INTERNATIONAL STANDARD

ISO 8178-4

First edition
1996-08-15

Reciprocating internal combustion engines — Exhaust emission measurement —

Part 4:
Test cycles for different engine applications

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

Partie 4: Cycles d'essai pour différentes applications des moteurs

Reference number
ISO 8178-4:1996(E)

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Annexes

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 8178-4 was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*, Subcommittee SC 8, *Exhaust gas emission measurement*.

ISO 8178 consists of the following parts, under the general title *Reciprocating internal combustion engines — Exhaust emission measurement*:

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

— *Part 2: Measurement of gaseous and particulate exhaust emissions at site*

— *Part 3: Definitions and methods of measurement of exhaust gas smoke under steady-state conditions*

— *Part 4: Test cycles for different engine applications*

— *Part 5: Test fuels*

— *Part 6: Test report*

— *Part 7: Engine family determination*

— *Part 8: Engine group determination*

— *Part 9: Test bed measurement of exhaust gas smoke emissions from engines used in non-road mobile machinery*

Annexes A, B and C of this part of ISO 8178 are for information only.

Introduction

In comparison with engines for on-road applications, engines for off-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 part of ISO 8178 is to rationalize the test procedures for off-road engines in order to simplify and make cost effective the drafting of legislation, the development of engine specifications and the certification of engines to control gaseous and particulate emissions.

This part of ISO 8178 embraces three principles in order 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 ensuring that the test cycles are representative of actual engine operation. The modes of these cycles have been selected so that the majority of test cycles are sub-sets of a universal test cycle.

The second principle is to express the emissions results on the basis of brake power as defined in ISO 8178-1:1996, 3.9. This ensures that alternative engine applications do not result in a multiplicity of tests.

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

Reciprocating internal combustion engines — Exhaust emission measurement —

Part 4:
Test cycles for different engine applications

1 Scope

This part of ISO 8178 specifies the test cycles for the measurement and the evaluation of gaseous and particulate exhaust emissions from reciprocating internal combustion (RIC) engines coupled to a dynamometer. With some certain restrictions this part of ISO 8178 can also be used for measurements at site. The tests are to be carried out under steady-state operation using test cycles which are representative of given applications.

This part of ISO 8178 is applicable to RIC engines for mobile, transportable and stationary use, excluding engines for motor vehicles primarily designed for road use. It may be applied to engines used, 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 powerplants) additional test conditions and special evaluation methods may apply.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 8178. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 8178 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

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

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

ISO 8178-5:—[1], *Reciprocating internal combustion engines — Exhaust emission measurement — Part 5: Test fuels.*

1) To be published.

ISO 8178-6:—[1], *Reciprocating internal combustion engines — Exhaust emission measurement — Part 6: Test report.*

ISO 8178-7:—[1], *Reciprocating internal combustion engines — Exhaust emission measurement — Part 7: Engine family determination.*

ISO 8178-8:—[1], *Reciprocating internal combustion engines — Exhaust emission measurement — Part 8: Engine group determination.*

ISO 8528-1:1993, *Reciprocating internal combustion engine driven alternating current generating sets — Part 1: Application, ratings and performance.*

3 Definitions

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

3.1 test cycle: A sequence of engine test modes each with defined speed, torque and weighting factor W_F (except cycle B "Universal" without weighting factors), where the weighting factors only apply if the test results are expressed in g/kWh.

3.2 preconditioning of the engine: Warming up of the engine at the rated power used in the test cycle to stabilize the engine parameters according to the recommendations of the manufacturer.

NOTE 1 A preconditioning phase should also protect the actual measurement against the influence of deposits in the exhaust system from a former test.

There is also a period of stabilization in the test modes which has been included to minimize point-to-point influences.

3.3 mode: An engine operating point characterized by a speed and a torque (or an output).

