

---

---

**Road vehicles — Air filters for passenger  
compartments —**

Part 2:  
**Test for gaseous filtration**

*Véhicules routiers — Filtres à air pour l'habitacle —  
Partie 2: Essai pour le filtrage des gaz*



Reference number  
ISO 11155-2:2009(E)

© ISO 2009

**PDF disclaimer**

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.



**COPYRIGHT PROTECTED DOCUMENT**

© ISO 2009

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
Case postale 56 • CH-1211 Geneva 20  
Tel. + 41 22 749 01 11  
Fax + 41 22 749 09 47  
E-mail [copyright@iso.org](mailto:copyright@iso.org)  
Web [www.iso.org](http://www.iso.org)

Published in Switzerland

# Contents

Page

Foreword.....	iv
<b>1 Scope .....</b>	<b>1</b>
<b>2 Normative references .....</b>	<b>1</b>
<b>3 Terms and definitions.....</b>	<b>1</b>
<b>4 Measurement accuracy .....</b>	<b>4</b>
<b>4.1 Flow rate .....</b>	<b>4</b>
<b>4.2 Pressure.....</b>	<b>4</b>
<b>4.3 Temperature .....</b>	<b>4</b>
<b>4.4 Relative humidity .....</b>	<b>4</b>
<b>4.5 Challenge gas.....</b>	<b>4</b>
<b>5 General conditions .....</b>	<b>4</b>
<b>5.1 Conditioning of challenge gas .....</b>	<b>4</b>
<b>5.2 Cleanliness of influent air .....</b>	<b>4</b>
<b>5.3 Challenge gas concentration stability .....</b>	<b>4</b>
<b>6 Test contaminants .....</b>	<b>5</b>
<b>6.1 Mandatory contaminants .....</b>	<b>5</b>
<b>6.2 Optional contaminants .....</b>	<b>5</b>
<b>6.3 Other contaminants .....</b>	<b>5</b>
<b>7 Test equipment .....</b>	<b>6</b>
<b>7.1 General layout .....</b>	<b>6</b>
<b>7.2 Test stand performance .....</b>	<b>6</b>
<b>7.3 Air supply .....</b>	<b>6</b>
<b>7.4 Test duct.....</b>	<b>6</b>
<b>7.5 Contaminant generation and supply .....</b>	<b>6</b>
<b>7.6 Sampling and analysis of challenge gas.....</b>	<b>7</b>
<b>7.7 Test equipment constituents .....</b>	<b>7</b>
<b>8 Experimental determination of <math>t_0</math>, using <math>t_{lag}</math>.....</b>	<b>8</b>
<b>9 Preparation of filter/filter element for testing .....</b>	<b>8</b>
<b>10 Test methods.....</b>	<b>8</b>
<b>10.1 Purpose.....</b>	<b>8</b>
<b>10.2 Air pressure loss.....</b>	<b>8</b>
<b>10.3 Preparation of challenge gases.....</b>	<b>9</b>
<b>10.4 Determination of efficiency/breakthrough .....</b>	<b>9</b>
<b>10.5 Determination of capacity.....</b>	<b>9</b>
<b>10.6 Data and analysis.....</b>	<b>9</b>
<b>10.7 Determination of desorption (optional) .....</b>	<b>10</b>
<b>11 System validation .....</b>	<b>10</b>
<b>11.1 Air flow uniformity .....</b>	<b>10</b>
<b>11.2 Verification challenge gas stability (without test filter) .....</b>	<b>10</b>
<b>12 Test report .....</b>	<b>11</b>
<b>Annex A (normative) Test stand configuration .....</b>	<b>12</b>
<b>Annex B (normative) Detailed definition and calculation of <math>t_0</math> and <math>t_{lag}</math>.....</b>	<b>13</b>
<b>Annex C (normative) Capacity determination .....</b>	<b>15</b>
<b>Annex D (informative) Conversion of test contaminant concentration units .....</b>	<b>16</b>
<b>Bibliography .....</b>	<b>17</b>

## 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.

ISO 11155-2 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 7, *Injection equipment and filters for use on road vehicles*.

This first edition of ISO 11155-2 cancels and replaces the ISO/TS 11155-2:2002, which has been technically revised.

ISO 11155 consists of the following parts, under the general title *Road vehicles — Air filters for passenger compartments*:

- *Part 1: Test for particulate filtration* [Technical Specification]
- *Part 2: Test for gaseous filtration*

# Road vehicles — Air filters for passenger compartments —

## Part 2: Test for gaseous filtration

### 1 Scope

This part of ISO 11155 specifies a test comprising several methods for measuring the dynamic gas adsorption of air filters in the passenger compartments of road vehicles. These laboratory test methods are applicable to air filters that improve air quality by reducing concentrations of gaseous, odorous or hazardous components from ambient or re-circulated air, or both, in the vehicle cabin. They provide a means of measuring air pressure loss, as well as gas and vapour removal characteristics.

### 2 Normative references

The following referenced documents are indispensable for the application 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/TS 11155-1, *Road vehicles — Air filters for passenger compartments — Part 1: Test for particulate filtration*

ISO 11841-1, *Road vehicles and internal combustion engines — Filter vocabulary — Part 1: Definitions of filters and filter components*

ISO 11841-2, *Road vehicles and internal combustion engines — Filter vocabulary — Part 2: Definitions of characteristics of filters and their components*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11841-1 and ISO 11841-2 and the following apply.

