
Indoor air —

**Part 23:
Performance test for evaluating the
reduction of formaldehyde
concentrations by sorptive building
materials**

Air intérieur —

*Partie 23: Essai de performance pour l'évaluation de la réduction des
concentrations en formaldéhyde par des matériaux de construction
sorptifs*



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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 16000-23 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 6, *Indoor air*.

ISO 16000 consists of the following parts, under the general title *Indoor air*:

- *Part 1: General aspects of sampling strategy*
- *Part 2: Sampling strategy for formaldehyde*
- *Part 3: Determination of formaldehyde and other carbonyl compounds — Active sampling method*
- *Part 4: Determination of formaldehyde — Diffusive sampling method*
- *Part 5: Sampling strategy for volatile organic compounds (VOCs)*
- *Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA[®] sorbent, thermal desorption and gas chromatography using MS/FID*
- *Part 7: Sampling strategy for determination of airborne asbestos fibre concentrations*
- *Part 8: Determination of local mean ages of air in buildings for characterizing ventilation conditions*
- *Part 9: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test chamber method*
- *Part 10: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test cell method*
- *Part 11: Determination of the emission of volatile organic compounds from building products and furnishing — Sampling, storage of samples and preparation of test specimens*
- *Part 12: Sampling strategy for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polycyclic aromatic hydrocarbons (PAHs)*
- *Part 13: Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDDs/PCDFs) — Collection on sorbent-backed filters*

- *Part 14: Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDDs/PCDFs) — Extraction, clean-up and analysis by high-resolution gas chromatography and mass spectrometry*
- *Part 15: Sampling strategy for nitrogen dioxide (NO₂)*
- *Part 16: Detection and enumeration of moulds — Sampling by filtration*
- *Part 17: Detection and enumeration of moulds — Culture-based method*
- *Part 18: Detection and enumeration of moulds — Sampling by impaction*
- *Part 23: Performance test for evaluating the reduction of formaldehyde concentrations by sorptive building materials*
- *Part 24: Performance test for evaluating the reduction of volatile organic compounds (except formaldehyde) concentrations by sorptive building materials*
- *Part 25: Determination of the emission of semi-volatile organic compounds by building products — Micro-chamber method*

The following parts are under preparation:

- *Part 19: Sampling strategy for moulds*
- *Part 26: Measurement strategy for carbon dioxide (CO₂)*
- *Part 28: Sensory evaluation of emissions from building materials and products*

The following parts are planned:

- *Part 20: Detection and enumeration of moulds — Sampling from house dust*
- *Part 21: Detection and enumeration of moulds — Sampling from materials*
- *Part 22: Detection and enumeration of moulds — Molecular methods*
- *Part 27: Standard method for the quantitative analysis of asbestos fibres in settled dust*
- *Part 30: Sensory testing of indoor air*

Furthermore

- *ISO 12219-1, Indoor air — Road vehicles — Part 1: Whole vehicle test chamber — Specification and method for the determination of volatile organic compounds in car interiors [planned document]*
- *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*
- *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*

focus on volatile organic compound (VOC) measurements.

Introduction

Sorptive building materials have been marketed in the form of sheet and board products for removing airborne pollutants via physical sorption or chemical reaction.

Harmonized test methods for evaluating sorptive effects are important for comparative assessment of the performance of sorptive building materials that are used for reducing levels of indoor air contaminants.

This part of ISO 16000 specifies procedures for evaluating the performance of sorptive building materials for reducing indoor air formaldehyde concentrations over time.

The performance of sorptive building materials is evaluated by sorption flux and saturation mass per area and is affected by a number of factors. Specific test conditions are therefore defined in this part of ISO 16000.

This part of ISO 16000 can be applied to most sorptive building materials used indoors and for formaldehyde as an indoor air contaminant.

This part of ISO 16000 is based on the test chamber method as specified in ISO 16000-9.

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Indoor air —

Part 23:

Performance test for evaluating the reduction of formaldehyde concentrations by sorptive building materials

1 Scope

This part of ISO 16000 specifies a general laboratory test method for evaluating the reduction of formaldehyde concentrations by sorptive building materials. This method applies to boards, wallpapers, carpets, paint products, and other building materials. The sorption of formaldehyde can be brought about by adsorption, absorption and chemisorption. The performance of the material with respect to its ability to reduce the concentration of formaldehyde in indoor air is evaluated by measuring sorption flux and saturation mass per area. The former directly indicates material performance with respect to formaldehyde concentration reduction at a point in time; the latter relates to the ability of a product to maintain that performance.

