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**Interior air of road vehicles —**

Part 1:

**Whole vehicle test chamber —  
Specification and method for the  
determination of volatile organic  
compounds in cabin interiors**

*Air intérieur des véhicules routiers —*

*Partie 1: Enceinte d'essai pour un véhicule complet — Spécification et  
méthode de détermination des composés organiques volatils dans les  
habitacles d'automobiles*





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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.

ISO 12219-1 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 6, *Indoor air*, in collaboration with Technical Committee ISO/TC 22, *Road vehicles*.

ISO 12219 consists of the following parts, under the general title *Interior air of road vehicles*:

- *Part 1: Whole vehicle test chamber — Specification and method for the determination of volatile organic compounds in cabin interiors*
- *Part 2: Screening method for the determination of the emissions of volatile organic compounds from vehicle interior parts and materials — Bag method*
- *Part 3 Screening method for the determination of the emissions of volatile organic compounds from vehicle interior parts and materials — Micro-scale chamber method*
- *Part 4: Screening method for the determination of the emissions of volatile organic compounds from vehicle interior parts and materials — Small chamber method*

The following part is under preparation:

- *Part 5: Screening method for the determination of the emissions of volatile organic compounds from vehicle interior parts and materials — Static chamber method*

## Introduction

Volatile organic compounds (VOCs) are widely used in industry and can be emitted by many everyday products and materials. They have attracted attention in recent years because of their impact on indoor air quality. After homes and workplaces, people spend a lot of time in their vehicles. It is important to determine the material emissions of interior parts and to reduce them to an acceptable level, if required. Therefore it is necessary to obtain comprehensive and reliable information about the types of organic compounds in the interior air of vehicles and also their concentrations.

This part of ISO 12219 outlines a method of measuring the types and levels of VOCs in vehicle cabin air under controlled conditions. It describes requirements for a whole vehicle test chamber and a test protocol. Measurements are carried out according to ISO 16000-6 (VOCs) and ISO 16000-3 (carbonyl compounds).

There are several national test methods available for measuring in-vehicle air quality, e.g. References [2][3]. However, this part of ISO 12219 requires a fixed heating radiation system whereas the methods of References [2][3] define a fixed temperature programme.

Before setting a fixed radiation density for heating the test vehicle, several validation measurements were performed (Reference [1]).

ISO 16000-3, ISO 16000-5,<sup>[6]</sup> ISO 16000-6, ISO 16000-9,<sup>[7]</sup> ISO 16000-10,<sup>[8]</sup> ISO 16000-11,<sup>[9]</sup> ISO 16000-24,<sup>[10]</sup> ISO 16000-25,<sup>[11]</sup> as well as ISO 16017-1 and ISO 16017-2<sup>[12]</sup> also focus on volatile organic compound (VOC) measurements.



# Interior air of road vehicles

## Part 1:

# Whole vehicle test chamber — Specification and method for the determination of volatile organic compounds in cabin interiors

**WARNING** — It is the responsibility of the user of this part of ISO 12219 to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use. National regulations for precautions shall be followed.

## 1 Scope

This part of ISO 12219 describes and specifies the whole vehicle test chamber, the vapour sampling assembly and the operating conditions for the determination of volatile organic compounds (VOCs), and carbonyl compounds in vehicle cabin air. There are three measurements performed: one (for VOCs and carbonyl compounds) during the simulation of ambient conditions (ambient mode) at standard conditions of 23 °C with no air exchange; a second only for the measurement of formaldehyde at elevated temperatures (parking mode); and a third for VOCs and carbonyl compounds simulating driving after the vehicle has been parked in the sun starting at elevated temperatures (driving mode). For the simulation of the mean sun irradiation, a fixed irradiation in the whole vehicle test chamber is employed.

The VOC method is valid for measurement of non-polar and slightly polar VOCs in a concentration range of sub-micrograms per cubic metre up to several milligrams per cubic metre. Using the principles described in this method, some semi-volatile organic compounds (SVOC) can also be analysed. Compatible compounds are those which can be trapped and released from the Tenax TA<sup>®1)</sup> sorbent tubes described in ISO 16000-6, which includes VOCs ranging in volatility from *n*-C<sub>6</sub> to *n*-C<sub>16</sub>.

The sampling and analysis procedure for formaldehyde and other carbonyl compounds is performed by collecting air on to cartridges coated with 2,4-dinitrophenylhydrazine (DNPH) and subsequent analysis by high performance liquid chromatography (HPLC) with detection by ultraviolet absorption. Formaldehyde and other carbonyl compounds can be determined in the approximate concentration range 1 µg/m<sup>3</sup> to 1 mg/m<sup>3</sup>.

The method is valid for passenger cars, as defined in ISO 3833.

This part of ISO 12219 describes:

- a) transport and storage of the test vehicles until the start of the test;
- b) conditioning for the surroundings of the test vehicle and the test vehicle itself as well as the whole vehicle test chamber;
- c) conditioning of the test vehicle prior to measurements;
- d) simulation of ambient air conditions (ambient mode);
- e) formaldehyde sampling at elevated temperatures (parking mode);
- f) simulation of driving after the test vehicle has been parked in the sun (driving mode).

Buses, motor caravans, and trucks, in accordance with the descriptions given in ISO 3833, are excluded.

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1) Tenax TA<sup>®</sup> is the trade name of a product supplied by Buchem. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

## 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 3833:1977, *Road vehicles — Types — Terms and definitions*

ISO 9060, *Solar energy — Specification and classification of instruments for measuring hemispherical solar and direct solar radiation*

ISO 16000-3, *Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds in indoor air and test chamber air — Active sampling method*

ISO 16000-6:2011, *Indoor air — Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA<sup>®</sup> sorbent, thermal desorption and gas chromatography using MS or MS–FID*

ISO 16017-1, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling*

## 3 Terms and definitions

For the purpose of this document, the terms and definitions of ISO 16000-3, ISO 16000-6 and the following apply.

### 3.1

#### **background concentration**

analyte concentration in the whole-vehicle test chamber when the test vehicle is inside

### 3.2

#### **test vehicle**

new or used vehicle to be tested

NOTE 1 The test vehicle can be of any type specified in ISO 3833:1977, 3.1.1, only.

NOTE 2 See also 4.5.

### 3.3

#### **total volatile organic compounds**

##### **TVOCs**

sum of volatile organic compounds sampled on Tenax TA<sup>®1</sup>) and eluting between and including *n*-hexane and *n*-hexadecane, detected with a flame ionization detector (TVOC<sub>FID</sub>) or mass spectrometric detector (TVOC<sub>MS</sub>) and quantified converting the total area of the chromatogram in that analytical window to toluene equivalents

NOTE Adapted from ISO 16000-6:2011, 3.4.

### 3.4

#### **carbonyl compound**

compound containing the functional group –C(=O)– determined according to a specified procedure

NOTE For the purposes of this part of ISO 12219, the procedure is that specified in ISO 16000-3.