#### 3.1

##### **test flow rate**

volume of air passing through the test duct per unit time

NOTE It is expressed in actual cubic metres per hour.

#### 3.2

##### **pressure loss**

difference in static pressure measured upstream and downstream of the filter at a specified flow rate

NOTE It is expressed in pascals.

**3.3**

**contaminant**

unwanted constituent dispersed in air

**3.4**

**concentration**

quantity of one constituent dispersed in another

NOTE Contaminant concentrations are generally expressed as mass concentrations, i.e. mass of contaminant in milligrams per cubic metre of air. However, when the contaminant is measured as a volume fraction, i.e. volume of contaminant per volume of air (often in parts per million), it is necessary to convert the volume of contaminant into a mass. Conversion factors are given in Annex D.

**3.5**

**influent air**

cleaned air used to dilute contaminants and produce the challenge gas

**3.6**

**challenge gas**

homogeneous mixture of influent air and contaminant used to challenge the filter

**3.7**

**challenge gas concentration**

ratio of the mass (or volume) of test contaminant per volume of influent air measured under specified conditions

NOTE Contaminant concentrations are generally expressed as mass concentrations, i.e. mass of contaminant in milligrams per cubic metre of air. However, when the contaminant is measured as a volume fraction, i.e. volume of contaminant per volume of air (often in parts per million), it is necessary to convert the volume of contaminant into a mass. Conversion factors are given in Annex D.

**3.8**

**test contaminant mass**

$m_T$

total mass of test contaminant to which the filter is exposed

NOTE It is expressed in milligrams.

**3.9**

**influent concentration**

$C_1$

homogeneous challenge gas concentration measured before (upstream of) the filter

NOTE Contaminant concentrations are generally expressed as mass concentrations, i.e. mass of contaminant in milligrams per cubic metre of air. However, when the contaminant is measured as a volume fraction, i.e. volume of contaminant per volume of air (often in parts per million), it is necessary to convert the volume of contaminant into a mass. Conversion factors are given in Annex D.

**3.10**

**effluent concentration**

$C_2$

homogeneous challenge gas concentration measured after (downstream of) the filter

NOTE Contaminant concentrations are generally expressed as mass concentrations, i.e. mass of contaminant in milligrams per cubic metre of air. However, when the contaminant is measured as a volume fraction, i.e. volume of contaminant per volume of air (often in parts per million), it is necessary to convert the volume of contaminant into a mass. Conversion factors are given in Annex D.

### 3.11 efficiency

ratio of the amount of contaminant removed or reduced by the filter relative to the amount exposed to it, calculated as a percentage by

$$E = \frac{100(C_1 - C_2)}{C_1} \quad (1)$$

where

$E$  is efficiency,

$C_1$  is the influent concentration,

$C_2$  is the effluent concentration

#### 3.11.1 1 min efficiency

efficiency measurement 1 min after time zero,  $t_0$

#### 3.11.2 2 min efficiency

efficiency measurement 2 min after  $t_0$

#### 3.11.3 5 min efficiency

efficiency measurement 5 min after  $t_0$

### 3.12 time zero

$t_0$   
calculated zero point based on the shape of the ramp-up curve of challenge gas breakthrough versus time

NOTE 1 See Clause 8 and Annex B.

NOTE 2 Once this curve is obtained, the  $t_0$  point can be found by calculation. All efficiency or penetration data are calculated from the designated  $t_0$ .

### 3.13 start of test time

$t_{\text{start}}$   
time at which the challenge gas is introduced into the test system

### 3.14 lag time

$t_{\text{lag}}$   
time difference between  $t_{\text{start}}$  and  $t_0$

NOTE See Annex B.

### 3.15 end of test time

$t_f$   
time at which a user-specified efficiency (typically 5 %) or user-specified time is reached

### 3.16 total test time

duration of exposure of the filter to the challenge gas, beginning at  $t_0$

**3.17**  
**capacity**

$m_c$

mass of contaminant removed from the challenge gas stream by the filter during the total test time

NOTE It is normally expressed in milligrams.

**3.18**  
**desorption**

release of previously trapped contaminants from a test filter

## **4 Measurement accuracy**

### **4.1 Flow rate**

The measurement devices shall be calibrated relative to the respective challenge or contaminant gases. Their accuracy shall be within  $\pm 3\%$  of the specified value.

### **4.2 Pressure**

Differential pressure accuracy shall be within  $\pm 2\%$  of the measured value.

### **4.3 Temperature**

Temperature shall be monitored to within  $\pm 0,5\text{ }^\circ\text{C}$  accuracy.

### **4.4 Relative humidity**

Relative humidity shall be monitored to within  $\pm 2\%$ .

### **4.5 Challenge gas**

Challenge gas measurement accuracy for *n*-butane, toluene and  $\text{SO}_2$  shall be  $\pm 3\%$  of the measured value.

## **5 General conditions**

### **5.1 Conditioning of challenge gas**

The temperature of the challenge gas shall be  $(23 \pm 3)\text{ }^\circ\text{C}$  and the relative humidity shall be  $(50 \pm 2)\%$ .