3.4 mode length: The time between leaving the speed and/or torque of the previous mode or the preconditioning phase and the beginning of the following mode. It includes the time during which speed and/or torque is changed and the stabilization at the beginning of each mode.

3.5 rated speed: Speed at which, according to the statement of the engine manufacturer, the rated power is delivered. (For details see ISO 3046-1.)

3.6 intermediate speed: That declared by the manufacturer, taking into account the requirements given in clause 6.

3.7 engine family: A manufacturer's grouping of engines which, through their design, are expected to have similar exhaust emission characteristics where members of the family must comply with the applicable emission limit values. [ISO 8178-7]

4 Symbols and abbreviations

For the use of this part of ISO 8178 the symbols and abbreviations defined in ISO 8178-1, ISO 8178-2, ISO 8178-3, ISO 8178-5, ISO 8178-6, ISO 8178-7 and ISO 8178-8 shall be used.

Essential units for this part of ISO 8178 are:

Symbol	Term	Unit
n	Engine speed	min^{-1}
M	Torque	Nm
P	Uncorrected brake power	kW
W_F	Weighting factor	1

5 Torque

5.1 The torque figures given in the test cycles (B, C1, C2, D1, D2, E1, E2, F, G1, G2 and G3) are percentage values which represent, for a given test mode, the ratio of the required torque to the maximum possible torque at this given speed. (See ISO 8178-1:1996, 11.5.) Figure 1 shows torque scales.

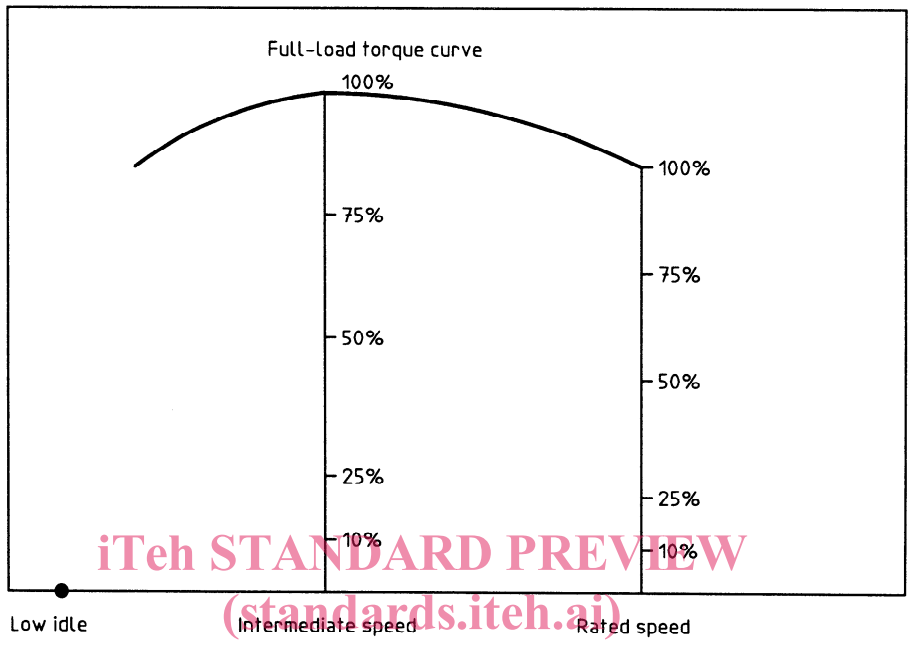

Figure 1 — Torque scales

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

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 ignited engine operation.

For the test cycle E5 the power figures are percentage values of the maximum rated power at the rated 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.

NOTE 2 Other propeller characteristic curves exist.

Figure 2 shows the two representative curves chosen by ISO TC70/SC8.

6 Intermediate speed

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

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

If the declared maximum torque speed is greater than 75 % of the rated speed then the intermediate speed shall be 75 % of rated speed.