The method specified in this part of ISO 16000 employs formaldehyde-spiked supply air to determine the performance of building materials in reducing formaldehyde concentrations. The characteristics of formaldehyde sorption depend greatly on humidity. Formaldehyde is less stable in air than other volatile organic compounds (VOCs), so it has to be tested on its own.

This part of ISO 16000 is based on the test chamber method specified in ISO 16000-9. Sampling, transport and storage of materials to be tested and preparation of test specimens are specified in ISO 16000-11. Air sampling and analytical methods for the determination of formaldehyde are specified in ISO 16000-3, which is part of the complete procedure.

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 554, *Standard atmospheres for conditioning and/or testing — Specifications*

ISO 6353-3, *Reagents for chemical analysis — Part 3: Specifications — Second series*

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

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

ISO 16000-9:2006, *Indoor air — Part 9: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test chamber method*

ISO 16000-11, *Indoor air — Part 11: Determination of the emission of volatile organic compounds from building products and furnishing — Sampling, storage of samples and preparation of test specimens*

3 Terms and definitions

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

3.1 breakthrough time

t_b

⟨indoor air⟩ time at which the formaldehyde concentration in the air eluting from the sample tube reaches 0,5 % of the concentration in the supplied air

NOTE Adapted from ISO 16000-24:2009, 3.1.

3.2 degradation coefficient

⟨indoor air⟩ ratio of the mass of formaldehyde removed by the initial performance divided by the mass of the same compound lost by deterioration

NOTE Adapted from ISO 16000-24:2009, 3.2.

3.3 elapsed time

t_e

⟨indoor air⟩ time from start of test to the start of air sampling

NOTE Elapsed time is expressed in days.

[ISO 16000-24:2009, 3.3.]

3.4 equivalent ventilation rate per area

$F_{V,eq}$

⟨indoor air⟩ increased clean air ventilation rate giving the same reduction in formaldehyde concentration as the building material

NOTE Adapted from ISO 16000-24:2009, 3.4.

3.5 guideline concentration

⟨indoor air⟩ guideline indoor air concentration for formaldehyde as specified by the the WHO

NOTE Adapted from ISO 16000-24:2009, 3.5.

3.6 half-lifetime

⟨indoor air⟩ time elapsed from the start of the test until the formaldehyde concentration decreases to one-half of the initial concentration

NOTE Adapted from ISO 16000-24:2009, 3.6.

3.7 lifetime

t_{lt}

⟨indoor air⟩ time period over which the product continues to reduce formaldehyde concentrations

NOTE 1 The lifetime is given in days or years.

NOTE 2 The lifetime is estimated from the sorption flux and sorption capacity measured by the sample tube test.

NOTE 3 Adapted from ISO 16000-24:2009, 3.7.

3.8**mass transfer coefficient** k_a

⟨indoor air⟩ coefficient arising from the concentration difference between the test specimen and ambient air over its surface

NOTE Mass transfer coefficient is expressed in meters per hour.

[ISO 16000-24:2009, 3.8]

3.9**recovery**

⟨indoor air⟩ measured mass of formaldehyde in the air leaving the test chamber with no sample present conditioned over a given time period divided by the mass of formaldehyde added to the test chamber in the same time period

NOTE 1 The recovery is expressed as a percentage and provides information about the performance of the entire method.

NOTE 2 Adapted from ISO 16000-24:2009, 3.9.

3.10**saturation mass per area** ρ_{Aa}

theoretical maximum mass of formaldehyde that could be removed per area of the sorptive material

NOTE 1 Saturation mass per area is expressed in micrograms per area. It corresponds to the total mass per area of sorption at the half-lifetime, or is extrapolated from the sorption capacity derived from the test referenced in Annex A.

NOTE 2 Adapted from ISO 16000-24:2009, 3.10.

3.11**sorption capacity** w_s

total mass of formaldehyde sorbed at breakthrough time per mass of sorbent

NOTE 1 Sorption capacity is expressed in micrograms per gram and is measured using the test specified in Annex A.

NOTE 2 Adapted from ISO 16000-24:2009, 3.11.