### **5.2 Cleanliness of influent air**

The content of organic contaminants in the influent air shall not exceed the equivalent of a volume fraction of  $2 \times 10^{-6}$  of total hydrocarbon. High efficiency particulate air (HEPA) filtration (see EN 779) is recommended for the removal of particulate contaminants.

### **5.3 Challenge gas concentration stability**

Influent concentration shall be maintained to within  $\pm 3\%$  of the set point concentration for the duration of the test.



## 6 Test contaminants

### 6.1 Mandatory contaminants

Mandatory test contaminants are chosen either because their presence at high levels signifies deterioration in air quality or because they provide useful indications of performance for certain types of purification systems. Mandatory contaminants, purities and concentrations are specified in Table 1.

**Table 1 — Test contaminants**

Test contaminant	Minimum purity %	Concentration	
		Set point Volume fraction in parts per million <sup>b</sup>	Conversion factor <sup>c</sup>
<i>n</i> -butane <sup>a</sup>	99,5	80 ± 8	2,39
Toluene	99,5	80 ± 8	3,79

<sup>a</sup> Included because it provides a useful and facile test for activated carbon-based adsorption systems. Butane could be of limited value for systems that do not rely on activated carbon adsorption. In these cases, another test contaminant may be substituted.

<sup>b</sup> See Annex D for calculation of conversion factors.

<sup>c</sup> Allows conversion to milligrams per cubic metre at 23 °C and a barometric pressure of 101 kPa.

### 6.2 Optional contaminants

Tests using the optional contaminant are subject to agreement between customer and manufacturer. Recommended contaminants, purities and concentrations are given in Table 2.

**Table 2 — Optional test contaminant**

Test contaminant	Minimum purity %	Concentration	
		Set point Volume fraction in parts per million <sup>b</sup>	Conversion factor <sup>c</sup>
SO <sub>2</sub> <sup>a</sup>	99,5	30 ± 3	2,64

<sup>a</sup> Included because it can be used to represent the family of acid gases in determining the performance of carbon-based adsorption systems.

<sup>b</sup> See Annex D for calculation of conversion factors.

<sup>c</sup> Allows conversion to milligrams per cubic metre at 23 °C and a barometric pressure of 101 kPa.

### 6.3 Other contaminants

See Annex D for other contaminants. The use of other gases could be of interest for dedicated applications. Gases of interest shall be agreed between customer and manufacturer.

## 7 Test equipment

### 7.1 General layout

The test stand shall meet the requirements given in 7.2 to 7.7. An example of a test stand configuration is given in Annex A. All parts of the system that come into contact with the challenge gas shall be chosen and designed such that they are chemically resistant and errors due to adsorptive effects on part surfaces are minimized. The test stand shall include equipment or apparatus for conditioning the air supply, flow measurement, pressure drop measurement, contaminant injection, sampling and sample analysis.

The test stand/equipment should preferably be operated in a sub-barometric pressure mode, i.e. with the fan/blower placed downstream of the test filter. This configuration prevents penetration of challenge gas into the ambient atmosphere in case of equipment leaks. Furthermore, systematic errors due to the challenge gas contacting the fan unit are excluded. Although operation in a sub-barometric pressure mode is preferred for these reasons, a system operating in a positive pressure mode that meets the requirements of 7.2 to 7.7 is acceptable.

### 7.2 Test stand performance

The test stand shall be validated as part of the overall test system (stand and associated equipment) as given in Clause 11. Validation shall be performed whenever test conditions (e.g. flow rate) or test stand configuration (e.g. mixing or fixture) are altered significantly. Test instruments shall be calibrated in accordance with the manufacturer's recommended practice and frequency.

### 7.3 Air supply

The influent air shall be conditioned and cleaned in accordance with 5.1 and 5.2. The system shall demonstrate the ability to maintain these conditions over the period of time required to complete a filter evaluation. The system shall be capable of delivering and maintaining a user-specified flow.

### 7.4 Test duct

In general, the test duct shall be designed so that adsorption of test contaminants on test stand surfaces is minimized. The test duct shall be designed so that the challenge gas is fed evenly to the complete filter surface. Punched sheets, static mixers or deflectors can be useful for this purpose. Mixing of the injected test contaminant with the influent air will require rigorous attention and validation. In general, a duct similar to that described in ISO/TS 11155-1 (particulate) may be used to meet these specifications. However, those design details of the ISO/TS 11155-1 layout that are specific to particle handling and measurement, and which do not influence the handling and measurement of gases, are not obligatory for the test equipment.

### 7.5 Contaminant generation and supply

Test contaminants that are already gaseous under test conditions may be supplied to the duct directly.

Test contaminants that are liquid under test conditions (e.g. toluene) shall be volatilized prior to injection into the duct. This can be accomplished by heating or providing energy by ultrasonic or other means. The temperature requirements given in 5.1 also apply in this particular case. Furthermore, condensation of test contaminants shall be avoided by appropriate means (e.g. heating, duct design), especially in the vicinity of the contaminant injection area.

Test contaminants generated via chemical reaction (e.g. NO<sub>2</sub>) shall be generated in a separate chamber and subsequently injected into the duct in order to ensure the required contaminant chemical purity.

