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Reciprocating internal combustion engines — Exhaust emission measurement —

Part 9:
Test cycles and test procedures for test bed measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions

AMENDMENT 1

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

Partie 9: Cycles et procédures d'essai pour le mesurage au banc d'essai des émissions de fumées de gaz d'échappement des moteurs alternatifs à combustion interne à allumage par compression fonctionnant en régime transitoire

AMENDEMENT 1

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

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.

Amendment 1 to ISO 8178-9:2000 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: Report of measuring results and test*

— *Part 7: Engine family determination*

— *Part 8: Engine group determination*

— *Part 9: Test cycles and test procedures for test bed measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions*

— *Part 10: Test cycles and test procedures for field measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions*

— *Part 11: Test-bed measurement of gaseous and particulate exhaust emissions from engines used in nonroad mobile machinery under transient test conditions*

Reciprocating internal combustion engines — Exhaust emission measurement —

Part 9: Test cycles and test procedures for test bed measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions

AMENDMENT 1

Introduction, page v

Add the following two paragraphs at the end:

The test cycle described in Annex E is representative for those engines that are used in applications as described in the E1, E2, E3 and E5 cycles of ISO 8178-4:1996.

The test cycle described in Annex F is representative for those engines that are used in applications as described in the F cycle of ISO 8178-4:1996.

Scope, page 1

Replace the sentence “Annexes A and B to this part of ISO 8178 each contain a test cycle that is relevant only for those specific applications listed in the Scope of that annex.” with the following:

Annexes A, B, E and F to this part of ISO 8178 each contain a test cycle that is relevant only for those specific applications listed in the Scope of that annex.

Clause 2, page 1

Replace ISO 8178-4 by ISO 8178-4:1996.

Clause 2, page 2

Add after ISO 8178-7:

ISO 8178-8:1996, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 8: Engine group determination*

ISO 8178-9:2000, *Reciprocating internal combustion engines — Exhaust emission measurement — Part 9: Test cycles and test procedures for test bed measurement of exhaust gas smoke emissions from compression ignition engines operating under transient conditions*

Page 41

Add after Annex D the following normative annexes as Annex E and Annex F.

Annex E
(normative)

Test cycle for marine propulsion engines

E.1 General

Marine engine operations occurs over a much more limited combination of speed and torque as compared to on-road and mobile off-road engines. This is partly due to the fact that marine engines are not equipped with a shiftable gearbox and partly to the physical behaviour of the power transmission from the propeller to the water.

There are two principle torque-to-speed relationships: the propeller law, defined by torque $= f(n^2)$, where n is the number of revolutions of the crankshaft in a given period of time, with a fixed propeller or water jet, and the constant-speed law (comparable to generator applications), which is applicable with a controllable-pitch propeller. These principles correspond with the E1, E2, E3 and E5 test cycles of ISO 8178-4:1996. Therefore, the smoke during the engine load increase, for both cases (with or without speed increase), is more stable and influenced mainly by the rate of load increase. This rate is subjected to automatic limitation procedures of various kinds.

One example is the power-increase rate. For marine engines, the power-increase rate is slower as compared to on-road or mobile off-road engines. This is partly due to the physical behaviour of the power transmission from the propeller to the water. In all such cases, the engine will be controlled by its management or control system depending on the kind of the vessel. This “standard case” is also the worst case, and is very suitable as basis for dynamic smoke measurements. Engines with various management or control settings can be combined in engine families or groups, with a worst case being tested for the complete family or group.

On board vessels, safety is always of paramount importance. Therefore, although automatic control is the general rule, an exception shall remain for emergency cases where overriding of the system is needed to reduce imminent danger. In such an emergency case, there might be an increased smoke rate due to greater engine acceleration. Such increased smoke rates are not considered in this annex.

E.2 Application of the smoke-test cycle

The smoke-test cycle described in this annex is applicable to those engines which are included in the E1, E2, E3 and E5 cycles of ISO 8178-4:1996. The factor governing whether to use the test cycle in this annex is the loaded acceleration time. This should be 20 s ± 5 s or be as declared by the manufacturer, taking into account the engine management or control system. Those marine propulsion engines that can be used in the application for mobile off-road engines may optionally be tested according the procedures in Annex A.