3.12**sorption flux** F_m

mass of formaldehyde sorbed per time per area at the specified elapsed time from the test start

NOTE Adapted from ISO 16000-24:2009, 3.12.

3.13**supply air concentration** ρ_s

mass concentration of formaldehyde in the air for supply to the test chamber

NOTE Adapted from ISO 16000-24:2009, 3.13.

3.14**test chamber concentration**

⟨indoor air⟩ concentration of formaldehyde measured at the outlet of a test chamber, derived by dividing the mass of the formaldehyde sampled at the outlet of the chamber by the volume of sampled air

NOTE Adapted from ISO 16000-24:2009, 3.14.

3.15

total mass per area of sorption

ρ_A
integral over time of sorptive flux from the start of the test to the specified elapsed time measured with the test chamber

NOTE Total mass per area of sorption is expressed in micrograms per area.

[ISO 16000-24:2009, 3.15]

3.16

vapour sampling period

(indoor air) period of time during which air is sampled from the outlet of the test chamber using sampling tubes or other devices

[ISO 16000-24:2009, 3.16]

4 Symbols

Symbol	Meaning	Unit
ρ_A	mass of sorptive material per area (surface density)	grams per square metre
ρ_{Aa}	saturation mass per area	micrograms per square metre
ρ_{Ac}	total mass per area of sorption measured by chamber test	micrograms per square metre
$\rho_{in, t}$	concentration of formaldehyde at test chamber inlet at elapsed time t	micrograms per cubic metre
$\rho_{out, t}$	test chamber concentration at elapsed time t	micrograms per cubic metre
ρ_s	supply air concentration in sample tube	micrograms per cubic metre
A	surface area of test specimen	square metres
F_m	sorption flux per time per area	micrograms per square metre per hour
$F_{V, a}$	air flow rate per area	cubic metres per square metre per hour
$F_{V, eq}$	equivalent ventilation rate	cubic metres per square metre per hour
k_a	mass transfer coefficient determined using water vapour	metres per hour
L	product loading factor	square metres per cubic metre
m	actual mass of test specimen in sample tube	grams
n	air change rate	changes per hour
q_c	air flow rate of test chamber	cubic metres per hour
q_s	air flow rate of sample tube	litres per minute
t_b	breakthrough time	minutes
t_e	elapsed time	hours or days
t_{lt}	lifetime of the pollutant-removing performance	hours or days or years
V	air volume of test chamber	cubic metres
w_s	sorption capacity measured by sample tube	micrograms per gram

5 Principle

The performance of a building material, the test material, with respect to its ability to reduce the concentration of formaldehyde is evaluated by monitoring the reduction of the vapour concentration inside a test chamber containing a test specimen of that material. The test includes an assessment of both the initial performance of the material and how long that performance is maintained.

In this test method, formaldehyde-spiked air is supplied to a test chamber containing the material under test. The spiked air should be prepared approximately at the WHO guideline level for formaldehyde in indoor air. Reference to national standards is possible if this is clearly highlighted in the test report and certificate.

Performance is determined by monitoring the difference in concentration of formaldehyde vapour at the inlet and outlet of the test chamber. Testing should be continued for the half-lifetime, i.e. until the concentration of formaldehyde drops to half that at the start of the test under constant ventilation conditions. With this test, sorption flux, F_m , and total mass per area of sorption, ρ_{AC} , at the half-lifetime are determined. The measured ρ_{AC} at the half-lifetime is defined as the saturation mass per area, ρ_{Aa} .

If a test material continues to reduce formaldehyde concentrations for longer than 28 days, alternative methods specified in Annex A for determining ρ_{Aa} may be applied.

The performance of sorptive building materials is mainly determined by the formaldehyde concentration, the mass transfer coefficient of formaldehyde to the surface, and the sorption characteristics of the building materials themselves (adsorption isotherm, diffusion resistance, and so on). Therefore, the performance test method shall specify both the concentration of formaldehyde and the mass transfer coefficient associated with the sorptive building material.

This method does not apply to materials capable of decomposing formaldehyde by catalytic reaction in the presence of ultraviolet and visible rays.

NOTE The long-term formaldehyde reduction performance is represented by the saturation mass per area, ρ_{Aa} , and, if necessary, the lifetime of the pollutant-removing performance, t_{lt} , as the subsidiary index.