## 7.6 Sampling and analysis of challenge gas

The challenge gas is sampled upstream and downstream of the test filter. Placement of the sampling ports shall give representative samples. This shall be validated in accordance with Clause 11. A defined partial flow shall be extracted from the test duct, preferably by means of an independently controlled flow to the gas analyser.

Sampling frequency should be sufficiently frequent that a meaningful efficiency curve can be created. A suggested initial guideline is once every 10 s, or as frequently as possible for the analyser used. For long tests, a lesser sampling frequency is acceptable, provided the efficiency curve is sufficiently well defined.

## 7.7 Test equipment constituents

### 7.7.1 Flow rate monitors

The measurement devices shall be calibrated relative to the respective test gases and to the accuracy specified in 4.1.

### 7.7.2 Pressure monitors

The differential pressure shall be measured by means of a high-precision pressure sensor or gauged electronic pressure sensor to the accuracy specified in 4.2.

### 7.7.3 Thermometers

Temperature shall be monitored to the accuracy specified in 4.3.

### 7.7.4 Hygrometers

Relative humidity shall be monitored to the accuracy specified in 4.4.

### 7.7.5 Data recording

Data relative to temperature, barometric and differential pressure and relative humidity shall be recorded periodically during the test.

### 7.7.6 Gas analysers

Gas analysers shall completely cover the range of concentration values specific to the respective challenge gas. A detection limit of 2 % of the upstream concentration shall be assured. A calibration function shall be determined over the complete range of concentration values for each contaminant gas. The concentration shall be measured to the accuracy specified in 4.5. The analyser's signal-to-noise (S/N) ratio shall exceed 3.

A gas analyser sampling frequency of once every 10 s, or sufficiently frequent to produce a meaningful curve, is recommended. The concentration of the challenge gas downstream of the filter,  $C_2$ , shall be sampled at this frequency. For configurations that show low change in downstream concentration, the sampling frequency may be reduced to 1 min, provided that the change in downstream concentration meets the required accuracy during the respective period. This applies especially to the period when the downstream concentration is below the analysers' detection limit. The sampling frequency shall be increased early enough to a value of 10 s (or more frequently) so that the increase in downstream concentration at this higher sampling frequency is completely recorded. The period with reduced sampling frequency shall be determined in a preceding, separate, test run.

## 8 Experimental determination of $t_0$ , using $t_{lag}$

This shall be carried out using the procedure below.

- a) Stabilize the test contaminant feed rate and influent air flow rate.
- b) Send the test contaminant to the exhaust.
- c) Insert the test filter holder without filter into the test duct.
- d) Allow the instrument to return to a zero concentration reading.
- e) Send the test contaminant into the test stand ( $t_{start}$ ).
- f) Record the gas concentration with the most frequent sampling allowed by the instrument. At least three to five samples shall be taken during the rise of concentration from zero to its maximum value.
- g) Allow the concentration of test contaminant to reach the maximum concentration.
- h) Send the test contaminant back to the exhaust. This completes one measurement.
- i) Calculate the slope of the test contaminant concentration curve at 50 % of maximum concentration (see Annex B).
- j) Calculate  $t_0$  and  $t_{lag}$  (see Annex B).
- k) Make the measurement several times under the same conditions in order to increase accuracy.
- l) For future gas performance tests, use  $t_{lag}$  to determine the time interval between  $t_{start}$  and  $t_0$ ; the determination of breakthrough times shall be made from  $t_0$ . The parts per million reading for the test may not be zero at  $t_0$ .

## 9 Preparation of filter/filter element for testing

Dry the test filter until its mass has stabilized to 2 % of measured value. Precondition the clean, unused filter at 50 % relative humidity and 23 °C for at least 14 h in a climate-controlled environment. Then place the test filter in the stand where it shall be challenged with preconditioned, clean air for at least 15 min. The flow rate should be the test flow rate.

## 10 Test methods

### 10.1 Purpose

The purpose of these tests is to determine the removal efficiency, capacity, desorption characteristics (optional) and flow resistance of filters that remove gases and vapours, using the equipment specified in Clause 7. The system shall be validated (see Clause 11) prior to testing the filters by these methods.

### 10.2 Air pressure loss

This test is used to determine the flow characteristics of a clean filter in clean air and, specifically, the flow rate air pressure loss curve by measurement of the air pressure loss at 25 %, 50 %, 75 % and 100 % of the nominal flow of the filter.

The air pressure loss test shall be performed in accordance with ISO/TS 11155-1.

### 10.3 Preparation of challenge gases

The preparation of challenge gases shall be made by introducing the contaminant gas or vapour into an influent stream of clean air, using measuring and controlling devices that will ensure that the concentration and total flow of the challenge gas is at the desired uniform concentration, purity and nominal flow of the filter.

### 10.4 Determination of efficiency/breakthrough

#### 10.4.1 General

The purpose of this test is to determine the contaminant removal capabilities of the test filter. The test is conducted with constant air flow and concentration of the test contaminant in accordance with Clause 6.

#### 10.4.2 Efficiency measurements

Efficiency measurements shall be made on new filters preconditioned in accordance with Clause 9. Filters are challenged with test contaminants at the test concentration under specified flow, temperature and humidity conditions. The test shall continue until the concentration of the measured effluent gas stream is equal to 95 % of the concentration of the measured influent gas stream or until a predetermined specified time period has elapsed.