The following are typical applications:

— E1: diesel engines for craft less than 24 m long (derived from test cycle B);

— E2: constant-speed, heavy-duty engines for vessel propulsion without limitation in length;

— E3: propeller-law, heavy-duty engines for vessel propulsion without limitation in length;

— E5: diesel engines for craft less than 24 m long (propeller law).

This annex has been confirmed for engines with rated power of up to 1 500 kW.

E.3 Terms and definitions

E.3.1
test under transient load
⟨variable-speed engines⟩ that portion of the procedure which consists of running the engine through a clearly defined cycle consisting of an acceleration mode under load, and a mode at 80 % of rated speed under load

E.3.2
test under transient load
⟨constant-speed engines⟩ that portion of the procedure which consists of running the engine at rated speed through a clearly defined cycle consisting of a load-increase mode and a mode at 50 % of rated power

E.3.3
load-increase time
⟨variable-speed engines⟩ time an engine requires to accelerate from low-idle speed to 80 % of rated speed, during which acceleration, the engine load is controlled so the engine torque corresponds to the transient load curve

E.3.4
load-increase time
⟨constant-speed engines⟩ time an engine requires at rated speed to increase the load from no-load to 50 % of rated power

E.3.5
transient-load curve
⟨variable-speed engines⟩ propeller curve, defined by the $= f(n^2)$, at the end point of which the rated power is reached at the rated speed

NOTE The variable n is the number of revolutions of the crankshaft in a given period of time.

E.3.6
transient-load curve
⟨constant-speed engines⟩ constant-speed curve at rated speed, at the end point of which the rated power is reached

E.3.7
peak smoke value
PSV
average of the three highest 1,0 s Bessel-averaged smoke values obtained during the test under transient load

E.4 Test cycle

E.4.1 General

During smoke measurement in the test under transient load (described in detail in E.4.2 and E.4.3), the engine load is increased as rapidly as possible, either on the propeller curve or at constant speed. The load-increase rate, and thus the load-increase time, is controlled by the engine management or control system.

This cycle is suitable for use on the test stand as well as for measurements with the engine installed in the vessel.

When engine smoke is measured on the test stand, the load-increase time can be varied within a range that covers the service conditions of an engine family or engine group, which shall be defined in accordance with ISO 8178-7 and ISO 8178-8.

E.4.2 Preconditioning of the engine

The engine shall be warmed up at rated power in accordance with the manufacturer's recommendations in order to stabilize the engine operating parameters.

NOTE This preconditioning phase also insulates the current measurement against the influence of a previous test and is considered as creating reference conditions.

E.4.3 Conducting a test under transient load

E.4.3.1 General

The test under transient load shall be performed immediately following the preconditioning, as described in E.4.2. Conducting a test under transient load begins with a conditioning cycle to improve repeatability of the results. The conditioning cycle is followed by three load-increase cycles. The loaded transient test sequence is described in E.4.3.4 and E.4.3.5.

E.4.3.2 Variable-speed engines

The test under transient load consists of accelerating the engine from low-idle speed to 80 % of rated speed against the load that is described by the function torque $= f(n^2)$. The sequence is shown graphically in Figure E.1.

E.4.3.3 Constant-speed engines

The test under transient load consists of increasing the engine load at rated speed from the lowest possible stabilized load to 50 % of the rated speed. The sequence is shown graphically in Figure E.2.

E.4.3.4 Test sequence for variable-speed engines

E.4.3.4.1 Conditioning cycle

The conditioning cycle is carried out as follows.

a) The engine shall be operated at the lowest possible stabilized load with the load/speed control lever in the lowest possible position at low-idle speed for 40 s ± 5 s.

b) From the low-idle speed, the load/speed control lever shall be moved

   1) to an open position allowing the engine to reach 80 % of its rated speed in 20 s ± 5 s, or

   2) rapidly to, and held at, the fully-open position. The engine shall accelerate against the load on the transient load curve to 80 % of its rated speed in the time permitted by the engine management or control system.

c) 80 % of rated speed and the given load as specified in the transient load curve shall be maintained for 60 s ± 5 s.

d) The load shall be reduced and the load/speed control lever shall be returned to the low-idle position.

