

# ISO 8178-9:2019 (E)

## Reciprocating internal combustion engines — Exhaust emission measurement — Part 9: Test cycles and test procedures for measurement of exhaust gas smoke emissions from compression ignition engines using an opacimeter

---

### Contents

	Foreword
	Introduction
1	Scope
2	Normative references
3	Terms and definitions
4	Symbols and abbreviated terms
4.1	Symbols
4.2	Abbreviated terms
5	Test conditions
6	Test fuels
7	Measurement equipment and accuracy
7.1	General
7.2	Engine and ambient related testing equipment
7.3	Opacimeters
7.3.1	General
7.3.2	Types of opacimeters
7.3.2.1	Partial-flow opacimeter
7.3.2.2	Full-flow opacimeters
7.3.3	Performance Specifications
7.3.3.1	Linearity
7.3.3.2	Zero drift
7.3.3.3	Opacimeter display and range
7.3.3.4	Instrument rise time
7.3.3.5	Neutral density filters
7.3.4	Calibration of the opacimeter
7.3.4.1	Calibration procedure
7.3.4.2	Linearity
8	Test run execution
8.1	Installation of the measuring equipment
8.1.1	General
8.1.2	Exhaust pipe
8.1.3	Rain caps
8.1.4	Field testing
8.2	Checking of the opacimeter
8.3	Test cycle
9	Data evaluation and calculation
9.1	Data evaluation
9.1.1	General requirements — Opacimeters
9.1.2	Beer-Lambert relationships
9.1.3	Data conversion
9.1.4	Effective optical path length input values
9.2	Signal filter algorithm

- 9.2.1 General
- 9.2.2 Calculation of filter rise time and Bessel constants
- 9.2.3 Calculation of Bessel filtered smoke
- 9.3 Alternative signal handling
- 9.3.1 General
- 9.3.2 Alternative specifications

## 10 Opacimeter Design Specifications

- 10.1 General
- 10.2 Full-flow opacimeter
- 10.2.1 General
- 10.2.2 Components of a full-flow opacimeter
  - 10.2.2.1 Light source (LS)
  - 10.2.2.2 Light detector (LD)
  - 10.2.2.3 Collimating lens (CL)
  - 10.2.2.4 Temperature sensor (TS)
  - 10.2.2.5 Optical path length (OPL)
- 10.3 Determination of effective optical path length (LA)
  - 10.3.1 General
  - 10.3.2 External versus internal tailpipe dimensions
    - 10.3.2.1 General
    - 10.3.2.2 Straight circular non-bevelled tailpipes
    - 10.3.2.3 Straight circular bevelled tailpipes
    - 10.3.2.4 Curved circular tailpipes
    - 10.3.2.5 Non-circular tailpipe
- 10.4 Partial-flow-opacimeter
  - 10.4.1 General
  - 10.4.2 Components of partial-flow opacimeter
    - 10.4.2.1 Sampling probe (SP)
    - 10.4.2.2 Transfer tube (TT)
    - 10.4.2.3 Flow monitoring device (FM)
    - 10.4.2.4 Measuring chamber (MC)
    - 10.4.2.5 Optical path length (OPL)
    - 10.4.2.6 Light source (LS)
    - 10.4.2.7 Light detector (LD)
    - 10.4.2.8 Collimating lens (CL)
    - 10.4.2.9 Temperature sensor (TS)
    - 10.4.2.10 Sampling pump (SPU)