### 3.5

#### **ambient mode**

mode in which sampling of VOCs and carbonyl compounds in the cabin of a test vehicle under standardized ambient temperature conditions is performed, defined by 23 °C

NOTE Engine off, radiators off, sampling time 30 min.



**3.6****parking mode**

mode in which sampling of formaldehyde in the cabin of a test vehicle under standardized elevated temperatures is performed

NOTE Sampling time 30 min.

**3.7****driving mode**

mode in which sampling of VOCs and carbonyl compounds in the cabin of a test vehicle under standardized conditions starting at elevated temperatures is performed, simulating a vehicle driven after being parked in the sun

NOTE Sampling time 30 min.

**3.8****sampling train**

apparatus to collect the sample gas inside the test vehicle cabin (indoor) and in the whole vehicle test chamber, trapping the VOCs and carbonyl compounds in sorbent tubes under standardized conditions

NOTE See ISO 16000-3 for formaldehyde and ISO 16000-6 for VOCs.

**4 Apparatus and materials**

**4.1 General.** The whole vehicle test chamber is big enough to house the test vehicle completely. An air-conditioning system is installed to allow standardized air conditions for a temperature of  $23\text{ °C} \pm 2\text{ °C}$ , humidity of  $50\% \text{ RH} \pm 10\% \text{ RH}$ . A solar radiator system is installed to heat the test vehicle cabin with a fixed irradiation. The resulting temperature inside the cabin depends on the insulation and the window glass material (the minimum requirements are specified in 6.1) (see also Figure 1).

**4.2 Heating radiator.** Infrared radiator, halogen radiator or other radiators (simulating sunlight) (wavelengths  $<300\text{ nm}$  shall be filtered out). The heating radiators used shall be powered to create a radiation density at the reference measurement point in the middle of the roof surface of the test vehicle of  $350\text{ W/m}^2$  to  $450\text{ W/m}^2$  ( $400\text{ W/m}^2 \pm 50\text{ W/m}^2$ ).

The heating area shall cover at least the area of the test vehicle cabin and an additional 0,5 m more to each side of the lower part of the glazing (footprint) (see Figure 1). Position the heating radiators on the roof with a shining angle of  $90^\circ$  to the heating area. There shall be no heating radiators shining from the side. The heating area shall be calibrated in squares of  $25\text{ cm} \times 25\text{ cm}$  with a radiation density of  $400\text{ W/m}^2 \pm 50\text{ W/m}^2$ . The required radiation density shall be available directly after the lamps are switched on (within a few minutes).

The irradiation shall be measured in accordance with ISO 9060.

Take care not to have too short a distance between radiator and surface in order to avoid hot spots.

**4.3 Sampling trains.**

**4.3.1 Sampling in the test vehicle.** Four sampling trains are employed: two for the VOC measurements in parallel and two for the carbonyl compound measurements in parallel in the test vehicle (to check the repeatability) (see ISO 16000-3 for carbonyl compounds and ISO 16000-6 or ISO 16017-1 for VOCs). There is one sampling line with a manifold for the division of the sampling flow outside the test vehicle (see 4.3.3). It consists of the probe, the sampling line (heated, if necessary), the sorbent tube for VOC or the DNPH cartridge for carbonyl compound sampling respectively, the gas meters and the pumps (see 4.5).

All sampling trains shall be checked for leaks and shall have a maximum vacuum decay rate of 30 kPa for an average time of 10 s. For the leak check, the nozzle shall be plugged. Other equivalent leak checks can be employed.

**4.3.2 Sampling in the whole vehicle test chamber.** Four sampling trains are used to determine the background concentration in the whole vehicle test chamber. The sampling trains are identical to those of 4.3.1, apart from the sampling line, which is much shorter and not heated.

All sampling trains shall have a maximum vacuum decay rate of 30 kPa for an average of 10 s. The nozzle is plugged for the leak check. Other equivalent leak checks can be employed.

**4.3.3 Sampling line.** Tubing, between the sampling point (probe) inside the test vehicle, via the manifold outside the test vehicle to the VOC sorbent tubes or DNPH cartridges respectively (see Figure 1).

The sampling line shall be constructed so as to be

- a) as short as possible (maximum 5 m) with an internal diameter of 4 mm or more;
- b) of inert, non-emitting and non-absorbing/non-adsorbing material [e.g. stainless steel or polytetrafluoroethylene (PTFE) or glass/quartz (deactivated)];
- c) proven that there are no contaminations or sink effects in the sampling line;
- d) with heating device, if necessary, to prevent condensation/deposition on the inner walls (best practice: temperature controlled to about 20 °C above air temperature inside the test vehicle).

The tubing should be inserted between the door and the door frame or between the door frame and the glazing and should be sufficiently non-compressible to ensure an unimpeded flow of air.

The second sampling line [tubing, between the sampling point (probe) in the whole vehicle test chamber in the vicinity of the test vehicle [see 6.1 b)] and the manifold and to the VOC sorbent tubes or DNPH cartridges, respectively] is identical to that described in the preceding, but no heating is necessary. This second sampling line is needed to monitor the background analyte concentration of the whole vehicle test chamber.

**4.4 Analytical equipment and materials.** The analytical equipment used for the determination of VOCs and carbonyl compounds or formaldehyde alone shall be in accordance with ISO 16000-6 (VOCs) or ISO 16000-3 (carbonyl compounds), respectively.

It shall be proven for the VOC sorbent tubes and the DNPH cartridges that there is no breakthrough. This can be identified by a back-up sorbent tube which is analysed separately (see ISO 16017-1).

**4.5 Test vehicle.** A new vehicle (i.e. one not driven more than 50 km and within  $28 d \pm 5 d$  after the completion of manufacture) to be tested shall have been manufactured by the normal production process. The test data are dependent on the trim level and exterior colour of the selected test vehicle. The colour of the test vehicles for the determination of the official VOC and carbonyl compound emissions is black. If there is no black test vehicle available, take the darkest colour.

All manual glazing shades shall remain open.

The test vehicle shall be stored and transported under conditions preventing direct solar heating, otherwise the vehicle shall be conditioned after arrival overnight with open doors and windows before it is transferred into the whole vehicle test chamber. This conditioning shall be undertaken if used vehicles are tested. No transport waxes for protection should be used. All transport foils or transit lacquers shall be removed carefully before the test. The test vehicle shall not be cleaned (inside) for at least 24 h before starting the measurements.

The method specified in this part of ISO 12219 can also be employed for used vehicles. In this case, it is possible that the measurement results are not identical to those obtained on a new test vehicle due to different usage.

