.1.2.5, the test mode is void and may be aborted. The test mode may be restarted by preconditioning with the previous or current mode.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

7.5.2 Ramped-modal test cycles

7.5.2.1 General remarks

An RMC is intended to provide a method for performing a steady-state test in a pseudo-transient manner. Each RMC consists of a series of steady state modes with a linear transition between them. The relative total time at each mode and its preceding transition match the weighting of the discrete mode steady state cycles. In some cases modes are not run in the same order as the discrete mode steady state cycles or are split to prevent extreme changes in temperature.

The exhaust emission measurement and evaluation shall be carried out using the appropriate test cycle for the application as described in general in 7.5.3. The corresponding test cycles are tabulated in Annex B. Where available the RMCs are numbered to correspond to the equivalent discrete mode cycle. Where no RMC exists for a given application the steady state test shall be conducted using the appropriate discrete mode cycle.

7.5.2.2 Requirements for conduct of test using RMC

7.5.2.2.1 Test sequence

Each test shall be performed with a warmed-up and running engine in the given sequence of the test modes for a particular test cycle.

7.5.2.2.2 Mode length

The engine shall be continuously controlled by the test bed control unit during the RMC test cycle. The mode length is defined in the respective table in Annex B. Advance from one mode to the next within a 20-second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode, and simultaneously command a similar linear progression for engine speed if there is a change in speed setting.

7.5.2.2.3 Emission measurement

The gaseous and particulate emissions shall be measured and sampled continuously during the RMC test cycle in the same way as in a transient cycle.

7.5.2.2.4 Repeat measurements

Due to the fact that emissions are measured continuously during the RMC test cycle, repeat measurements within the test cycle are not permitted.

In case of engine stall during the test the entire test is void and may be aborted. The entire test shall be restarted.

7.5.2.2.5 Equipment malfunction

If at any time during a test mode, the test equipment malfunctions or the engine speed and load do not meet the requirements of 7.5.1.2.5, the entire test is void and shall be aborted. The entire test shall be restarted.

7.5.3 Cycle types and applicability

This clause provides a general description of the test cycles for different engine applications.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

7.5.3.1 Test cycles type C "Non-road machinery and industrial equipment"

7.5.3.1.1 Test cycle type C1 "Compression-ignition engine powered non-road machinery and industrial equipment"

General-purpose variable-speed test cycle. Tables of discrete and RMC test modes are listed in A.1 and B.1 respectively.

Typical examples of applications are:

— industrial drilling rigs, compressors etc.;

— construction equipment including wheel loaders, bulldozers, crawler tractors, crawler loaders, truck-type loaders, dumpers, hydraulic excavators etc.;

— agricultural equipment, rotary tillers;

— forestry equipment;

— self-propelled agricultural vehicles (including tractors);

— material handling equipment;

— fork-lift trucks;

— road maintenance equipment (graders, road rollers, asphalt finishers);

— snow plough equipment;

— snow tractors;

— airport supporting equipment;

— aerial lifts;

— mobile cranes.

This list is not exhaustive.

NOTE 1 Compression-ignition engines with rated power typically below 19 kW intended for applications listed under 7.5.3.5 (test cycles G), can be tested according to the test cycles given in 7.5.3.1 (test cycles C).

NOTE 2 Compression-ignition engines that operate within ±15 % of the rated speed and spend less than 15 % of their time at idle speed can be tested according to test cycle D2.

This test cycle may optionally be used for spark-ignition engines >56 kW.

7.5.3.1.2 Cycle C2 "Spark-ignition engine powered non-road machinery and industrial equipment", >19 kW

Variable-speed test cycle with focus on intermediate speed operation. Tables of discrete and RMC test modes are listed in A.1 and B.1 respectively.

Typical examples of applications are:

— fork-lift trucks;

— airport supporting equipment;

— material handling equipment;

— road maintenance equipment;

— agricultural equipment.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

This list is not exhaustive.

Test cycle C1 may optionally be used for spark-ignition engines >56 kW.

7.5.3.2 Test cycles type D "Constant speed"

Test cycles for engine applications where the load is driven at constant speed. Tables of discrete and RMC test modes are listed in A.2 and B.2 respectively.

Typical examples of applications are:

— cycle D1:

  — power plants;

— cycle D2:

  — gas compressors;

  — irrigation pumps;

  — generating sets with intermittent load including generating sets on board of ships and trains (not for propulsion), welding sets;

  — turf care, chippers, snow removal equipment, sweepers.