#### 10.4.3 Efficiency test procedure

This shall be carried out using the procedure below.

- a) Install the conditioned filter in the test stand, establish the specified flow rate and measure the temperature and the relative humidity.
- b) Continuously inject the amount of contaminant necessary to establish and maintain the required challenge gas concentration and expose the challenge gas to the filter to start the test. Record the start test time.
- c) Measure the concentration of the influent challenge gas initially and monitor it thereafter.
- d) Measure the concentration of the effluent gas at the required intervals in accordance with 7.7.6.
- e) Continue concentration measurements until the concentration of the effluent gas is equal to a predetermined percentage of the influent gas (typically 95 %) or until a predetermined time period has elapsed. Note the end test time.
- f) At the conclusion of the test, stop the contaminant injection and the air flow through the test filter.
- g) Calculate the efficiency (or penetration) from the concentration data.

### 10.5 Determination of capacity

Filter capacity is calculated by integrating the efficiency curve over the test time (see Annex C).

### 10.6 Data and analysis

Data are recorded numerically and shall be presented in both graphical and tabular form. Raw numbers should be presented such that a normalization procedure can be utilized to correct for differences from standard conditions if necessary.

**10.7 Determination of desorption (optional)**

After completion of the breakthrough test in accordance with 10.4, stop the injection of test contaminant. Confirm that the upstream test contaminant concentration is less than 5 % of the set-point challenge gas concentration.

Monitor the effluent concentration as a function of time, until the concentration falls below 5 % of the set-point challenge gas concentration.

**11 System validation**

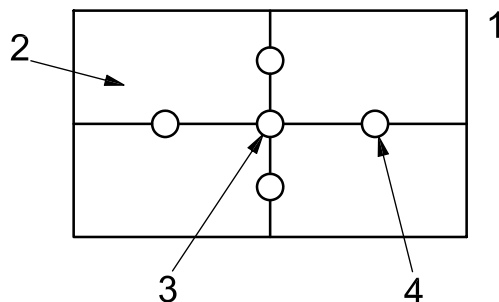
**11.1 Air flow uniformity**

The air flow uniformity shall be in accordance with ISO/TS 11155-1.

**11.2 Verification challenge gas stability (without test filter)**

This verification test is carried out for the purpose of ensuring that stable gas concentrations will be maintained across the filter face and for verifying that minimal gas adsorption occurs in the vicinity of the filter holder. It should be conducted at both the maximum and minimum flow rates for which the test stand will be used. In addition, it should be conducted at both the specified test contaminant concentration and at 10 % of the specified test contaminant concentration.

- a) Establish the test air flow rate, temperature and relative humidity through the test stand without a test filter installed.
- b) Start the injection of the test contaminant at the desired concentration.
- c) Gas concentration readings shall be taken at five positions in the filter-housing opening. In the filter housing, one reading should be taken at the centre of the opening and the other four readings between the centre point and the edge of the opening at 90° intervals from each other (see Figure 1). The sampling probe shall be located in the same plane as the filter. A minimum of three gas concentration readings shall be taken at each sampling location and the concentration readings shall be averaged.
- d) Compare the five average upstream and downstream concentrations. These average readings should all be within 5 % of each other.



**Key**

- 1 filter-housing opening
- 2 inner area of filter housing
- 3 central sampling location
- 4 off-centre sampling locations

**Figure 1 — Locations for measurements of challenge gas concentrations**

## 12 Test report

The test report shall include at least the following information:

a) general data:

- 1) date of test;
- 2) test laboratory and name of technician performing the test;
- 3) test method and a detailed description if any deviation from standard test method;
- 4) unambiguous identification of test filter;
- 5) sample face area, in square centimetres, and depth of test filter, in centimetres;
- 6) test air condition, in degrees Celsius, and percentage of relative humidity (RH);
- 7) flow rate, in cubic metres per hour;
- 8) contaminant (mandatory; mandatory plus optional, and/or other gases), i.e. type of gas and mass concentration;
- 9) preconditioning of the test filter;
- 10) barometric and system pressure upstream of the filter and at the flow meter;