## 5 Principle

A whole vehicle test chamber (see Annex A) reserved for this purpose is assembled. The air in the test vehicle cabin is measured according to a uniform standardized programme (see Figure 1). Sampling of VOCs and carbonyl compounds is performed for the ambient mode at 23 °C. Subsequently, formaldehyde is determined alone under elevated temperature conditions in the parking mode (see Figure 3). Sunshine is simulated by the

use of heating radiators providing a mean fixed irradiation for 4,5 h, after which a third sample is taken in the driving mode.

The humidity and temperature of the air inside the whole vehicle test chamber are measured. The VOC and carbonyl compound vapour samples are taken in the driver breathing zone and collected on VOC sorbent tubes and DNPH cartridges. Later the samples shall be analysed in the laboratory according to ISO 16000-6 or ISO 16000-3, respectively.

Furthermore VOC and carbonyl compound vapour samples are taken in the whole vehicle test chamber to determine the background concentrations. Altogether a total of eight VOC and 12 carbonyl compound samples are required [two duplicate room temperature samplings (ambient mode) and two duplicate elevated temperature samplings (driving mode), and the same duplicate background samples in the whole test chamber in each of the modes as well as the two formaldehyde measurements under the elevated temperature conditions (parking mode)].

The temperature resulting from use of the heating radiators inside the test vehicle cabin depends upon the model of the test vehicle and is influenced by the insulation, the window material, etc.

The analytical part of the overall measurement procedure is based on the use of sorbent tubes with subsequent thermal desorption and gas chromatographic analysis for VOCs (according to ISO 16000-6) and the use of 2,4-dinitrophenylhydrazine (DNPH) cartridges for the determination of carbonyl compounds (according to ISO 16000-3). The sampling of VOCs is referenced to Tenax TA<sup>®1</sup> sorbent tubes; however, other equivalent sorbents may be used if they produce the same results (see ISO 16000-6).

## 6 Requirements of the whole vehicle test chamber, test vehicle and measurement procedures

### 6.1 Requirements for the whole vehicle test chamber

The whole vehicle test chamber with the following requirements is assembled as shown in Figure 1. The following requirements shall be met.

- a) The whole vehicle test chamber shall be large enough to accommodate the complete test vehicle.
- b) The whole vehicle test chamber shall be capable of maintaining a temperature of  $23\text{ °C} \pm 2\text{ °C}$ . A heating and ventilation system (including the adjustment of the humidity) and, if necessary, a cooling system is necessary. The sampling point for the background concentrations in the whole test chamber shall be more than 1 m from the side of the test vehicle and at the height of the lower window frame of the front door.

NOTE An air filter system can be used to keep the whole vehicle test chamber clean.

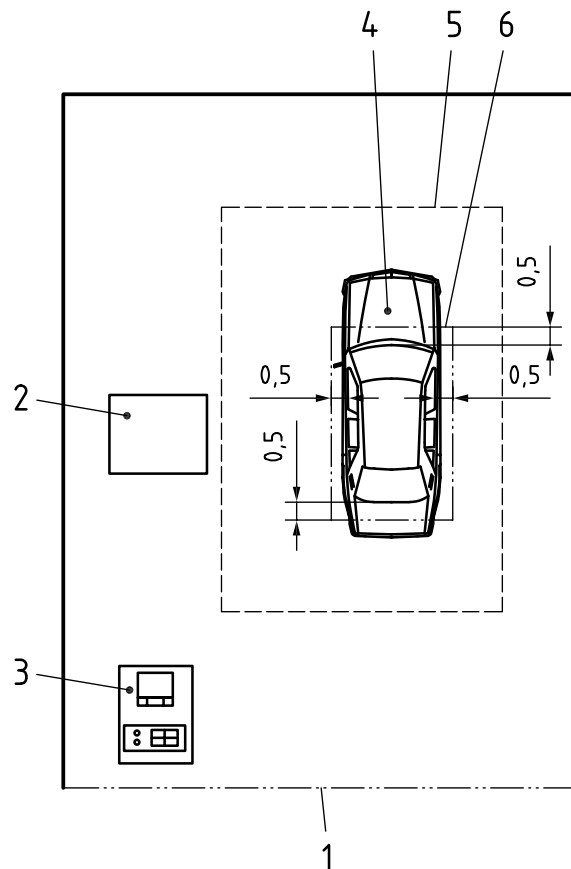
- c) The temperature profile shall be in accordance with Figure 3.
- d) Relative humidity (RH) during the ambient mode in the whole vehicle test chamber shall be  $50\% \text{ RH} \pm 10\% \text{ RH}$ .
- e) Relative humidity RH during the parking and driving mode in the whole vehicle test chamber shall be documented.
- f) The maximum background concentration for each analyte shall not exceed  $20\text{ }\mu\text{g}/\text{m}^3$  for each single component and  $200\text{ }\mu\text{g}/\text{m}^3$  for TVOCs or a maximum of 10 % of the respective measured values (whichever is greater). If this is not met, the source of the contamination shall be identified and removed or covered to exclude it from the test.
- g) Two duplicate VOCs and two duplicate carbonyl compound background samples (one during ambient mode and one during driving mode) as well as one duplicate formaldehyde background sample (parking mode) are required.

The VOC sorbent tubes and the DNPH cartridges for the VOC and carbonyl compound sampling in the test vehicle as well as the pumps and the other sampling devices are positioned in the whole vehicle test chamber.

The air exchange rate of the whole vehicle test chamber during the driving mode should be a minimum of twice per hour.

- h) The heating radiators are fixed above the test vehicle overlapping the footprint of the cabin of the test vehicle by 0,5 m to each side with an irradiation density on the roof surface of  $400 \text{ W/m}^2 \pm 50 \text{ W/m}^2$ .
- i) Optional trolley or table to carry sampling devices (Figure 1, label 2).
- j) Various measuring instruments and data recording for continuous recording of signals measured (e.g. for temperature measurements and humidity measurements (Figure 1, label 3).
- k) Door for the entry and exit of the test vehicle (Figure 1, label 1).
- l) A hydrocarbon air warning system should be installed (option) to avoid explosive workplace atmospheres; the workplace regulations shall be followed.
- m) A pipe is fixed at the exhaust pipe liner of the test vehicle to remove the waste gas outdoors.

Dimensions in metres



**Key**

- |                                       |                 |
|---------------------------------------|-----------------|
| 1 door test chamber                   | 4 test vehicle  |
| 2 sampling device                     | 5 test area     |
| 3 controlling and data-logging device | 6 radiator area |

**Figure 1 — Schematic arrangement of whole vehicle test chamber components and the test vehicle**

Care shall be taken to ensure that sampling train components remain at or near ambient temperature and are protected from the direct effects of the heating radiators of the whole vehicle test chamber.

## 6.2 Requirements for the test vehicle

**6.2.1** A new vehicle to be tested shall have been manufactured by the normal production process. The test data depends on the trim level and exterior colour of the selected test car. A detailed specification of the trim level of the test vehicle shall be included in the test report. Any deviation from that specified for the ideal situation shall be noted and the effect of any deviation from the test results shall be explained and reported.