6 Apparatus and materials

Usual laboratory equipment, and in particular the following.

6.1 Test chamber, complying with relevant specifications and requirements of ISO 16000-9 (see Figure 1). No air shall be allowed to circulate from the outlet back to the inlet.

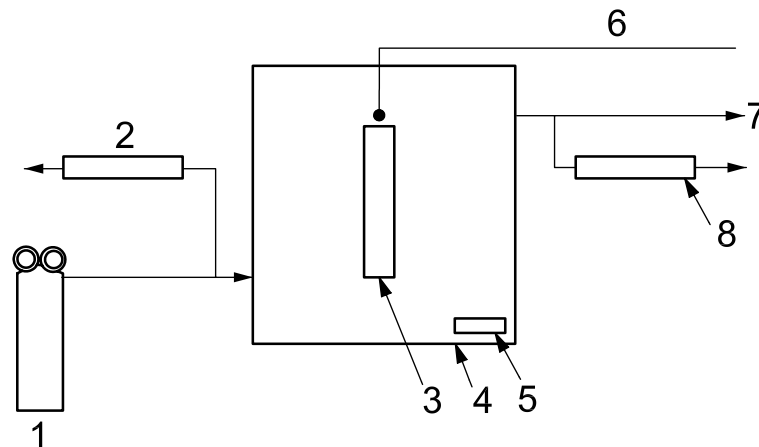
6.2 Sealing material for test specimens, such as **aluminum foil** or a **tape covered with aluminum foil** to cover the edges and the back of the test specimen, if only the surface normally directly exposed to the indoor environment under the intended conditions of use is the subject of the test.

6.3 Air purifier or cylinder of clean air. The purifier shall ensure the supply air is as clean as possible before being spiked with formaldehyde, i.e. shall not contain any contaminants at levels greater than the chamber background requirements. In order to prevent a rise in background concentration, an air purifier shall be provided or a cylinder of clean air shall be used.

6.4 Supply air spiked with formaldehyde. Apply a standard gas (with known formaldehyde concentration) to the test chamber. Alternatively, use a stable source like a formaldehyde solution as specified in ISO 6353-3), or paraformaldehyde, to generate air spiked with formaldehyde that can be supplied to the test chamber. The stability of the spiked formaldehyde concentration shall be monitored.

6.5 Temperature and humidity control. Temperature shall be maintained either by installing a test chamber in a place maintained at the required temperature, such as a constant-temperature climate chamber, or by maintaining the required temperature in the chamber. Relative humidity shall be maintained at the required humidity of the supply air. Temperature and humidity controls of the supply air are described in ISO 16000-9.

6.6 Air flow meter, installed at the inlet or the outlet of the test chamber to measure the air flow rate through the chamber.



Key

- 1 supply air spiked with formaldehyde
- 2 sampling device
- 3 test specimen
- 4 test chamber
- 5 device to circulate air and control of air velocity
- 6 temperature/humidity monitoring apparatus
- 7 test chamber outlet
- 8 sampling device

Figure 1 — Outline of the test chamber system

6.7 Air sampling devices. Use the inlet and outlet air of the test chamber for sampling. When a separate sampling port is used, sample directly from the inlet or outlet of the chamber.

If a duct or tube is used, it shall be as short as possible and maintained at the same air temperature as that in the test chamber. Such a duct or tube shall be made of a material with a very low sorption capacity, e.g. polytetrafluoroethylene.

The sum of sampling air flow rates shall be smaller than the air flow rate into the chamber. Sampling devices shall comply with the specifications of ISO 16000-3. When the air is sampled from the inlet, ensure the supply air flow rate remains constant.

A multiport sampling manifold may be used to provide flexibility for duplicate air sampling. A mixing chamber between the test chamber and the manifold or between the air inlet and the test chamber can be included to permit addition and mixing of internal standard gases with the test chamber air stream.

The exhaust from the test chamber should be ducted into a fume hood, ensuring that formaldehyde-spiked air and any chemicals emitted from the test material are isolated from the laboratory environment.

6.8 Analytical instrument. A high performance liquid chromatograph (HPLC) shall be used as specified in ISO 16000-3.

7 Test conditions

7.1 General

The test conditions shall comply with 7.2 and 7.3. This test shall be conducted under atmospheric pressure conditions.