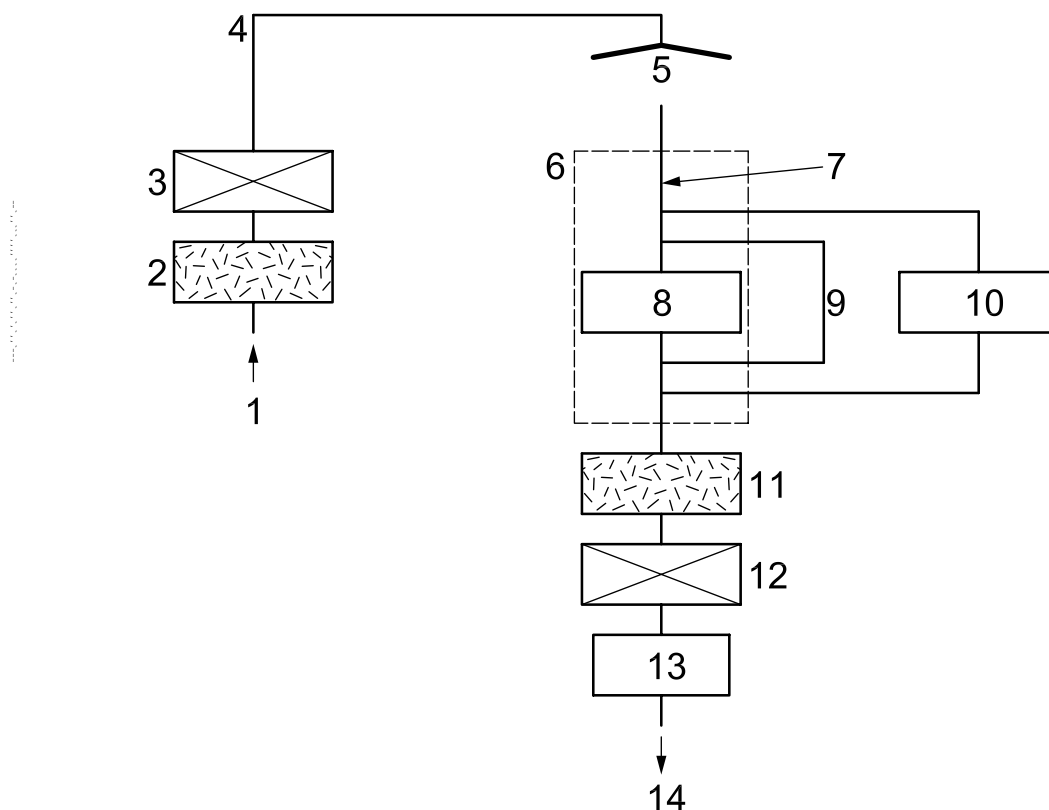
b) test results:

- 1) pressure loss, in pascals, at test flow rate;
- 2) graphic adsorption curve using efficiency [see Equation (1)] versus time, in minutes;
- 3) efficiency, in percent, measured at time  $t$  after  $t_0$  (see Annex B) or as determined by the customer; the minimum times of the percentage efficiency measurements should be:
  - *n*-butane: 1 min;
  - toluene: 2 min;
  - SO<sub>2</sub>: 5 min;
- 4) adsorption capacity (integrated area under curve to specified percentage efficiency or predetermined test time), in milligrams;
- 5) desorption data, if desired.

## Annex A (normative)

### Test stand configuration

Figure A.1 shows a typical test stand configuration.



**Key**

- |   |   |    |                                   |
|---|---|----|-----------------------------------|
| 1 | conditioned air                             | 8  | test filter                       |
| 2 | gaseous clean-up filter                     | 9  | differential pressure measurement |
| 3 | particle clean-up filter                    | 10 | gas measurement device            |
| 4 | contaminant injection                       | 11 | gaseous clean-up filter           |
| 5 | mixer/diffuser                              | 12 | particle clean-up filter          |
| 6 | test section                                | 13 | flow measurement device           |
| 7 | temperature and humidity measurement device | 14 | exhaust air                       |

**Figure A.1 — Test stand configuration**



## Annex B (normative)

### Detailed definition and calculation of $t_0$ and $t_{lag}$

The lag time,  $t_{lag}$ , is the time taken for the test system to detect the challenge gas at the maximum challenge concentration without a test filter in the system; it is dependent on the actual test stand configuration, air flow rate, challenge gas and challenge gas concentration.

Because of these differences, the start of test time,  $t_{start}$ , cannot simply be used to calculate efficiency or breakthrough. Time zero,  $t_0$ , shall be determined for each test contaminant concentration and flow rate and used to standardize the differences in test stand configurations, contaminant type and test conditions.  $t_{lag}$  is used to calculate time,  $t_0$ , for future gas performance tests that determine 1 min, 2 min or 5 min efficiency, or breakthrough values.

A standardized method is required for calculating  $t_{lag}$  and  $t_0$ . The slope at the 50 % breakthrough point is found and a line drawn with this slope to the 100 % line. The point at which these two lines intersect determines the time defined as  $t_0$ . The difference between  $t_{start}$  and the calculated  $t_0$  gives  $t_{lag}$ .

The gas detection method should be able to determine the gas concentration at least three to five times during the rise in the concentration level from zero to its maximum value when no filter is in the test rig.

The following procedure shall be used to calculate  $t_0$ :

- a) fit the graphed points of the breakthrough versus time curve with a spline or akima function to create a continuous curve;
- b) calculate the slope,  $a$ , of this curve at 50 % maximum effluent concentration level;
- c) at the 50 % point, run a line of slope,  $a$ , at a tangent to the gas concentration curve;
- d) the time at the intersection point of the line and the 100 % maximum concentration level is  $t_0$ , calculated according to Equation (B.1):

$$t_0 = \frac{\rho_0}{2a} + t_{50} \quad (\text{B.1})$$

where

$\rho_0$  is the measured maximum effluent concentration;

$a$  is the slope of the interpolated tangent curve at 50 % of  $\rho_0$ ;

$t_{50}$  is the time at which the interpolated tangent curve reaches 50 % of  $\rho_0$ .