**6.2.2** The test for a new test vehicle shall be carried out within  $28 \text{ d} \pm 5 \text{ d}$  after completion of assembly. The test vehicle shall be stored and transported under conditions with no direct heating such as in the shadow or sales rooms which are described in 4.5. All transport foils or transit lacquers shall be removed carefully.

**6.2.3** The sensors and cables for the temperature measurements (optional features) are installed according to Annex B.

**6.2.4** The sampling line (with the probe at one end) for the VOC and carbonyl compound measurements is installed according to Figures 1 and 2. The sampling line is connected with a manifold situated outside the test vehicle. The manifold is connected to four sampling trains which are used to perform the following consecutive measurements:

- a) monitoring of the test vehicle cabin in the ambient mode at  $23 \text{ °C} \pm 2 \text{ °C}$  [(two VOC measurements (duplicate) and two carbonyl compound measurements (duplicate))],
- b) monitoring of the test vehicle cabin in the parking mode at elevated temperatures [two formaldehyde measurements (duplicate); only two sampling trains are needed],
- c) monitoring of the test vehicle cabin in the driving mode [two VOC measurements (duplicate) and two carbonyl compound measurements (duplicate)].

The sampling line should be flushed with acetone and dried before each new sampling series with the next test vehicle to avoid contaminations in the sampling line and to avoid memory effects.

**6.2.5** The sampling probe of the sampling trains shall be positioned in the breathing zone of the driver (50 cm from the top of steering wheel in line with the bottom of the head-rest). To this end, position the seat as far back as possible and as low as possible and move the steering wheel back to the highest possible position (see Figure 2).

**6.2.6** Pipe the vehicle exhaust emissions outdoors.

**6.2.7** Set the air conditioner during the driving mode (as defined in 7.3.6.2) in which sampling of VOCs and carbonyl compounds is undertaken in the cabin of a test vehicle under standardized conditions starting at elevated temperatures, to simulate a vehicle driven after being parked in the sun, with engine and air conditioning (auto) on, or, if no automatic air-conditioning system is available, with the ventilation set to its highest position, (air) recirculation off, and radiators on, according to Table 1.

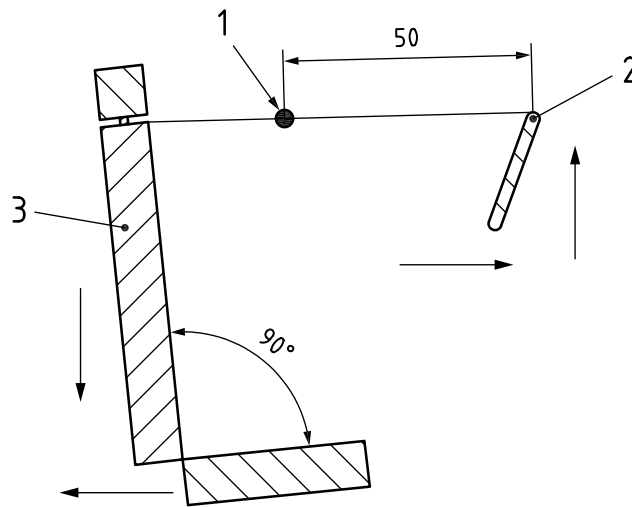
**6.2.8** Set the air conditioner of the test vehicle in accordance with Table 1.

## 6.3 Requirements for VOC and carbonyl compound air sampling and measurement methods

For VOC and carbonyl compound sampling and measurement of the air in the cabin of the test vehicle and in the whole vehicle test chamber, the following procedures shall be followed [see also 6.1 g)]:

- a) carbonyl compounds including formaldehyde: ISO 16000-3;
- b) VOCs: ISO 16000-6.

Dimensions in centimetres



**Key**

- 1 sampling point
- 2 steering wheel
- 3 seat with head-rest

**Figure 2 — Schematic arrangement of the sampling position in the test vehicle**

**Table 1 — Setting of air conditioner**

Condition	Automatic air conditioner	Semi-automatic or manual air conditioner	No air conditioner
Air-conditioning ON/OFF	ON	ON	—
Indoor and outdoor air change-over	Automatic	Fresh air circulation	—
Air flow selector	Automatic All registers to be upright and fully open	Face mode Ventilation in highest position, with fresh-air ventilation All registers to be upright and fully open	Ventilation in highest position, with fresh-air ventilation All registers to be upright and fully open
Temperature	23 °C	Lowest (or medium to avoid an automatic air recirculation mode)	Lowest
NOTE These different air conditions are not necessarily equivalent but represent a customer reaction and the specifications of the vehicle.			

**6.4 Blank measurements**

**6.4.1 Field blanks**

The sorbent tubes used as field blanks (for VOC and carbonyl compounds) shall be from the same batch and treated in the same way as those used for sampling and analysis (including all devices and handlings), except that no gas is drawn through the sampling trains (see 7.2.4).

A field blank procedure shall be performed at least before each measurement series (series of consecutive measurements of several vehicles).

The field blank shall not be deducted from the measured value.

All field blanks shall be reported with the corresponding measured values.

### 6.4.2 Analytical blanks

The requirements for analytical and GC–MS blanks are specified in ISO 16000-3 and ISO 16000-6.

## 7 Standard test procedure

### 7.1 General

The standard test procedure is divided into three parts:

- conditioning of the whole vehicle test chamber,
- conditioning of the test vehicle,
- performing sampling and analytical measurement.

### 7.2 Pre-arrangements and preconditioning of the whole vehicle test chamber and the vehicle and performing the field blanks

#### 7.2.1 Pre-arrangements

Connect the test apparatus with the test vehicle. Attach the cables and sampling lines to the door frame so that, when the doors are closed, there is a (nearly) airtight sealing. Furthermore, the sampling line for VOC and carbonyl compound sampling shall be installed in the test vehicle. The probe is positioned as specified in 6.2.5.

- Connect the sampling line with the manifold and the manifold with the sampling trains for VOC and carbonyl compound measurements outside the test vehicle.
- Connect the test apparatus within the whole vehicle test chamber.

Install the heating radiators and the other installations listed in 6.1.

#### 7.2.2 Preconditioning of the whole vehicle test chamber

Adjust the temperature of the whole vehicle test chamber to  $23\text{ °C} \pm 2\text{ °C}$  during the ambient mode test. There may be the need for a heating or cooling device. The humidity shall be  $50\% \text{ RH} \pm 10\% \text{ RH}$  in the ambient mode. The whole vehicle test chamber should be under good ventilation, and the air exchange rate should be twice per hour or higher. The interior materials of the whole vehicle test chamber shall have no appreciable emissions regarding the indoor air inside the test vehicle (see 6.1 and 6.4 background concentrations). The heating of the interior of the cabin and the surfaces of the test vehicle is performed by heating radiators from outside the test vehicle.