7.2 Test conditions for concentration reduction performance determination

7.2.1 Temperature and relative humidity

Building materials for use in Europe and America shall be tested in accordance with ISO 554 at a temperature of $23\text{ °C} \pm 2\text{ °C}$ and relative humidity $50\% \pm 5\%$ during the test.

Building materials for use in Japan shall be tested at a temperature of $28\text{ °C} \pm 1\text{ °C}$ and relative humidity $50\% \pm 5\%$ during the test.

For building materials with applications under other climatic conditions, alternative temperatures and air humidity conditions may be used, preferably as specified in ISO 554. State the conditions in the test report.

Initial variations can be observed in the test chamber climate after opening the test chamber door and loading a test specimen. These variations should be recorded.

NOTE Temperature and relative humidity can affect sorption flux and re-desorption from the test material.

7.2.2 Supply air quality and background concentration

The background concentration of the supply air for the test chamber and the air prior to spiking with formaldehyde shall be low enough not to interfere with the test. The total VOC background concentration shall be lower than $20\text{ }\mu\text{g}/\text{m}^3$. The background concentration of formaldehyde shall be lower than $2\text{ }\mu\text{g}/\text{m}^3$. Purified water used for humidification shall not contain interfering VOCs that may affect the test.

7.2.3 Mass transfer coefficient

The mass transfer coefficient in terms of ambient air velocity over the surface of the test specimen inside the test chamber shall be in the range $15\text{ m}/\text{h} \pm 3\text{ m}/\text{h}$ (equivalent to $0,25\text{ m}/\text{s} \pm 0,05\text{ m}/\text{s}$) when determined using water vapour. To check the dependence of the mass transfer coefficient on material performance, take measurements under other conditions that influence in an appropriate manner the mass transfer coefficient.

NOTE 1 The mass transfer coefficient is analogous to the convective heat transfer coefficient where geometry and boundary conditions are similar. The mass transfer coefficient can be estimated with a formulation that relates the mass transfer flux (sorption flux) to a surface to the concentration differences across the boundary layer. For details concerning the mass transfer coefficient and its measurement method, see Reference [5].

NOTE 2 Reduction performance depends on the mass transfer coefficient. Mass transfer coefficient depends on the indoor concentration of the substance, air flow, and the surface area of the test specimen.

7.2.4 Area specific ventilation rate and air change rate

The air change rate shall be kept constant at $0,50\text{ /h} \pm 0,05\text{ /h}$. The product loading factor shall comply with ISO 16000-9:2006, Annex B or be derived from geometry and volume of an appropriate model room.

NOTE The selection of air flow rate per area, $F_{V,a}$, affects the steady-state concentration of formaldehyde in the test chamber air.

For comparison of results from different test chambers, the air change rate, n , and the product loading factor, L , shall be the same for each test chamber. The air change rate, n , and the product loading factor, L , may affect the sorption flux, F_m .

7.2.5 Supply air concentration

The concentration of formaldehyde vapour in the air supplied to the test chamber shall be approximately equal to the WHO guideline concentration.

Other concentrations may be applied if relevant for the purpose of the test. This shall be stated explicitly in the test report.

7.3 Factors affecting the concentration reduction performance

7.3.1 General

For evaluation of the effect of temperature, humidity, and contaminants in air on the formaldehyde concentration reduction performance, modify each of the factors listed separately in 7.3.2 to 7.3.4.

7.3.2 Effects of temperature and humidity

The temperature in the test chamber should be set to $18\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, $23\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ and $28\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$, with the relative humidity in the test chamber as specified in 7.2.1 and the supply air concentration in the test chamber set as specified in 7.2.5.

The relative humidity in the test chamber should be set to $25\% \pm 5\%$, $50\% \pm 5\%$ and $75\% \pm 5\%$, with the temperature in the chamber as specified in 7.2.1 and the supply air concentration in the chamber set as specified in 7.2.5.

7.3.3 Effect of formaldehyde concentration in supply air

The formaldehyde supply air concentration should be set to twice the guideline concentration specified in 7.2.5, and then to one-half of the guideline concentration, with the test chamber temperature and relative humidity set as specified in 7.2.1.

7.3.4 Effects of interfering gases

Various interfering gases are expected to exist in indoor environments. It is possible to measure their effect on the performance of test materials in formaldehyde concentration reduction by measuring such performance while varying the concentration of each such interfering gas.