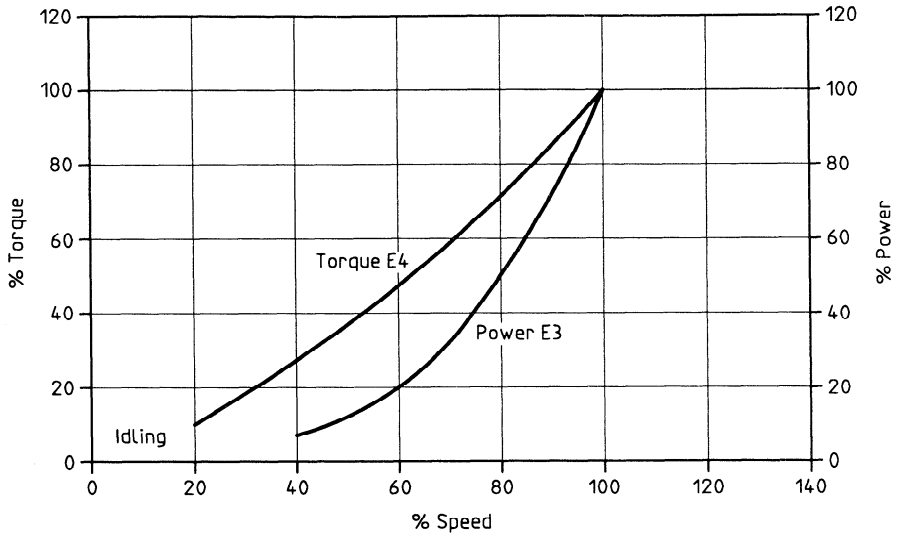

Figure 2 — Examples of power scales

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

6.3 For engines which are to be used to propel vessels with a fixed propeller specified in 8.5 the intermediate speeds are defined in clause 8.

6.4 For engines to be tested on test cycle G1, the intermediate speed shall be 85 % of the maximum rated speed.

7 Information regarding preparation of the test

No.	Item	See ISO 8178-1:1996, clause or subclause	See ISO 8178-2:1996, clause or subclause
7.1	Test conditions	5.2	5.2
7.2	Power	3.9, 5.3	3.9, 5.3
7.3	Engine air inlet system	5.4	5.4
7.4	Engine exhaust system	5.5	5.5
7.5	Test fuels, reference fuels (ISO 8178-5)	6	6
7.6	Measurement equipment and data to be measured	7	7
7.7	Accuracy of the measuring instruments	7.3	7.3
7.8	Determination of exhaust gas flow	7.2	7.2
7.9	Determination of the gaseous components	7.4, 15	7.4, 15 [1)]
7.10	Determination of the particulates	7.5, 16	7.5, 16 [1)]

No.	Item	See ISO 8178-1:1996, clause or subclause	See ISO 8178-2:1996, clause or subclause
7.11	Calibration of the analytical instruments	8	8 1)
7.11.1	Calibration procedure	8.5	8 1)
7.11.2	Verification of the calibration	8.6	8 1)
7.12	Efficiency test of the NO_x converter	8.7	8 1)
7.13	Checking of HFID hydrocarbon response	8.8	8 1)
7.14	Calibration intervals	8.10	8 1)
7.15	Calibration of the particulate sampling system	9	9 1)
7.17	Test run	11	11 1)
7.18	Data evaluation for gaseous and particulate emissions	12	12 1)
7.19	Calculation of gaseous emissions	13	13 1)
7.20	Calculation of particulate emissions	14	14 1)
7.21	Analytical and sampling systems	15	15 1)

1) For this item the clause of ISO 8178-2 contains references to the applicable clause(s) of ISO 8178-1. In some cases the necessary differences for the site conditions are described in ISO 8178-2.

8 Modes and weighting factors for test cycles

8.1 General

8.1.1 Remarks

The exhaust emission measurement and evaluation shall be carried out using the appropriate test cycle for the application as described in general in 8.2 to 8.7. For special cases not shown, an adequate choice has to be made and to be agreed upon by the parties concerned.