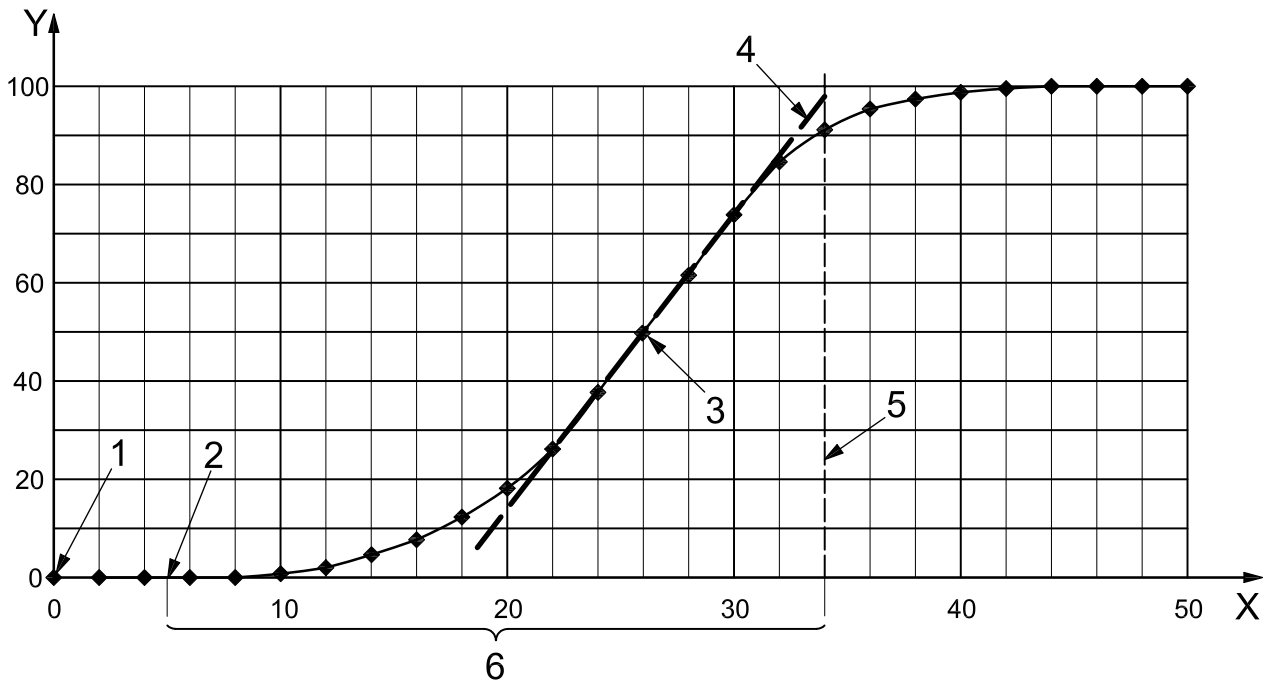
Define  $t_{lag}$  according to Equation (B.2):

$$t_{lag} = t_0 - t_{start} \quad (\text{B.2})$$

For a new gas measurement with the same volume-flow and sampling settings,  $t_0$  shall be calculated according to Equation (B.3):

$$t_0 = t_{start} + t_{lag} \quad (\text{B.3})$$

See Figure B.1.



**Key**

X time, in seconds

Y test contaminant concentration relative to maximum concentration, in percent

1 gas detector started

2 start test contaminant at  $t_{start} = 5,0$  s

3 tangent at 50 % test contaminant concentration relative to maximum concentration;  $t_{50} = 26,0$  s; slope at  $t_{50} = 6,25$  %/s

4 intersection of tangent and 100 % test contaminant concentration relative to maximum concentration

$$5 \quad t_0 = \frac{100 \%}{2 \times 6,25 \% / s} + 26,0 \text{ s} = 34,0 \text{ s}$$

$$6 \quad t_{lag} = t_0 - t_{start} = 34,0 \text{ s} - 5,0 \text{ s} = 29 \text{ s}$$

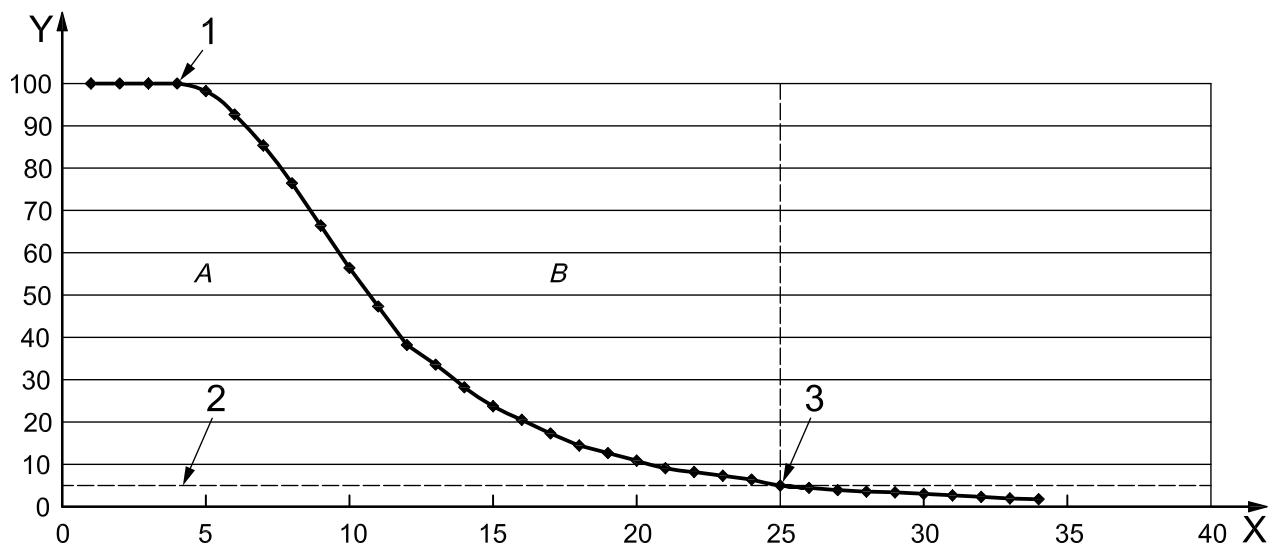
**Figure B.1 — Example of breakthrough curve showing determination of  $t_0$  and  $t_{lag}$**