8 Verification of test conditions

8.1 Monitoring of test conditions

Temperature, relative humidity, and air flow rate shall be monitored and recorded continuously with instruments meeting the following accuracy specifications:

- temperature: $\pm 1\text{ }^{\circ}\text{C}$
- relative humidity: $\pm 3\%$
- air flow rate: $\pm 3\%$

Temperature and relative humidity of air may be measured in the outlet of the chamber if the point of measurement is constructed in a manner that ensures values identical to those inside the test chamber.

8.2 Air tightness of test chamber

Air tightness of the test chamber should be checked regularly as specified in ISO 16000-9 either by pressure drop measurements, by comparison of simultaneous measurement of flow rates at the inlet and the outlet ports, or by measuring tracer gas dilution.

8.3 Air change rate in test chamber

The air change rate shall be regularly checked as specified in ISO 16000-9.

NOTE If the test is carried out in the outlet with an air flow meter that is not permanently installed, note that the back pressure introduced by the instrument can lower the flow rate through the test chamber.

8.4 Efficiency of the internal test chamber air mixing

Determine the efficiency of the air mixing as specified in ISO 16000-9.

8.5 Recovery

Recovery tests shall be performed in the test chamber by introducing supply air with the same formaldehyde concentration as to be used in the performance test and then comparing air measurement results at the outlet and inlet of the test chamber. The mean recovery shall be greater than 80 %. The results of the recovery test shall be reported (expected concentration versus measured concentration).

NOTE Sink effect, leakage or poor calibration can cause difficulties in meeting minimum requirements for the test.

9 Preparation of test chamber

The test chamber shall be cleaned in order to fulfil the requirements of 7.2.2. Cleaning can be done by washing the inner surfaces of the test chamber with a detergent followed by two separate rinsings with freshly distilled water. The test chamber is then dried and purged under test conditions. The test chamber can also be cleaned by thermal desorption.

The adsorption of formaldehyde by the test chamber itself shall be monitored by performing a test as described in 11.1 but without any test specimen. The adsorption capacity of the test chamber itself shall be subtracted from the measured adsorption capacity.

For cleaning of the test chamber, an oven may be used to volatilize any aldehyde or VOCs on the internal walls of the test chamber. Alternative methods can be used instead of an oven.

10 Preparation of test specimens

After completing test preparations, supply air spiked with the formaldehyde to the test chamber. Take a sample of the material to be tested from its package. The sample shall be a part or piece that is representative of a building material. Prepare a test specimen from the sample as specified in ISO 16000-11.

For the measurement of formaldehyde sorption by only one surface of a test specimen, seal the cut edges and the back of the specimen with aluminum foil or other sealing material, or place two test specimens back-to-back with sealed edges.

11 Test methods

11.1 Background concentration and spiked supply air

Prior to beginning a test, ventilate the test chamber for 1 day by running empty, and then measure and determine the background formaldehyde concentration of the empty test chamber.

The background concentration shall be low enough not to affect the test.

Then start flushing the test chamber with supply air spiked with formaldehyde. Allow at least five air exchanges before introducing the test specimen.

11.2 Placing the test specimen in the test chamber

Place the test specimen in the middle of the test chamber to ensure that air may uniformly flow over the sorptive surface of the test specimen. Close the chamber. Take this time as the start of the test.

Place the test specimen in test chamber as quickly as possible.

11.3 Time intervals for measurement of test chamber concentration

11.3.1 Test for formaldehyde concentration reduction

After the start of the test, sample air from the chamber inlet and the chamber outlet in accordance with 11.4 at predefined elapsed times.

Measure the quantity of formaldehyde removed from the test chamber air per area of the test specimen exposed to the test chamber air, under the measuring conditions specified in 7.2.

Check the total air flow through the test chamber and ensure that there is no air leakage from it. Then, ensure that the outlet air flow rate during air sampling is equal to the inlet air flow rate minus the sum of the sampling air flow rates. The remaining outlet air flow rate shall be at least 20 % of the total sampling air flow rates. Air samples shall be taken $24 \text{ h} \pm 2 \text{ h}$, $72 \text{ h} \pm 6 \text{ h}$, $168 \text{ h} \pm 14 \text{ h}$, $14 \text{ days} \pm 1 \text{ day}$, and $28 \text{ days} \pm 2 \text{ days}$ after the start of the test. Additional air samples may be collected. Duplicate sampling is recommended.