#### 7.2.3 Preconditioning of the test vehicle

The essential conditions for the surroundings are as follows.

The temperature during the ambient mode is adjusted to  $23\text{ °C} \pm 2\text{ °C}$  via the whole test chamber conditioning system (see Figure 3). The preconditioning is started by opening the door for 1 h. After this, the door is closed for a minimum of 8 h (see Figure 3).

#### 7.2.4 Field blanks

Prepare the field blanks before the measurements are started (see 6.4.1). Install one Tenax TA<sup>®1</sup> sorbent tube for VOCs and one DNPH cartridge for carbonyl compounds in the sampling trains to measure the background concentration of the whole vehicle test chamber as well as one Tenax TA<sup>®1</sup> sorbent tube and one DNPH cartridge in the sampling trains to measure the background concentration of the test vehicle. The field blank samplers shall be handled in the same way as those used for VOC or carbonyl compound measurements, but without drawing air through the sampling trains. As soon as the samplers have been connected into the sample train, they shall be removed, sealed and retained for analysis with the real samples.

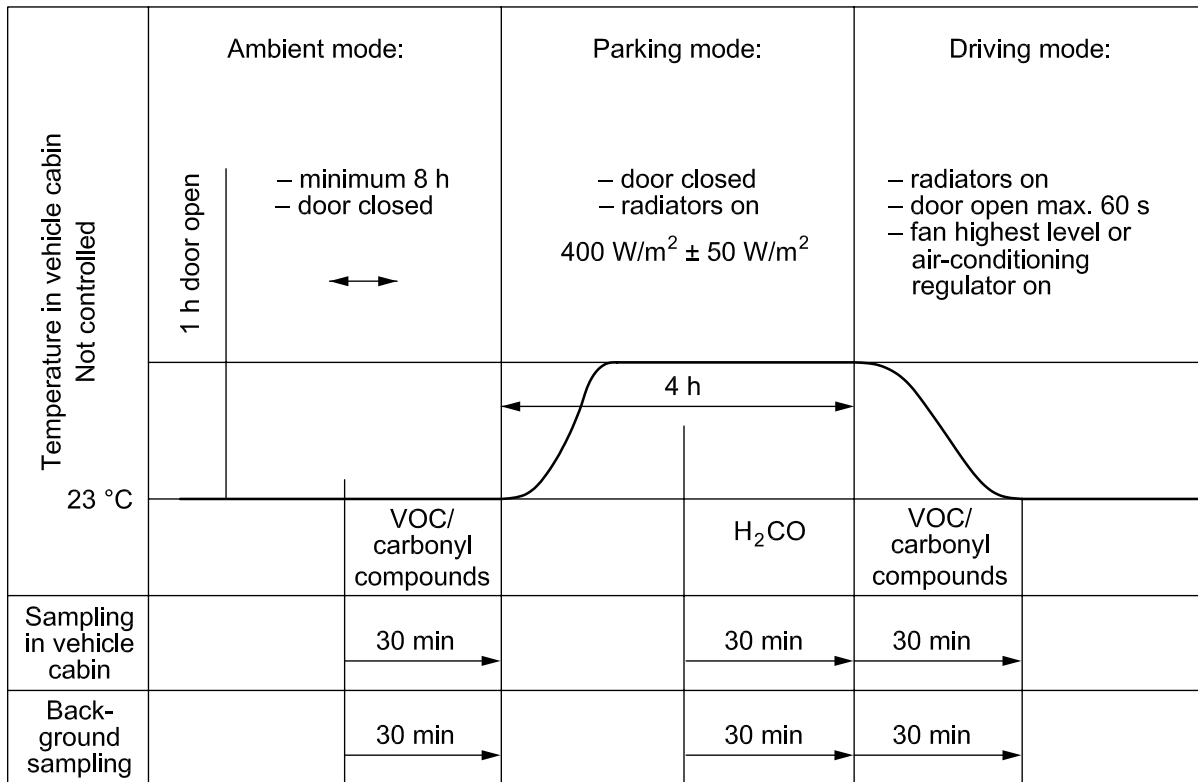


Perform at least one field blank for each measurement series. Analytical GC–MS or HPLC blanks shall be performed according to 6.4.

**7.3 Detailed description of the test procedure**

**7.3.1 Time: 0 (see schema in Figure 3)**

After the conditions of the whole test chamber have been set at 23 °C ± 2 °C and 50 % RH ± 10 % RH and the air exchange rate in the test chamber has been adjusted to a recommended value of at least twice per hour (see 7.2.2), the test procedure is started. Start the conditioning of the test vehicle by opening all doors for 1 h. Install the sampling train including the two VOC sorbent tubes and the two DNPH cartridges, and leak-check the sampling train (see 4.3.1). An overview of the number of samples to be taken is given in Annex E.



**Figure 3 — Schematic temperatures and test schedule**

**7.3.2 Time: 1,00 h**

Continue by conditioning the whole-vehicle test chamber and close all doors of the test vehicle for at least 8 h or more (e.g. overnight) at 23 °C ± 2 °C and 50 % RH ± 10 % RH and keep the air exchange rate in the whole vehicle test chamber at a minimum of twice per hour (recommended value). There is no dynamic ventilation of the test vehicle.

**7.3.3 Time: 8,50 h**

There is no dynamic ventilation of the test vehicle. Before the sampling starts, purge the dead volume of the sampling line. Switch on the pumps of the four sampling trains (two for VOC and two for carbonyl compounds, each in parallel). Perform the sampling of gaseous organic compounds in the test vehicle cabin in the ambient mode at room temperature (23 °C ± 2 °C) for 30 min. Adjust the flow rate to maximum 0,1 l/min for VOC and 1 l/min for carbonyl compound measurements. The measurement procedures specified in ISO 16000-6 (VOCs) and ISO 16000-3 (carbonyl compounds) shall be followed.



At the same time, switch on the four sampling trains in the whole vehicle test chamber to determine the VOC and carbonyl compound background concentrations (two sampling trains for VOCs and two for carbonyl compounds). The probe is positioned 1 m in front of the cabin air intake. The relative humidity and the temperature are measured in the same position.

#### 7.3.4 Time: 9,00 h

Switch off the pumps for the VOC and carbonyl compound measurements, read and register the measurement volumes and take the VOC sorbent tubes and DNPH cartridges, which are placed outside the vehicle cabin, out of the sampling train. Seal the sorbent tubes or cartridges and analyse according to ISO 16000-6 and ISO 16000-3.

Furthermore, start the parking mode with the heating-up procedure (see Figure 3).

The following tasks shall be performed.

Start heating with the heating radiators (see 4.2). The irradiation is adjusted to  $400 \text{ W/m}^2 \pm 50 \text{ W/m}^2$  and maintained at that level for 4,5 h.

Adjust the air exchange rate to twice per hour or higher (recommended value) in the whole vehicle test chamber.