E.4.3.4.2 Measurement cycle

Repeat steps E.4.3.4.1 a) through d) until three consistent, consecutive results are obtained.

E.4.3.5 Test sequence for constant-speed engines

E.4.3.5.1 Conditioning cycle

The conditioning cycle is carried out as follows.

a) The engine shall be operated at the lowest possible stabilized load at rated speed for 40 s ± 5 s.

b) At rated speed, the load/speed control lever shall be moved

— to an open position allowing the engine to reach 50 % of its rated load in 20 s ± 5 s;

— rapidly to the 50 % position and held at this position. The engine load shall increase at constant engine speed to 50 % of its rated load in the time permitted by the engine management or control system.

c) 50 % of rated power at rated speed shall be maintained for 60 s ± 5 s.

d) The load shall be reduced and the load control lever shall be returned to the lowest possible stabilized load position at rated speed.

E.4.3.5.2 Measurement cycle

Repeat steps E.4.3.5.1 a) through d) until three consistent, consecutive results are obtained.

E.4.3.6 Test validation criteria — Test under transient load

The acceleration test results under load shall be considered valid only after the following test cycle criteria are met:

The arithmetic difference between the highest and the lowest maximum 1,0 s Bessel-averaged smoke values from the three successive acceleration tests under load shall not exceed 5,0 % opacity.

Additional test validation criteria are given in ISO 8178-9:2000, 5.1.2 and 7.3.2.3.

E.5 Analysis of results

E.5.1 General

Subclause D.5 describes how to analyse the results of the test under transient load. Many opacimeters used for this test have a smoke output signal corresponding to $X = 0{,}5$ s Bessel-averaged smoke value according to the algorithm described in 10.2. For these opacimeters, further signal conditioning is needed to produce results equivalent to the formula in which $X = 1{,}0$ s, and where the value for $(t_p^2 + t_e^2)$ used in ISO 8178-9:2000, 10.2.2, Equation (11), is $0{,}5^2$. Analysis of the raw smoke results, e.g. those not already processed according to the 0,5 s Bessel algorithm, shall use a value for $(t_p^2 + t_e^2)$ which represents the opacimeter system used.

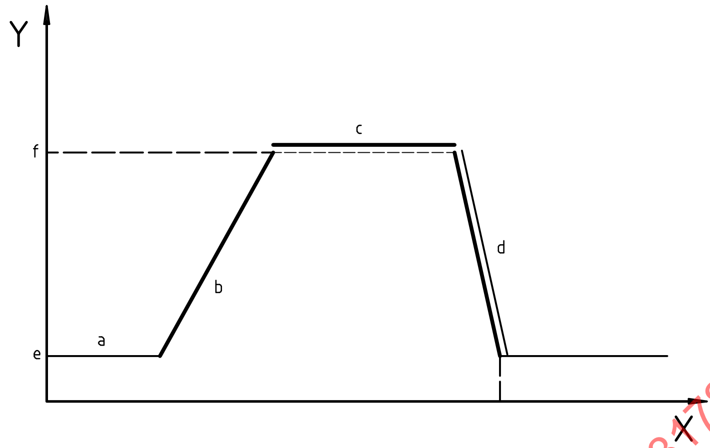
E.5.2 Peak smoke value (PSV)

Determine the highest 1,0 s Bessel-averaged smoke value among the three repetitions mentioned in E.4.3. Care should be taken to assure that the smoke data which are analysed correspond to the time during which the load increase occurs (see ISO 8178-9:2000, 10.1.1). PSV is the average of the three highest 1,0 s Bessel-averaged smoke values obtained during load increase.

The methodology for calculating Bessel-averaged numbers can be found in ISO 8178-9:2000, 10.2. For peak smoke values, the value of X in Equation (11) is 1,0 s.

E.6 Reported results

The following smoke values shall be reported: PSV_1, PSV_2, PSV_3, plus PSV_a (the average of PSV_1, PSV_2 and PSV_3). The duration for the three tests (during the load increases) shall also be reported.



Key

X time, s

Y engine speed

[a] "Control lever" in no-load position; 40 s ± 5 s.