This list is not exhaustive.

NOTE 1 Diesel engines with rated power typically below 19 kW intended for application listed under 7.5.3.5 (test cycles G) can be tested according to the test cycles given in 7.5.3.2 (test cycles D).

NOTE 2 Diesel engines that operate within ±15 % of the rated speed and spend less than 15 % of their time at idle speed can be tested according to test cycle D2.

7.5.3.3 Test cycles type E "Marine applications"

Test cycles for marine propulsion engines. Tables of discrete and RMC test modes are listed in A.3 and B.3 respectively.

Selection of test cycles shall conform to the following criteria:

— cycle E1: compression ignition engines for propulsion of craft less than 24 m in length except tug boats and push boats;

— cycle E2: constant-speed heavy duty engines for propulsion of ships of any length including diesel-electric drive and variable-pitch propeller applications;

— cycle E3: propeller-law heavy duty engines for propulsion of ships of any length;

— cycle E4: spark-ignition engines for propulsion of craft less than 24 m in length except tug boats and push boats;

— cycle E5: compression ignition engines for propulsion of craft less than 24 m in length when operated on a propeller law except for tug boats and push boats.

For compression ignition engines in craft less than 24 m in length, test cycle E1 or E5 can be applied depending on which cycle is closer to the actual operation.

For constant-speed marine propulsion engines cycle E2 applies. For variable pitch propeller sets cycle E2 or E3 may be used depending on which cycle is closer to the actual operation; usually the operation is closer to constant-speed operation (cycle E2).

For spark-ignition engines in craft less than 24 m in length test cycle E4 applies.

Documents
Document Sharing Hub

© ISO 2020 – All rights reserved

Full document details: BS ISO 8178-4:2020

7.5.3.4 Test cycle type F "Rail traction"

Test cycle for rail propulsion. Tables of discrete and RMC test modes are listed in A.4 and B.4 respectively.

Typical examples of applications are:

— locomotives;

— rail cars;

— shunting locomotives.

This list is not exhaustive.

NOTE Diesel engines for railcars can be tested according to the cycle given in 7.5.3.1.1 (C1).

7.5.3.5 Test cycles type G "Utility, lawn and garden"; typically <19 kW

Tables of discrete and RMC test modes are listed in A.5 and B.5 respectively.

If the primary end use of an engine model is known then the test cycle may be chosen based on the examples given in 7.5.3.5. If the primary end use of an engine model is uncertain then the appropriate test cycle should be chosen based upon the engine specification. Both compression ignition and spark-ignition engines may be tested in any of the three cycles; whichever is most appropriate.

Typical examples of applications are:

— cycle G1:

  — pedestrian-controlled rotary or cylinder lawn mowers;

  — front or rear engine riding lawn mowers;

  — rotary tillers;

  — edge trimmers;

  — lawn sweepers;

  — waste disposers;

  — sprayers;

  — snow removal equipment;

  — golf carts;

— cycle G2:

  — portable generators, pumps, welders, air compressors;

  — may also include lawn and garden equipment that operates at engine-rated speed;

— cycle G3:

  — edge trimmers;

  — string trimmers;

  — blowers;

  — vacuum equipment;

  — chain saws;

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

— portable saw mills.

These lists are not exhaustive.

NOTE Diesel engines of any rated power intended for applications listed in other test cycles can be tested according to that cycle (e.g. cycles D and C1).

7.5.3.6 Test cycle type H "Snowmobile"

Test cycle for snowmobile engines. Tables of discrete and RMC test modes are listed in A.6 and B.6 respectively.

7.5.3.7 Test cycle type I "Transport refrigeration unit"

Test cycle for transport refrigeration unit applications that operate at two speeds. Tables of discrete and RMC test modes are listed in A.7 and B.7 respectively.

7.6 Transient cycles

7.6.1 General

Transient cycles are listed in Annex C as a second-by-second sequence of normalized speed and torque values. In order to perform the test on an engine test cell, the normalized values shall be converted to their equivalent reference values for the individual engine to be tested, based on specific speed and torque values identified in the engine mapping curve. The conversion is referred to as denormalization, and the resulting test cycle so developed as the reference cycle of the engine to be tested. With those reference speed and torque values, the cycle shall be run on the test cell, and the actual speed, torque and power values shall be recorded. In order to validate the test run, a regression analysis between reference and actual speed, torque and power values shall be conducted upon completion of the test. For calculation of the brake specific emissions, the actual cycle work shall be calculated by integrating actual engine power over the cycle. For cycle validation, the actual cycle work must be within prescribed limits of the cycle work of the reference cycle (reference cycle work).