#### 7.3.5 Time: 12,50 h

Install the two DNPH cartridges in the two sampling trains for the test vehicle measurement and two for the whole vehicle test chamber. Before the sampling begins, check the sampling train for leaks (see 4.3.1) and purge the dead volume. Switch the pumps of the four sampling trains on. Perform formaldehyde sampling in the test vehicle cabin at elevated temperatures for 30 min. The flow rate is adjusted to maximum 1 l/min for carbonyl compound measurements. The measurement procedure specified in ISO 16000-3 (carbonyl compounds) shall be followed.

#### 7.3.6 Time: 13,00 h

##### 7.3.6.1 Parking mode

Switch off the pumps for the formaldehyde measurements and take the DNPH cartridges out of the sampling train to be analysed according to ISO 16000-3. Read and register the measurement volumes.

##### 7.3.6.2 Driving mode

Before the sampling in the driving mode begins, install the two VOC sorbent tubes and the two DNPH cartridges, and purge the dead volume.

Open the driver's door, start the engine, and turn on the air conditioning in less than 60 s (at 23 °C in case of automatic conditioning or lowest operation for semi-automatic and manual conditioning systems; for test vehicles without automatic air-conditioning systems, the fan is in highest performance mode with fresh-air ventilation) (see Table 1).

At the same time, switch on the pumps of the four sampling trains (two for VOCs and two for carbonyl compounds, each in parallel). The sampling of gaseous organic compounds in the test vehicle cabin is performed at elevated temperature for 30 min. The flow rate is adjusted to maximum 0,1 l/min for VOCs and 1 l/min for carbonyl compound measurements. The measurement procedures specified in ISO 16000-6 (VOCs) and ISO 16000-3 (carbonyl compounds) shall be followed.

At the same time, switch on the four sampling trains in the whole vehicle test chamber to determine the VOC and carbonyl compound background concentrations (two sampling trains for VOCs and two for carbonyl compounds).

#### 7.3.7 Time: 13,50 h

Stop the pumps of the sampling trains and switch off the engine and the heating radiators. The sampling volumes are read and registered. The VOC sorbent tubes and DNPH cartridges are taken out of the sampling train for the analysis as specified in ISO 16000-6 and ISO 16000-3.

Stop the continuous measurements for temperature and humidity.

This is the end of the test cycle.

## **8 Calculation, presentation of results, and precision and uncertainty**

Calculation and presentation of results are performed according to ISO 16000-6 and ISO 16000-3. The precision and uncertainty shall also be followed as specified in ISO 16000-6 and ISO 16000-3. There is an informative test report (see Annex C) which should be agreed on between the client and the laboratory.

## **9 Performance characteristics**

The detection limits and standard deviations for VOCs given in ISO 16000-6 and for carbonyl compounds in ISO 16000-3 are met in this measurement procedure. The condition to meet these performance characteristics is that there are no contaminations or sink effects in the sampling lines. This shall be proven before the measurements and shall be documented.

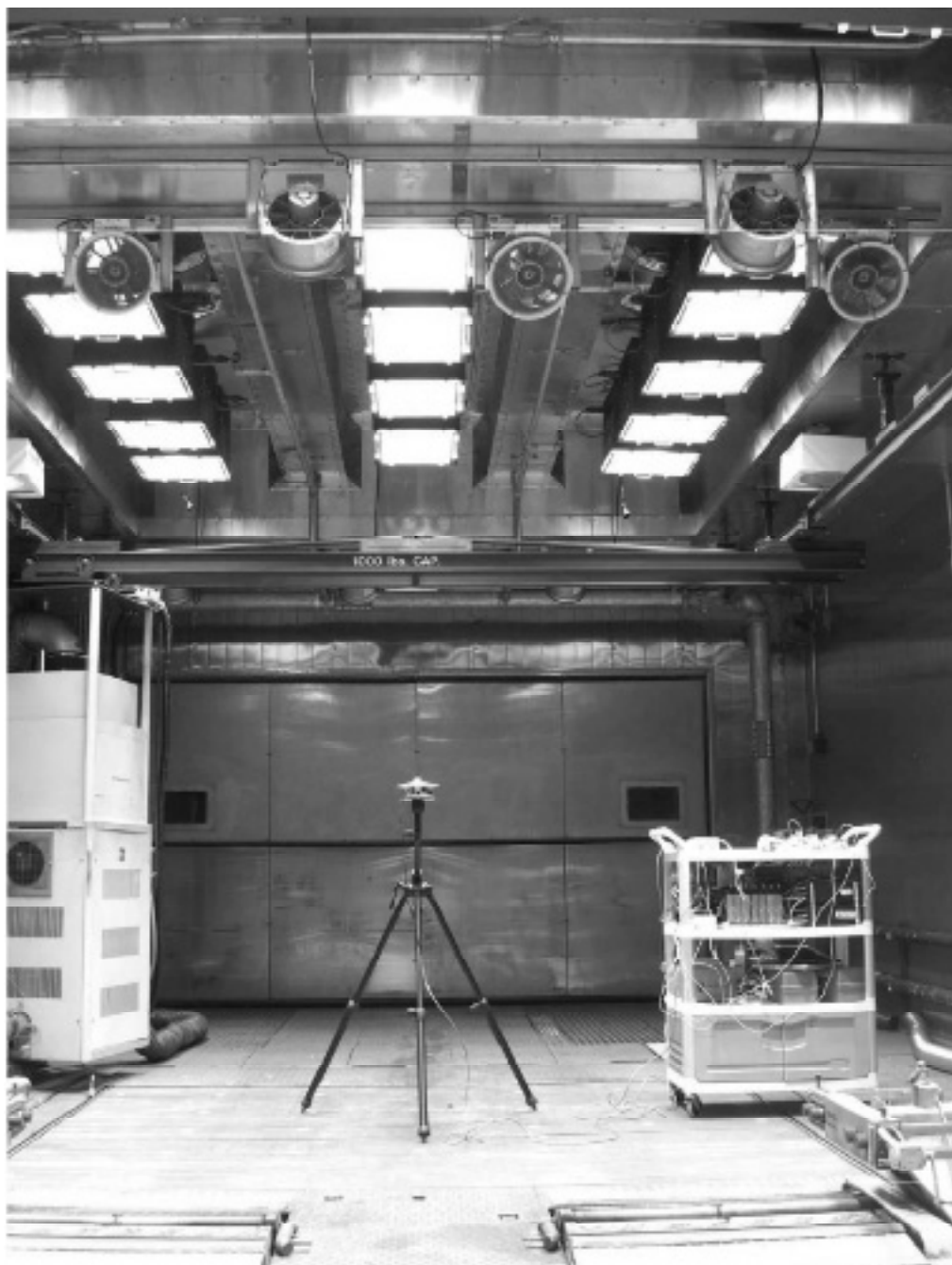
## **10 Quality assurance/quality control**

An appropriate level of quality control shall be employed following ISO 16000-3 and ISO 16000-6, namely:

- field blanks are prepared according to 6.4;
- the field blank level is acceptable if artefact peaks are no greater than 10 % of the typical areas of the analytes of interest;
- desorption efficiency of VOCs and carbonyl compounds should be checked according to ISO 16000-3 and ISO 16000-6;
- the collection efficiency can be assessed by using back-up tubes or taking samples of different sampling volumes less than the safe sampling volume;
- repeatability of the measuring method shall be determined, e.g. using collection and analysis of duplicate samples — a coefficient of variation  $\leq 15$  % (ISO 16000-3 and ISO 16000-6) from the duplicate measurements should be reached;
- the recovery of C<sub>6</sub> to C<sub>16</sub> hydrocarbons shall be 95 % mass fraction (ISO 16000-6);
- documentation illustrating traceable calibrations for temperature, humidity, and flow measurements.