Thus for all future gas tests,  $t_0$  would be 34 s after turning on the challenge gas. This time zero point would be used to calculate breakthrough at 1 min, 2 min and 5 min intervals after time zero  $t_0$ . Since this is a calculated value, the measured test contaminant concentration will not be zero at the calculated  $t_0$  point.

## Annex C (normative)

### Capacity determination

Figure C.1 shows an example of an efficiency versus time plot for an odour filter test, where  $t_0$  is the start of test time and  $t_f$  the end of test time. A predetermined end of test contaminant efficiency is shown by the dotted line at 5 %. A predetermined time limit could also be used to determine  $t_f$ . Area  $A$ , under the curve and to the left of  $t_f$ , represents the total amount of contaminant removed by the filter during the testing period. Area  $B$ , above the curve and to the left of  $t_f$ , represents the total amount of contaminant penetrating the filter during the test period. The sum of these two areas ( $A + B$ ) represents the total amount of contaminant to which the filter was exposed during the test period.



#### Key

X time, in seconds

Y concentration relative to maximum concentration, in percent

$A$  Area of retained gas.

$B$  Area of penetrated gas.

1 start time  $t_0 = 5$  min

2 terminal condition (5 % concentration relative to maximum concentration)

3 end time  $t_f = 25$  min, defined by intersection of concentration curve and terminal condition line

**Figure C.1 — Example of capacity determination**

Assuming a constant influent, the capacity of the filter,  $m_c$ , can be calculated according to Equation (C.1) by relating area,  $A$ , and areas ( $A + B$ ) to the total mass of contaminant,  $m_T$ , to which the filter was exposed, determined by multiplying the contaminant feed rate by the test time:

$$m_c = \frac{A}{A + B} \times m_T \quad (\text{C.1})$$

## Annex D (informative)

### Conversion of test contaminant concentration units

The conversion factors for mandatory and optional test contaminants are given in Table D.1.

Equation (D.1) is used to determine the conversion factor,  $F$ , for converting a volume fraction, expressed in parts per million, into a mass concentration, expressed in milligrams per cubic metre:

$$F = \frac{M \times p}{R \times T \times 10} \quad (\text{D.1})$$

where

$M$  is the molar mass, in grams per mole;

$R$  is the molar gas constant equal to 8,314 J/mol/K;

$p$  is the pressure, in hectopascals;

$T$  is the temperature, in Kelvin.

**Table D.1 — Common test gases and conversion factors at  $T = 23\text{ °C}$  and  $p = 1\ 013\ \text{hPa}$**

Test contaminant	Formula	Used as substitute for	Concentration volume fraction in parts per million	Molar mass g/mol	Conversion factor
Butane	C <sub>4</sub> H <sub>10</sub>	VOC	80	58,12	2,39
Toluene	C <sub>7</sub> H <sub>8</sub>	VOC	80	92,14	3,79
Fluorobenzene	C <sub>6</sub> H <sub>5</sub> F	Benzene	80	96,10	3,95
Acetaldehyde	C <sub>2</sub> H <sub>4</sub> O	Formaldehyde	30	44,05	1,81
Hydrogen sulfide	H <sub>2</sub> S	Farm odour	0,4	34,08	1,40
Ammonia	NH <sub>3</sub>	Farm odour	30	17,03	0,70
Sulfur dioxide	SO <sub>2</sub>	—	30	64,06	2,64
Hydrogen chloride	HCl	—	—	36,46	1,50
Nitric acid	HNO <sub>3</sub>	—	—	63,01	2,59
Nitrogen oxide	NO	—	30	30,10	1,23
Nitrogen dioxide	NO <sub>2</sub>	—	30	46,01	1,89
Ozone	O <sub>3</sub>	—	—	48,00	1,97
Nitrogen	N <sub>2</sub>	—	—	28,01	1,15
Oxygen	O <sub>2</sub>	—	—	32,00	1,32
EXAMPLE $1 \times 10^{-6}$ butane C <sub>4</sub> H <sub>10</sub> = 2,39 mg/m <sup>3</sup> at 23 °C and 1 013 hPa.					

## Bibliography

- [1] ISO 5011, *Inlet air cleaning equipment for internal combustion engines and compressors — Performance testing*
- [2] ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*
- [3] ISO 12103-1, *Road vehicles — Test dust for filter evaluation — Part 1: Arizona test dust*
- [4] EN 779, *Particulate air filters for general ventilation — Determination of the filtration performance*

www.iso.org

---

---

**ICS 43.040.60**

Price based on 17 pages