TECHNICAL SPECIFICATION

ISO/TS 12103-3

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Road vehicles — Test contaminants for filter evaluation —

Part 3:
Soot contaminant

Véhicules routiers — Poussière pour l'essai des filtres —

Partie 3: Poussière de suie

Reference number
ISO/TS 12103-3:2023(E)

Contents

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.

This document was prepared by Technical Committee ISO/TC 22, *Road Vehicles*, Subcommittee SC 34, *Propulsion, powertrain and powertrain fluids*.

This second edition cancels and replaces the first edition (ISO/TS 12103-3:2020), which has been technically revised.

The main changes are as follows:

— modification to requirement regarding analysis equipment;

— modification to requirement regarding instrument calibration.

A list of all parts in the ISO 12103 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.

Introduction

This document specifies a grade of test aerosol, which is composed of soot from a combustion source similar to soot occurring in the environment that motor vehicles are commonly subjected to. This test contaminant is developed for air filter media and element testing.

Ambient aerosols include at least two distinct modes of aerosol: a sub-micron mode and a super-micron mode. Generally, the sub-micron mode comes from combustion sources or condensation of gases. The super-micron mode comes from physical abrasion processes and wind-blown dust. The test dusts described in ISO 12103-1 can be used to simulate the super-micron mode of ambient aerosol for testing air filters. The soot aerosol described in this document is intended to simulate the sub-micron mode of ambient aerosol.

There are several possible methods of generating soot aerosol, to simulate the sub-micron mode for air filter testing purposes such as dispersing soot from a powder or using generated soot from a combustion process.

Particle size of soot dispersed from bulk powder exceeds the environmental soot considerably.

For generated soot from a combustion process, a new procedure is described in this document. Using aliphatic hydrocarbons, the soot consists of a combination of carbon, organic hydrocarbons and other substances.

Road vehicles — Test contaminants for filter evaluation —

Part 3:
Soot contaminant

1 Scope

This document defines particle size distribution by number and chemical content limits involving one grade of test aerosol made from combustion soot.

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 15900, *Determination of particle size distribution — Differential electrical mobility analysis for aerosol particles*

ISO 29904:2013, *Fire chemistry — Generation and measurement of aerosols*

NIOSH *Elemental carbon (diesel particulate): Method 5040, Issue 3*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15900, ISO 29904 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
diffusion flame
flame from a burner which gets its oxygen from the ambient surrounding air by diffusion and convection mechanisms instead of having the oxygen forcibly premixed into the fuel

3.2
generation
process in which airborne particles are produced and injected into a defined airstream

3.3
mobility particle size
particle size provided by an electro-static classifier

Note 1 to entry: The method is based on a principle that uses the forces exerted on charged particle in an electro-static field. The method is used for particles in the nm range and the classifier is typically combined with a condensation particle counter to actually determine the concentration.

3.4
particle size distribution
number, mass or volume of particles as function of the particle size

Note 1 to entry: In this document the term is used for number distributions only. Particle size distributions may have a wide variety of shapes but for the purpose of this document and application the distributions of *soot* (3.6) particles can be assumed to be of a lognormal type.

3.5
particle number sizer
system consisting of a method to classify particles by electrical mobility and measures the number concentration of particulate at each size through means of one or more condensation particle counters and or electrometers

3.6
soot
particles from a combustion process consisting of carbon and being created during incomplete incineration of organic fuels

Note 1 to entry: The particles start with clusters of several hundred carbon atoms and can form large grains up to several hundred µm. Small soot particles have the tendency to agglomerate. A soot particle from combustions consists of elemental carbon (EC) and organic carbon (OC). A lot of organic compounds are known and most of them are bound on the EC-agglomerates. Some of the organic compounds are carcinogenic like poly aromatic hydrocarbon (PAH).

3.7
thermal-optical transmission
method to measure elemental carbon (EC) with its relationship to atmospheric *soot* (3.6)

Note 1 to entry: For the thermal-optical transmission method (TOT), an emphasis on optical behaviour presents it as a method for the accurate measurement of light-absorbing particulate carbon and thus allows EC to be defined as black carbon (BC) as in the aethelometer.

4 Symbols and abbreviated terms

Symbol	Explanation
μ	mean value of a Gaussian standard distribution
σ	standard deviation of a Gaussian standard distribution
σ_{geo}	geometric standard deviation (the logarithm of the GSD is the standard deviation)

Abbreviations	Explanation
Sub-micron	particles < 1 µm
Super-micron	particles > 1 µm
EC	elemental carbon
OC	organic carbon
TOT	thermal-optical transmission
PAH	poly aromatic hydrocarbons

5 Test contaminant

5.1 Definition

Test aerosols according to this document are generated by combustion of an organic fuel in the test lab. They consist primarily of agglomerates of carbon particles where the primary carbon particles are on the order of 20 nm diameter. Some organic compounds may be condensed on the carbon agglomerates during the combustion and dilution processes. The amount of condensed organic material determines the category of the test aerosol per 5.2.

5.2 Test contaminant designation

Soot contaminants are produced by burning a fuel (gas or liquid) and are listed in the grade as follows:

— ISO 12103-3, S1 for ≥ 67 % carbon content.