**Annex A**  
(informative)

**Whole vehicle test chamber**



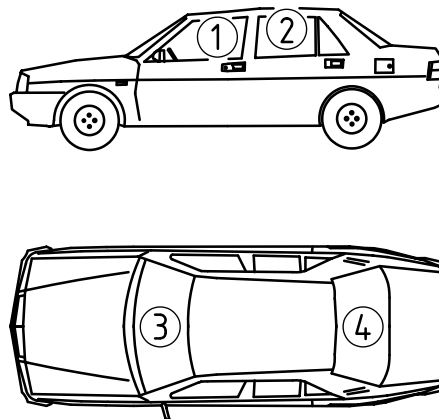
**Figure A.1 — Example of the illustration of a whole vehicle test chamber reproduced by permission of the Ford Motor Company (USA)**

## Annex B (informative)

### Temperature measuring points for parking mode

The temperature can be measured at the sampling point (inside the test vehicle).

Other temperature measurements at other points can be of interest, depending on the particular problem, e.g. instrument panel, top of the test vehicle, rear parcel shelf (see Figure B.1) (e.g. measured with standard Pt<sub>100</sub> air thermometers).



#### Key

- 1 temperature of the test vehicle cabin air (near sampling probe)
- 2 surface temperature, top of the test vehicle (inside)
- 3 surface temperature, instrument panel
- 4 surface temperature, rear shelf (alternative if there is no rear shelf: rear luggage cover)

**Figure B.1 — Example for temperature measurement points**

## Annex C (informative)

### Test report

NOTE ISO grants the user of this part of ISO 12219 the right to reproduce or otherwise use the sampling protocol on this page solely for the purpose of implementing this part of ISO 12219.

#### C.1 General

Client:	
Experts:	
Telephone:	
Fax:	
E-mail:	
Date of report:	
Pages:	
Order number:	
<b>Name of laboratory</b>	
Address:	

**C.2 Sampling records and continually recorded measured data**

**C.2.1 Protocol for test vehicle data**

**Table C.1 — Test vehicle data**

Sample cover sheet number:	
Vehicle type:	
VIN (vehicle identification number):	
Number of km/miles upon delivery:	
Vehicle colour	
Interior specification:	
<b>Glazing:</b>	
Shade and type of the window glass:	
Tank capacity:	
Sliding sun-roof/glass roof:	
Airbag in the steering wheel on the left and on the right:	
Central locking system:	
ABS und ASC:	
Fire extinguisher:	
<b>Volume of interior:</b>	
Passenger compartment: in m <sup>3</sup>	
Trunk: in m <sup>3</sup>	
Total volume: in m <sup>3</sup>	
Method of determination:	
The adjustment of the control elements for the ventilation system is done:	
History:	
Preservation of outer skin:	
De-preservation:	
<b>Conditioning phase:</b>	
Location outdoors:	
Location under sales room conditions:	
Have doors and windows been closed tight all the time?	
Test vehicle delivered on (date):	
Test vehicle pushed or driven into test garage by:	

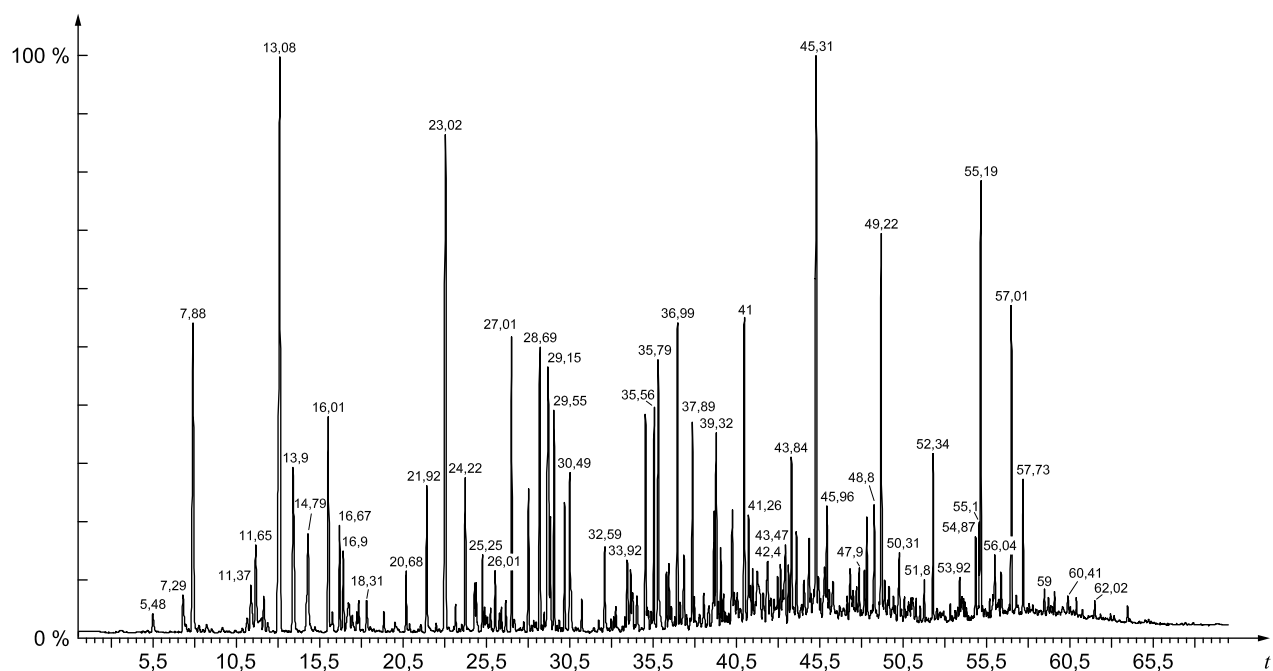
## C.2.2 Example of sampling records of volatile aldehydes and ketones (ambient mode)

Table C.2 — Concentrations of volatile aldehydes and ketones

Sample: Sampling condition: test vehicle cabin air 23 °C (ambient mode)		
Compound	CAS number	Concentration $\mu\text{g}/\text{m}^3$
Formaldehyde		
Acetaldehyde		
Acetone		
Acrolein		
2-Furaldehyde		
Propionaldehyde		
Crotonaldehyde		
2-Butanone		
<i>n</i> -Butyraldehyde		
Benzaldehyde		
Cyclohexanone		
Valeraldehyde		
4-Methyl-2-pentanone		
Hexaldehyde		
Heptaldehyde		

NOTE Table C.2 according to 3.4 and ISO 16000-3.