7.6.2 Non-road transient cycle (NRTC)

The non-road transient cycle (NRTC) may be applied to variable-speed compression-ignition or spark-ignition engines for mobile use (NRMM) with a maximum power output between 19 kW and 560 kW that are also subject to the C1 steady-state (discrete- or ramped- modal) cycle. This cycle does not apply to non-road engines for applications that are not subject to the C1 test cycle.

The sequence of normalized speed and torque values is given in C.2.

7.6.2.1 Test sequence for NRTC

The transient test cycle shall be run twice after completion of pre-conditioning:

a) As cold start after the engine and aftertreatment systems have cooled down to room temperature after natural engine cool down, or as cold start after forced cool down and the engine, coolant and oil temperatures, aftertreatment systems and all engine control devices are stabilized between 20 °C and 30 °C. The measurement of the cold start emissions shall be started with the start of the cold engine.

b) Hot soak period – Immediately upon completion of the cold start phase, the engine shall be shut-down and conditioned for the hot start by a 20 min ±1 min hot soak period.

c) The hot-start shall be started immediately after the soak period with the cranking of the engine. The gaseous analysers shall be switched on at least 10 s before the end of the soak period to avoid switching signal peaks. The measurement of emissions shall be started in parallel with the start of the hot start phase including the cranking of the engine.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

Brake specific emissions expressed in (g/kWh), or number per kilowatt-hour (#/kWh) for PN, shall be determined by using the procedures of Clause 9 or H.7 for both the cold and hot start NRTC. Composite weighted emissions shall be computed by weighting the cold start results by 10 % and the hot start results by 90 % as detailed in Clause 9 or H.7. Other weighting factors for cold start (e.g. 5 %) and hot start (e.g. 95 %) NRTC can be used if required by the parties involved. Sum of the two-weighting factor must add to 100 %

7.6.3 Large spark-ignition non-road transient cycle

The large spark-ignition non-road transient cycle (LSI-NRTC) may be applied to variable-speed spark-ignition engines for mobile use (NRMM) that are also subject to the C2 steady-state (discrete- or ramped- modal) cycle and conform to characteristics a) or b), and c):

a) a maximum power output between 19 kW and 30 kW with a swept volume ≥1 l;

b) a maximum power output greater than 30 kW but less than 560 kW;

c) a maximum engine speed ≤3 400 rpm.

This cycle does not apply to non-road engines that are not subject to the C2 test cycle and does not apply to engines for non-road utility vehicles with displacement ≤1 l and maximum power ≤30 kW, snowmobiles, off-highway motorcycles or all-terrain vehicles (ATVs).

The sequence of normalized speed and torque values is given in C.3.

7.6.3.1 Test sequence for LSI-NRTC

The transient test cycle shall be run once after completion of pre-conditioning:

a) Warm up the test engine by starting and operating for the first 180 s of the duty cycle, then operate at idle without load for 30 s. Emissions are not measured during this warm-up sequence.

b) At the end of the 30-second idling period start measuring emissions and operate the engine over the entire duty cycle starting from the beginning.

Brake specific emissions expressed in (g/kWh), or number per kilowatt-hour (#/kWh) for PN, shall be determined by using the procedures of Clause 9 or H.7.

If the engine was already operating before the test, use good engineering judgment to let the engine cool down enough so measured emissions will accurately represent those from an engine starting at room temperature. For example, if an engine starting at room temperature warms up enough in 3 min to start closed-loop operation and achieve full catalyst activity, then minimal engine cooling is necessary before starting the next test.

With the agreement of the parties involved, the engine warm-up procedure may include up to 15 min of operation over the duty cycle.

7.7 Test cycle generation

7.7.1 Generation of steady-state discrete-mode or RMC test cycles

This clause shall be used to generate the engine speeds and loads over which the engine shall be operated during steady-state discrete-mode or RMC tests.

