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Reciprocating internal combustion engines — Exhaust emission measurement —

Part 3: Test procedures for measurement of exhaust gas smoke emissions from compression ignition engines using a filter type smoke meter

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Moteurs alternatifs à combustion interne — Mesurage des émissions de gaz d'échappement —
Partie 3: Définitions et méthodes de mesure de la fumée des gaz d'échappement dans des conditions stabilisées

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Foreword

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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).

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This document was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*, Subcommittee SC 8, *Exhaust gas emission measurement*.

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This second edition cancels and replaces the first edition (ISO 8178-3:1994), which has been technically revised.

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

— smoke measurement by an opacimeter has been removed; this will be handled in ISO 8178-9;

— definitions of exhaust gas components related to exhaust gas smoke has been added.

This document is intended to be used in conjunction with ISO 10054.

A list of all 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.

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Introduction

There exist several measurement methods to determine the components of smoke emissions. Each method is measuring special properties of smoke. Therefore, the results obtained with different methods are typically not comparable among each other.

The objective of this document is to give a guidance for measurement of soot with a filter type smoke meter, knowing about the different components of the smoke of compression ignition engines and their particular properties.

An overview of the measurement methods specified by ISO 8178-1, ISO 8178-3, ISO 8178-9 and ISO 9096 is given in Annex B.

Correlation formulae to calculate the mass concentration of black carbon out of the filter smoke number (FSN) are given in Annex C.

The characteristics required for filter-type-smoke meters are defined in ISO 10054.

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Reciprocating internal combustion engines — Exhaust emission measurement —

Part 3: Test procedures for measurement of exhaust gas smoke emissions from compression ignition engines using a filter type smoke meter

1 Scope

This document specifies a method for the measurement of smoke from exhaust gas of reciprocating internal combustion (RIC) engines at a steady state condition. The method evaluates the soot content by measurement of the blackening of a filter and derivation of black carbon mass concentration (mg/m^3) from FSN. Where necessary, individual requirements may be specified for particular engine 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.

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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 10054, *Internal combustion compression-ignition engines — Measurement apparatus for smoke from engines operating under steady-state conditions — Filter-type smokemeter*

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
filter-type smoke meter
instrument in which a given exhaust gas volume is passed through a clean filter of a certain area and the blackness condition of this filter is subsequently used to define the *filter smoke number* (3.3)

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3.2
effective filtered column length
L_F
length of the gas column actually passing through the filter, taking into account dead volume and leakage in the sampling system

Note 1 to entry: Effective filtered column length is expressed in mm.

3.3
filter smoke number
FSN
standardized unit conforming to ISO 10054, expressing the smoke characteristics of an exhaust gas, represented by the degree of blackening of a clean filter caused by the *soot* (3.6) in a given column of exhaust gas passing through this filter

3.4
Bosch smoke number
SN
measuring unit expressing the smoke characteristic of the exhaust gas, obtained with a Bosch smoke meter, represented by the degree of blackening of a filter, caused by the *soot* (3.6) in a given column of exhaust gas passing through this filter

Note 1 to entry: The Bosch smoke number corresponds to an *effective filtered column length* (3.2) of 405 mm, but it does not have a defined pressure and temperature as the basis.

3.5
exhaust gas smoke
visible suspension of solid and/or liquid particles in gases resulting from combustion or pyrolysis

Note 1 to entry: The exhaust gas smoke, may be black smoke, blue smoke, brown smoke or white smoke depending on the components present in the exhaust gas after the combustion or pyrolysis process. Black smoke [also referred to as "*soot*" (3.6)] is mainly due to the presence of carbon particles. Blue smoke is usually due to droplets resulting from the incomplete combustion of fuel or lubricating oil. Brown smoke is due to the presence of NO_2 in the exhaust gas. White smoke is usually due to condensed water and/or liquid fuel.

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3.6
soot
all components contained in the exhaust gas and blackening a filter

Note 1 to entry: Major component of soot is *black carbon* (3.8), formed by incomplete combustion of fossil fuels, renewable fuels and biomass.

3.7
particulate matter
PM
any 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

EXAMPLE *Elemental carbon* (3.9), condensed hydrocarbons and sulphates with associated water.

3.8
black carbon
BC
distinct type of carbonaceous material, formed only in flames during combustion of carbon-based fuels

Note 1 to entry: It is distinguishable from other forms of carbon and carbon compounds contained in atmospheric aerosol because it has a unique combination of the following physical properties: strong absorption of light, refractory nature, insoluble and graphitic structure.

Note 2 to entry: This definition is adapted from Reference [8].

Note 3 to entry: The black carbon is reported in the following according to the details in Reference [9], Table 1.

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3.9
elemental carbon
EC
carbonaceous fraction of *particulate matter* (3.7) that is not removed from a filter sample heated to temperatures greater than 1 143 K (870 °C) in an inert atmosphere, excluding char

Note 1 to entry: See Reference [12], Figure 5.1.

4 Smoke measurement by a filter-type smoke meter (FSN)

4.1 Application

This method is suitable for evaluating the content of soot in exhaust gas.

4.2 Principle

A sample of exhaust gas is extracted from the exhaust pipe through a sampling line and passed through a filter of a known area. The blackening of the filter is caused by soot contained in this sampled gas column. The blackening is a measure of the content of soot in the exhaust gas and is calculated from the optical reflectance of the blackened filter relative to a clean filter according to Formula (1).

$$\mathrm{FSN} = \left(1 - R'_{\mathrm{b}} / R'_{\mathrm{c}}\right) \times 10 \tag{1}$$

where

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R'_{b} is the reflectometer value of the blackened filter;

R'_{c} is the reflectometer value of the clean filter.

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For an accurate measurement of low soot concentrations a prolonged column length may be necessary. This may be obtained either by multiple operations of the instrument without changing the filter paper or — where the suction volume is controlled by a continuously working pump — by an extended operating time of the pump.

4.3 Measurement with a filter-type smoke meter

4.3.1 Installation of a filter-type smoke meter

A probe and sampling line recommended by the instrument manufacturer is to be used. The probe shall be installed in the exhaust gas pipe in a way that a representative sampling is possible and the engine operation is not affected.

If water or a reagent for an exhaust gas after treatment device is injected into the exhaust system, the probe shall be installed upstream of the point of injection.

The temperature of the exhaust sample in the sampling system is to be maintained above the dew point.

4.3.2 Engine operating conditions

A steady-state engine operation is required for the FSN method. Operating values like load, speed and exhaust gas temperature may be used to judge the steadiness of the engine. Speed and load may vary only in a small range. Declarations of the engine manufacturer shall be respected.

4.3.3 Sensitivity to fuel oil

The type of fuel which is burned during the measurement may cause sensitivities to the measurement.

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