C.2.3 Identification of volatile hydrocarbons (volatile organic compounds, VOCs)



Retention time <i>t</i>	Retention index	Compound X	CAS number	Concentration $\mu\text{g}/\text{m}^3$
23,0	767	Toluene	108-88-3	162
28,7	863	Ethylbenzene	100-41-4	49
29,2	871	<i>m</i> -Xylene + <i>p</i> -xylene	108-38-3 + 106-42-3	67
30,2	891	Styrene	100-42-5	24
30,5	894	<i>o</i> -Xylene	95-47-6	29
33,2	1 021	1,4-Dichlorobenzene	104-46-7	< 5
43,8	1 400	Tetradecane	629-59-4	15
54,5	1 983	Di- <i>n</i> -butyl phthalate	84-74-2	< 5
68,4	2 565	Di(2-ethylhexyl)phthalate	117-81-7	< 5

Figure C.1 — Chromatogram of vapour phase organic substances with some examples listed — Test vehicle cabin air measurement at 23 °C room temperature (ambient mode)



### C.3 Test report

The results of the quantitative measurements are concentrations of substances expressed in mass per volume units [e.g. micrograms per metre cubed, standardized for gas in the following conditions: temperature of 20 °C (or according to the national regulations), pressure of 101,3 kPa, dry]. As a rule, these measured values relate only to the time span of the sampling, and the circumstances of the conditioning of the vehicle's interior present at that time. A proposal for a presentation of the results is given in Table C.3.

**Table C.3 — Results of TVOC value and selected compounds in the different modes**

Sampling condition	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
	Test vehicle: ambient mode	Whole vehicle test chamber: ambient mode	Test vehicle: parking mode	Whole vehicle test chamber: parking mode	Test vehicle: driving mode	Whole vehicle test chamber: driving mode
	23 °C	23 °C	sampling point <i>x</i> °C (optional)	sampling point <i>y</i> °C (optional)	sampling point <i>x</i> °C (optional)	sampling point <i>y</i> °C (optional)
	Concentration µg/m <sup>3</sup>					
Sample	xxx	xxx	xxx	xxx		
Compound 1						
Compound 2						
TVOC value						

## Annex D (informative)

### Very volatile organic compounds, volatile organic compounds, and semi-volatile organic compounds

Volatile organic compounds can be classified as volatile, very volatile or semi-volatile. The World Health Organization (WHO) has classified VVOCs, VOCs and SVOCs based on ranges of boiling points, as in Table D.1 (see Reference [4]).

**Table D.1 — Classification of VVOCs, VOCs, and SVOCs**

Description	Abbreviation	Boiling point range	
		from °C	to °C
Very volatile organic compounds	VVOC	<0	50 to 100
Volatile organic compounds	VOC	50 to 100	240 to 260
Semi-volatile organic compounds	SVOC	240 to 260	380 to 400

NOTE Boiling points of some compounds are difficult or impossible to determine because they decompose before they boil at atmospheric pressure. Vapour pressure is another criterion for the classification of compound volatility that may be used to classify organic chemicals (see Reference [4]). VOCs generally have saturation vapour pressures at 25 °C greater than 10<sup>-2</sup> kPa. SVOCs have vapour pressures between 10<sup>-2</sup> kPa to 10<sup>-8</sup> kPa, respectively. VVOCs typically have vapour pressures greater than 15 kPa.

## Annex E (normative)

### Overview of the number of samples to be taken

According to the description in this part of ISO 12219, a minimum of 24 samples shall be taken.

Samples are always taken in duplicate. The field blank should be taken in duplicate (one is placed temporarily in the background sample train and one in the vehicle sample train) before the ambient mode samples are taken. There are three sampling modes: ambient; parking; and driving.

There are three sampling locations: field blank; background; and vehicle.

**Table E.1 — Number of samples to be taken**

Sampling mode per ISO 12219-1	Ambient mode	Ambient mode	Parking mode	Driving mode	Driving mode
Sample media	Tenax TA <sup>®1)</sup>	DNPH	DNPH	Tenax TA <sup>®1)</sup>	DNPH
Measured compounds	VOCs	Carbonyl compounds	Carbonyl compounds	VOCs	Carbonyl compounds
Sampling location:					
— Whole vehicle test chamber and vehicle for field blank	2 <sup>a</sup>	2 <sup>a</sup>			
— Whole vehicle test chamber for background	2	2	2	2	2
— Vehicle	2	2	2	2	2
<b>Totals</b>	<b>6</b>	<b>6</b>	<b>4</b>	<b>4</b>	<b>4</b>
<sup>a</sup> A field blank procedure shall be performed at least before each measurement series (series of consecutive measurements of several vehicles).					

NOTE Extra samples for specific compounds can be taken as appropriate.

The requirements for analytical and GC–MS blanks are described in ISO 16000-3 and ISO 16000-6.

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- [2] JAMA Report No.98|JASO Z125-09, *Road vehicles — Interior — Measurement methods of diffused volatile organic compounds (VOC)*
- [3] BMBF PROJECT FKZ: 07INR27A8/07INR27B0. *Entwicklung und Erprobung von Standard-Messverfahren für die Bewertung des Fahrzeugeigenen Beitrages zu organischen Luftverunreinigungen in Fahrgasträumen von Personenkraftwagen* [Development and testing of standard measuring procedures for the evaluation of the contribution from the vehicle to organic air pollution in passenger compartments of passenger cars]
- [4] WHO. *Indoor air quality: Organic pollutants*. Copenhagen: World Health Organization, Regional Office for Europe, 1989. (EURO Reports and Studies No. 111.)
- [5] LEWIS R. G., GORDON S. M. Sampling of organic chemicals in air. In: KEITH, L. H., editor. *Principles of environmental sampling*, 2nd edition, pp. 401–470. Washington, DC: American Chemical Society, 1996

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- [6] ISO 16000-5, *Indoor air — Part 5: Sampling strategy for volatile organic compounds (VOCs)*
- [7] ISO 16000-9, *Indoor air — Part 9: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test chamber method*
- [8] ISO 16000-10, *Indoor air — Part 10: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test cell method*
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- [10] ISO 16000-24, *Indoor air — Part 24: Performance test for evaluating the reduction of volatile organic compound (except formaldehyde) concentrations by sorptive building materials*
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- [12] ISO 16017-2, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 2: Diffusive sampling*