[b] Time, 20 s ± 5 s or as declared by engine manufacturer:
1) "control lever" in open position
2) "control lever" in fully open position.

[c] Maintained speed; 60 s ± 5 s.

[d] "Control lever" returned to idling position; time declared by engine manufacturer.

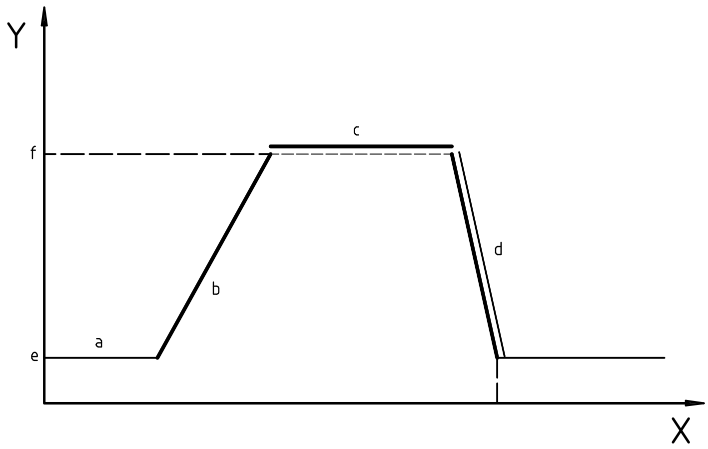
[e] Idle.

[f] 80 % rated.

Time lapses [a] to [d] refer to the list items in E.4.3.4.1.

Note Depending on engine specifications, deviations from a linear ramp are possible in accordance with E.4.1

Figure E.1 — Testing under transient load — Variable-speed engines



Key

X time, s

Y engine power

[a] “Control lever” in no-load position; 40 s ± 5 s.

[b] Time, 20 s ± 5 s or as declared by engine manufacturer:
1) “control lever” in open position
2) “control lever” in fully open position.

[c] Maintained speed; 60 s ± 5 s.

[d] “Control lever” returned to no.load position; time declared by engine manufacturer.

[e] 0 %.

[f] 50 % rated.

Time lapses [a] to [d] refer to the list items in E.4.3.5.1.

Note Depending on engine specifications, deviations from a linear ramp are possible in accordance with E.4.1

Figure E.2 — Loaded acceleration test — Constant-speed engines

Annex F
(normative)

Test cycle for variable-speed engines type F (rail traction)

F.1 General

An acceleration test against the engine's inertial moment (no-load) is not relevant for rail-traction engines, because, to avoid locomotive wheel slip, the throttle response of rail-traction engines is not as rapid as that of off-road (C1) engines. When the engine is accelerating, the throttle of rail-traction engines is not opened quickly but on a time-based load-increase rate. Engines with differing settings for the engine management or control system can be combined into engine families or groups for which the worst case, representative of the complete family or group, is tested.

The test will normally be carried out with the engine on a test bench with all static equipment and measurement instruments. In some cases, it is possible to absorb the produced power in a static test bench installation (e.g. load-bank system) without dismantling the engine from the locomotive.

F.2 Application of the test cycle

This annex has been confirmed for engines with rated power up to 1 500 kW.

F.3 Terms and definitions

F.3.1
test under transient load
that portion of the procedure which consists of running the engine through a clearly defined cycle consisting of an acceleration mode under load, and a rated-speed, full-load mode

F.3.2
acceleration time under load
time an engine requires to accelerate from idle speed to the rated speed; during acceleration, the engine load is controlled so the engine power lies on the acceleration load curve

NOTE The acceleration time under load is controlled by the engine management or control system.

F.3.3
acceleration load curve
transient load curve chosen for this test, representative of the natural load curve of hydraulic dynamometers, which is approximately of the form torque $= f(n^2)$ which in turn represents actual load curves in service

NOTE In cases where the test is carried out with a generator, the relationship torque $= f(n^2)$, where n is the number of revolutions of the crankshaft in a given period of time, is used.

F.3.4
peak smoke value
PSV
average of the three highest 1,0 s Bessel-averaged smoke values obtained during the acceleration modes of the tests under transient load