This flame shall lead to an aerosol consisting of 70 % ± 3 % elemental carbon, 29 % ± 3 % organic carbon, and < 1 % other substances. The air-to-fuel ratio of the flame shall be set as ± 10 % stoichiometric balanced with adjustment of an inert mixing gas addition to the fuel flow to adjust the particle distribution. The stoichiometric balance is described in Annex F.

Soot contaminant shall be tested per the methods in Annex E and the above requirements.

5.3 Generation of soot aerosol

Test aerosols according to this document are generated by combustion of an organic fuel in the test lab. They consist primarily of agglomerates of carbon particles where the primary carbon particles are on the order of 20 nm diameter. Organic compounds may be condensed on the carbon agglomerates during the combustion and dilution processes.

5.4 Particle size distribution

The unimodal particle size distribution shall be determined using electrical mobility sizing method and shall meet the distribution and tolerances given in Annex A. The size distributions shall be presented as normalized number distribution.

5.5 Stability of aerosol concentration and particle size distribution

The soot aerosol mass concentration limits and tolerances are given in Annex A.

Care should be taken to ensure that the concentration is low enough to prevent size changes due to coagulation from occurring in the test system. Recommendation for maximum number concentration is $10^7/cm^3$. More detailed information is provided in Annex C.

5.6 Chemical composition

For generating the soot, a diffusion flame with gas (e.g. propane) can be used. But any fuel yielding the defined chemical composition and size distribution is accepted. More detailed information is provided in Annex D.

This flame shall lead to an aerosol consisting of the content breakdowns presented in 5.2.

To achieve accurate reproducible filter test results, a soot aerosol ideally consisting of solely elemental carbon (EC) would be preferable. Because soot from combustion always contains more or less organic carbon (OC), the content of OC in the test aerosol shall be demonstrated.

Samples of the aerosol shall be taken and analysed per NIOSH test method 5040 issue 3 for EC/OC.

The ratio of OC shall be demonstrated by thermal-optical transmission analysis by the thermal protocol NIOSH 700+. It shall be demonstrated only once for each soot generator or after any significant modification of the unit, e.g. after changing geometric dimensions of the burner, using another fuel gas or other flow settings.

It shall be demonstrated for all fixed operating points which fit the described standardized soot aerosol in this document. For soot generators with continuously adjustable settings it shall be demonstrated by a suitable method that the OC content does not exceed 29 % within the adjustable range. This can be realized by analysis of probes at some single set-points at the minimum and at the maximum of the adjustable range at least and one or more between.

For more information about the thermal-optical transmission and about the sampling method refer to Annex E.

6 Analysis equipment and operating procedure

6.1 General

This clause will identify the analysis equipment and procedure to sample, classify, and identify the soot aerosol, which is being produced in this document. General handling information is provided in Annex B.

6.2 Analysis equipment

The analysis equipment specified in ISO 29904:2013, 5.6.5 and 5.6.6, specifically the particle number sizers which use the electrical mobility method shall be used to characterize the soot contaminant. ISO 29904 has four clauses per piece of equipment; principle, method description, parameters produced, and the advantages and disadvantages of each piece of equipment.

6.3 Particle size analysis procedure

Analysis of ISO-specified soot test aerosol shall be performed using a differential mobility classifier with condensation particle counter detector or equivalent equipment at the outlet of the soot generator.

Mobility particle size shall cover the range from 10 nm up to 400 nm, with at least 8 channels per decade. Particle measurement devices which do not fulfil this requirement are not suitable, since small particles will not be detected.

Characterizing of the distribution, the location of the characterization shall occur at the introduction point of the test. The sampling method specified in ISO 29904:2013, 5.6, shall be used to identify the method to sample the soot aerosol.

6.4 Instrument calibration

Calibration of the differential mobility analysing systems (where used), as defined in ISO 15900, shall be calibrated as per ISO 15900. ISO 15900 is not applicable to multi-electrometer based fast response particle number sizers.

Annex A
(normative)

Particle size distributions by number

A.1 General

For typical soot sources used within the scope of this document the particles usually are lognormal distributed with regards to their size. These distributions can easily be converted into a standard normal distribution. A normal distribution is distinctly defined by two parameters. Therefore, this document describes the range of acceptable particle size distributions by defining those two parameters together with a set of tolerances. This annex describes how this is done and how real particle size distributions can be checked for conformance with those targets.

A.2 Lognormal distribution and Gaussian normal distribution

A typical particle size distribution for soot is shown in Figure A.1 on a linear size axis together with a mathematically fitted lognormal curve. The general formula of that function is:

$$f(x) = \frac{a}{\sqrt{2 \cdot \pi} \cdot \sigma \cdot x} \cdot e^{\frac{-(\ln x - \mu)^2}{2 \cdot \sigma^2}} \quad \text{(A.1)}$$

for x > 0

a is a scaling factor;

x is the particle diameter.

μ is the mean of distribution;

σ is the standard deviation.

$$\mu = \ln E - \frac{1}{2} \cdot \ln\left[1 + \left(\frac{\sigma}{E}\right)^2\right] \quad \text{(A.2)}$$