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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

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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.

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).

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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 146, *Air quality*, Subcommittee SC 6, *Indoor air*.

This second edition cancels and replaces the first edition (ISO 12219-1:2012), which has been technically revised.

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

- Adaption of temperatures, number of samples to be taken and the pre-conditioning and measuring times to be consistent with the UN mutual resolution concerning the common definitions of vehicle categories, masses and dimensions.

A list of all parts in the ISO 12219 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

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 document 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][4]. However, this document 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,^[6] ISO 16000-6, ISO 16000-9,^[7] ISO 16000-10,^[8] ISO 16000-11,^[9] ISO 16000-24,^[10] ISO 16000-25,^[11] as well as ISO 16017-1 and ISO 16017-2^[12] also focus on volatile organic compound (VOC) measurements.

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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

1 Scope

This document 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 23-25 °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 specified 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^{®1)} sorbent tubes described in ISO 16000-6, which includes VOCs ranging in volatility from n -C₆ to n -C₁₆.

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/m³ to 1 mg/m³.

The method is valid for passenger cars, as defined in ECE-TRANS-WP.29/1045.

This document give guidelines for:

- 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).

1) Tenax TA[®] 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 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 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*

ECE-TRANS-WP.29/1045, *Special resolution No 1, Concerning the common definitions of vehicle categories, masses and dimensions (S.R. 1)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

— IEC Electropedia: available at <http://www.electropedia.org/>

3.1 background concentration

substance concentrations in the whole vehicle test chamber when the test vehicle is inside

3.2 test vehicle

new category 1-1 vehicle (3.12), not older than 28 d ± 5 d after the production date (3.13) to be tested.

Note 1 to entry: Excludes busses used for public transport and trucks only used for the transport of goods

3.3 total volatile compounds TVOCs

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

3.4 carbonyl compound

compound containing the functional group -C(=) determined according to specified procedure

Note 1 to entry: For the purposes of this document. The procedure is that specified in ISO 16000-3.

3.5 ambient mode

mode in which sampling of substances in the interior air of a test vehicle under standardized ambient temperature conditions is performed, defined by 23-25 °C, as close as possible to 25 °C

3.6 parking mode

mode in which sampling of substances in the interior air of a test vehicle under elevated temperatures resulting from defined external heat radiation is performed

3.7**driving mode**

mode in which sampling of substances in the interior air of a test vehicle, under standardized conditions starting at elevated temperatures and with the engine on using air conditioning

Note 1 to entry: Driving is simulated with an idle test procedure of a vehicle driven after being parked in the sun

3.8**breathing zone**

semi-sphere area with 50 cm radius in front of the drivers face

3.9**sampling train**

apparatus to collect the air sample inside the test vehicle cabin from the breathing zone and to collect the air sample from in the whole vehicle test chamber, trapping the test substances in sorbent tubes under standardized conditions

3.10**volatile organic compound (VOC)**

volatile organic compound, ranging in volatility from n-C₆ to n-C₁₆

EXAMPLE Benzene, Toluene, Xylene, Ethylbenzene and Styrene

3.11**production date**

date a new vehicle leaves the production line

3.12**category 1 vehicle**

power-driven vehicle with four or more wheels designed and constructed primarily for the carriage of (a) person(s)

3.13**category 1-1 vehicle**

category 1 vehicle (3.12) comprising not more than eight seating positions in addition to the driver's seating position

Note 1 to entry: A category 1-1 vehicle cannot have standing passengers.

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 23-25 °C and for a humidity of 50 % RH ± 10 % 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 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 W/m² to 450 W/m² (400 W/m² ± 50 W/m²).

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° to the heating area. There shall be no heating radiators shining from the

side. The heating area shall be calibrated in squares of 25 cm × 25 cm with a radiation density of 400 W/m² ± 50 W/m². 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).

Prior to sampling, the sampling system shall be checked under sampling load conditions for air tightness. Do not skip this critical step because leaks have a high impact on the test results due to the large backpressure of the tubes and cartridges. To check for leaks, plug the inlet to the sample system. Then use a vacuum pump to bring the sampling system to 71 kPa vacuum, then close a valve between the sample system and the pump. After 30 seconds, the sample system vacuum shall be greater than 68 kPa to proceed. Do not change the sample trains in any way after the leak check procedure is performed. Other equivalent leak checks can be performed.

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 a)] 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. This measurement is taken after the 24 h temperature acclimation phase and just prior to opening the vehicle doors for the VOC conditioning phase.

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 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. No transport waxes for protection should be used. All transport foils or transit lacquers shall be removed at least 24 h before the test.

To establish quality control, it is recommended to measure several vehicles and take multiple air samples of one vehicle for one result. Therefore, it was decided because of cost reasons that measuring one vehicle. However, general quality measures shall not be neglected and should be periodically assessed.

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5 Principle

A whole vehicle test chamber (see [Annex A](#) for an example) 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 23-25 °C, as close as possible to 25 °C. Subsequently, formaldehyde is determined alone under elevated temperature conditions in the parking mode (see [Table 1](#)). 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. Substances to be measured are: formaldehyde, acetaldehyde, benzene, toluene, xylene, ethylbenzene, styrene, and acrolein.

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. The sampling trains are identical to those of [4.3](#), but the sampling line is shorter and not heated. Altogether a minimum of 24 samples are required (see [Annex D](#)).

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^{®1} 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.

The whole vehicle test chamber shall be large enough to accommodate the complete test vehicle. It should include a heating, cooling, humidity, ventilation, and filter system for the air and solar lights if necessary.

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

- a) The whole vehicle test chamber shall be capable of maintaining a temperature of 23-25 °C. 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.
- b) The temperature profile shall be in accordance with [Table 1](#).
- c) Relative humidity (RH) during the ambient mode in the whole vehicle test chamber shall be 50 % RH ± 10 % RH.
- d) Relative humidity RH during the parking and driving mode in the whole vehicle test chamber shall be documented.
- e) The maximum background concentration for each analyte shall not exceed 20 µg/m³ for each single component and 200 µg/m³ for TVOCs or a maximum of 10 % of the respective measured values (whichever is less). If this is not met, the source of the contamination shall be identified and removed or covered to exclude it from the test.
- f) 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.
- g) 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.
- h) The air exchange rate of the whole vehicle test chamber during the driving mode should be a minimum of twice per hour.
- i) 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 W/m² ± 50 W/m².
- j) Optional trolley or table to carry sampling devices.
- k) Various measuring instruments and data recording systems for continuous recording of signals measured (e.g. for temperature and humidity measurements).
- l) Door for the entry and exit of the test vehicle.
- m) A hydrocarbon air warning system should be installed (option) to avoid explosive workplace atmospheres; the workplace regulations shall be followed.
- n) A pipe is fixed at the exhaust pipe liner of the test vehicle to remove the waste gas outdoors.