Most of the following test cycles have been derived from the test modes of the UN-ECE R49 13-mode steady-state test cycle. This test cycle is described in annex A as cycle type A.

Apart from the test modes of cycles E3, E4 and E5, which are calculated from propeller curves, the test modes of the other cycles can be combined into a universal cycle (B) without weighting factors. From emissions data for each of the modes of cycle B, emissions values for each of the other cycles may be calculated using the appropriate weighting factors.

To evaluate the particulate emission from the universal cycle (B) 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.

The test equipment and test cycles of ISO 8178-1 and this part of ISO 8178 may also be used for the measurement of particulate emissions from spark ignited engines, e.g. 2-stroke engines.

8.1.2 Requirements

Each test shall be performed in the given sequence of the test modes for a particular test cycle or in the sequence of test modes in cycle B if two or more cycles have been combined. The minimum test mode length is 10 min

which is the standard, except for test cycles G (see 8.7.2). If necessary the mode length may be extended, e.g. to collect sufficient particulate sample mass or to achieve stabilization with large engines.

The mode length shall be recorded and reported.

The gaseous exhaust emission concentration values shall be measured and recorded for the last 3 min of the mode, except for test cycles G (see 8.7.2).

The completion of particulate sampling shall be coincident with the completion of the gaseous emission measurement and shall not commence before engine stabilization, as defined by the manufacturer, has been achieved.

8.2 Test cycle type B "Universal"

8.2.1 Test modes and weighting factors

Mode number (cycle B)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Speed [1]	Rated speed					Intermediate speed					Low-idle speed
Torque [1], %	100	75	50	25	10	100	75	50	25	10	0
1) See ISO 8178-1:1996, 11.5, and clauses 3.5, 3.6, 5 and 6 of this part of ISO 8178.											

8.2.2 Performing the test

The test shall be performed in ascending order of mode numbers of cycle B.

The provisions of 8.1.2 shall be taken into account.

8.2.3 Criteria for the application of this test

This test should be used only as a basis for calculation of emissions for the other test cycles.

8.3 Test cycles type C "Off-road vehicles and industrial equipment"

8.3.1 Cycle C1 "Off-road vehicles, diesel-powered off-road industrial equipment"

8.3.1.1 Test modes and weighting factors

Mode number (cycle B)	1	2	3	4	5	6	7	8	9	10	11
Mode number (cycle C1)	**1**	**2**	**3**		**4**	**5**	**6**	**7**			**8**
Speed [1]	Rated speed					Intermediate speed					Low-idle speed
Torque [1], %	100	75	50		10	100	75	50			0
Weighting factor	0,15	0,15	0,15		0,1	0,1	0,1	0,1			0,15
1) See ISO 8178-1:1996, 11.5, and clauses 3.5, 3.6, 5 and 6 of this part of ISO 8178.											

8.3.1.2 Performing the test

The test shall be performed in ascending order of mode numbers of cycle C1.

The provisions of 8.1.2 shall be taken into account.

Alternatively, it is possible to calculate the emission results from test cycle type B.

8.3.1.3 Criteria for the application of this test

Typical examples are:

— industrial drilling rigs, compressors, etc.;

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

— agricultural equipment, rotary tillers;

— forestry equipment;

— self-propelled agricultural vehicles (including tractors);

— material handling equipment;

— fork-lift trucks;

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

— snow-plough equipment;

— airport supporting equipment;

— aerial lifts;

— mobile cranes.

This list is not exhaustive.

NOTES

3 Diesel engines with rated power typically below 20 kW intended for applications listed under 8.7.3 (test cycles G), may be tested according to the test cycles given in 8.3 (test cycles C).

4 Diesel engines with hydrostatic or hydraulic transmission which operate within ± 15 % of the rated speed and spend less than 15 % of their time at low idle speed may be tested according to test cycle D2 (see 8.4).