7.7.1.1 Generation of test speeds for engines tested with both transient and steady-state cycles

For engines that are tested with a transient cycle in addition to a steady-state cycle the MTS specified in 7.2.1 shall be used as the 100 % speed for both transient and steady state tests. A declared MTS as specified by 7.2.1.2 is permitted at the choice of the manufacturer.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

The MTS shall be used in place of rated speed when determining intermediate speed according to 7.2.3.

The idle speed shall be determined according to 7.2.4.

7.7.1.2 Generation of test speeds for engines only tested with steady-state cycles

For engines that are not tested with a transient cycle, the maximum test speed specified in 7.2.2 shall be used as the 100 % speed.

The rated speed shall be used to determine the intermediate speed according to 7.2.3. If the cycle in Annex A or B specifies additional speeds as a percentage they shall be calculated as a percentage of the rated speed.

The idle speed shall be determined according to 7.2.4.

At manufacturers' discretion, MTS may be used to replace rated speed for the generation of test speeds in this clause.

7.7.1.3 Generation of load settings for each test mode

The per cent load for each test mode of the chosen test cycle shall be taken from the appropriate table of Annex A or B. Depending upon the test cycle, the load in these tables is expressed as either power or torque relative to a specified value at the specified engine speed, as listed in 7.3 and in the footnotes for each table.

The 100 % value at a given test speed shall be the measured or declared value taken from the mapping curve generated according to 7.4.2 or 7.4.3 respectively, expressed as power (kW). The engine setting for each test mode shall be calculated using the formula:

$$S = \left(\left(P_{100\%} + P_{AUX} \right) \times \frac{L}{100} \right) - P_{AUX} \tag{12}$$

where

S is dynamometer setting in kW;

$P_{100\%}$ is 100 % value of measured or declared power at the specified test speed in kW;

P_{AUX} is sum of the declared total power absorbed by auxiliaries that are to be removed for the test but which are installed minus the declared total power absorbed by auxiliaries that should be fitted for the test but were not installed, (see 5.2.4) at the specified test speed in kW;

L is % torque.

A warm minimum torque that is representative of in-use operation may be declared. For example, if the engine is typically connected to a machine that does not operate below a certain minimum torque, this torque may be declared and used for any load point that would otherwise fall below this value.

In the case of cycle D1 and D2 the manufacturer shall declare the maximum continuous power and rated power respectively and these shall be used as 100 % power when generating the test cycle.

7.7.2 Generation of NRTC and LSI-NRTC

This clause shall be used to generate the engine speeds and loads over which the engine shall be operated during NRTC or LSI-NRTC tests.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020

7.7.2.1 Denormalization of engine speed

Each engine speed from Annex C shall be denormalized using the following formula:

$$n_{\text{ref}} = \frac{n_{\text{norm}} \times (n_{\text{MTS}} - n_{\text{idle}})}{100} + n_{\text{idle}} \tag{13}$$

where

n_{ref} is reference speed;

n_{MTS} is maximum test speed;

n_{idle} is idle speed;

n_{norm} is value of NRTC or LSI-NRTC normalized speed taken from Annex C.

A declared MTS as specified by 7.2.1.2 is permitted at the choice of the manufacturer.

7.7.2.2 Denormalization of engine torque

The torque values in the engine dynamometer schedule of Annex C are normalized to the maximum torque at the respective speed. The torque values of the reference cycle shall be denormalized, using the mapping curve determined according to 7.4.1, as follows:

$$T_{\text{ref}} = \frac{T_{\text{norm}} \times T_{\text{max}}}{100} \tag{14}$$

where

T_{ref} is reference torque for the respective reference speed;

T_{max} is maximum torque for the respective test speed taken from the engine mapping performed according to 7.4.1 adjusted where necessary according to 7.7.2.2.1;

T_{norm} is value of NRTC or LSI-NRTC normalized torque taken from Annex C.

7.7.2.2.1 Adjustment of engine torque due to auxiliaries fitted for the emissions test

Where auxiliaries are fitted in accordance with Annex G there shall be no adjustment to the maximum torque for the respective test speed taken from the engine mapping performed according to 7.4.1.

Where, according to 5.2.1 or 5.2.2 necessary auxiliaries that should have been fitted for the test are not installed, or auxiliaries that should have been removed for the test are installed, the value of T_{max} shall be adjusted according to this clause.

$$T_{\text{max}} = T_{\text{map}} - T_{\text{AUX}} \tag{15}$$

where

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 8178-4:2020