Annex A (informative) Overview particulate and soot measurement methods

Annex B (informative) Example of calculation procedure

- B.1 General
- B.2 General remarks on the Bessel filter
- B.3 Calculation of the Bessel algorithm
  - B.3.1 General
  - B.3.2 Step 1: Required Bessel filter rise time tF
  - B.3.3 Step 2: Estimation of cut-off frequency, fc, and calculation of Bessel constants E and K for first iteration
  - B.3.4 Step 3: Application of Bessel filter on step input
  - B.3.5 Step 4: Filter rise time of first iteration cycle tF,iter
  - B.3.6 Step 5: Deviation between required and obtained filter rise time,  $\Delta$ , of first iteration cycle
  - B.3.7 Step 6: Checking the iteration criteria
  - B.3.8 Step 7: Final Bessel algorithm
- B.4 Calculation of the smoke values
  - B.4.1 General
  - B.4.2 Calculation of the unfiltered k-value (optional)
  - B.4.3 Calculation of Bessel averaged smoke (filtered k-value)

Annex C (informative) Remarks on test cycles

Annex D (normative) Test cycle for variable-speed non-road engines

- D.1 General

D.2	Test cycle
D.2.1	General
D.2.2	Preconditioning of the engine
D.2.3	Free acceleration test
D.2.3.1	General
D.2.3.2	Test validation criteria — Free acceleration test
D.2.3.3	Determination of free acceleration time (FAT)
D.2.4	Reconditioning of the engine
D.2.5	Loaded transient test
D.2.5.1	General
D.2.5.2	Loaded transient test times
D.2.5.3	Conducting a loaded transient test
D.2.5.4	Conducting a loaded transient test — Alternative procedure
D.3	Analysis of results
D.3.1	General
D.3.2	Peak smoke value (PSVF, PSV3, PSV6, PSV9)
D.3.3	Lug smoke value (LSV)
D.4	Reported results

**Annex E (normative) Test cycle for constant-speed non-road engines**

E.1	General
E.2	Test cycle
E.2.1	Engine load step
E.2.2	Preconditioning of the engine
E.2.3	Test procedure
E.2.4	Test Validation Criteria
E.3	Analysis of results
E.3.1	General
E.3.2	Steady-state smoke value (SSSV)
E.3.3	Peak smoke value (PSV)
E.4	Reported results

**Annex F (normative) Test cycle for marine propulsion engines**

F.1	General
F.2	Application of the smoke-test cycle
F.3	Test cycle
F.3.1	General
F.3.2	Preconditioning of the engine
F.3.3	Conducting a test under transient load
F.3.3.1	General
F.3.3.2	Variable-speed engines
F.3.3.3	Constant-speed engines
F.3.3.4	Test sequence for variable-speed engines
F.3.3.4.1	Conditioning cycle
F.3.3.4.2	Measurement cycle
F.3.3.5	Test sequence for constant-speed engines
F.3.3.5.1	Conditioning cycle
F.3.3.5.2	Measurement cycle
F.3.3.6	Test validation criteria — Test under transient load
F.4	Analysis of results
F.4.1	General
F.4.2	Peak smoke value (PSV)
F.5	Reported results

**Annex G (normative) Test cycle for variable speed engines type F (rail traction)**

G.1	General
G.2	Application of the test cycle
G.3	Test cycle
G.3.1	General
G.3.2	Preconditioning of the engine
G.3.3	Test under transient load
G.3.3.1	General
G.3.3.2	Acceleration time under transient loading
G.3.3.3	Conducting a test under transient load

- G.3.3.3.1 General**
- G.3.3.3.2 Conditioning cycle**
- G.3.3.3.3 Measurement cycle**
- G.3.3.4 Test validation criteria — Test under transient load**
- G.4 Analysis of results**
- G.4.1 General**
- G.4.2 Peak Smoke value (PSV)**
- G.5 Reported results**

**Annex H (informative) Test at steady speeds over full-load curve**

- H.1 General**
- H.2 Test cycle**
- H.2.1 General**
- H.2.2 Test conditions**
- H.2.3 Preconditioning of the engine**
- H.2.4 Measurement cycle**
- H.2.5 Test validation criteria**
- H.3 Analysis of results**
- H.4 Reported results**

**Annex I (normative) Reporting smoke test results**

- I.1 General**
- I.2 Smoke emissions test report**

**Page count: 65**