Other time intervals may be selected according to the purpose of the test. If data on long-term performance of the testing material are required, further test samples may be collected at even longer times from test start; i.e. $> 28 \text{ days}$. When the reduction performance decreases to one half of the initial value, terminate the test.

A subsequent test of re-emission is recommended by subsequently supplying clean air to the test chamber. It is preferable to undertake re-emission tests routinely as part of the formaldehyde concentration reduction performance test. Air samples should be taken 24 h (and other times if required) after the start of the re-emission test. In cases where significant sorption of formaldehyde to test chamber surfaces occurs, it is necessary to understand the relative contribution of the sample and the chamber walls to the total emission. This may be achieved by appropriate control tests without material samples.

If VOCs and other organic vapours of interest are emitted from the material sample, measure their emission rates as described in ISO 16000-3, ISO 16000-6, and ISO 16000-9.

11.3.2 Test for long-term reduction performance

Determine the point at which the efficiency of the material at reducing formaldehyde concentrations (see 11.3.1) is only half of what it was initially (i.e. 24 h after the start of the test) and then measure the total mass per area of sorption, ρ_{AC} , of formaldehyde and the elapsed time, t_e .

11.3.3 Factors affecting the reduction performance

The effect of each environmental factor may be measured by varying the value of only one factor at a time against those conditions used for the measurement of the reduction performance in 11.3.1. The measuring conditions shall be as specified in 7.2.

11.4 Air sampling

A tube filled with DNPH as specified in ISO 16000-3 shall be used for air sampling for the determination of formaldehyde concentration.

12 Determination of formaldehyde

Elute the DNPH derivative of formaldehyde from the DNPH tube and analyse as specified in ISO 16000-3.

13 Expression of results

13.1 Calculation of sorption flux

Calculate the sorption flux per time per area, F_m , using Equation (1):

$$F_m = \frac{(\rho_{\text{in}, t_e} - \rho_{\text{out}, t_e}) q_c}{A} \quad (1)$$

where

ρ_{in, t_e} is the concentration of formaldehyde at test chamber inlet at elapsed time, t_e ;

ρ_{out, t_e} is the test chamber concentration at elapsed time, t_e ;

q_c is the air flow rate of test chamber;

A is the surface area of test specimen.

When the adsorption capacity of the test chamber itself cannot be disregarded, subtract the sorption flux of the test chamber itself when measured with no test specimen from the measured sorption flux.

13.2 Calculation of equivalent ventilation rate per area

Assuming that the concentration falls due to increasing air flow rate of clean air, calculate the equivalent ventilation rate per area, $F_{V, \text{eq}}$:

$$F_{V, \text{eq}} = \frac{\left(\frac{\rho_{\text{in}, t}}{\rho_{\text{out}, t}} - 1 \right) q_c}{A} \quad (2)$$

13.3 Calculation of total mass per area of sorption and saturation mass per area

Calculate the total mass per area of sorption, ρ_{Ac} , at the half-lifetime:

$$\rho_{Ac} = \sum_i (F_{m,i} \times \Delta t_{e,i}) \quad \text{where} \quad \Delta t_{e,i} = t_{e,i} - t_{e,i-1} \quad (3)$$

where t_e is elapsed time.

The saturation mass per area, ρ_{Aa} , is given by the Identity:

$$\rho_{Aa} \equiv \rho_{Ac} \quad (4)$$

14 Test report

The test report shall include at least the following information:

- a) test laboratory:
 - 1) name and address of the test laboratory,
 - 2) name of the responsible person;

- b) sample description:
- 1) type of building material (and brand name, if appropriate),
 - 2) sample selection process (e. g. random),
 - 3) product history (date of production, batch number, date of arrival at the test laboratory, date and time of unpacking, date and time of preparation of test specimen, etc.);
- c) test results:
- 1) sorption flux of formaldehyde, total mass per area of sorption, the equivalent ventilation rate per area at the specified elapsed time,
 - 2) the saturation mass, and the reduction performance in the presence of interfering gases,
 - 3) details of the method used, with reference to this part of ISO 16000;
- d) test conditions:
- 1) test chamber conditions (temperature, relative humidity, air change rate, mass transfer coefficient, supply air concentration spiked with formaldehyde),
 - 2) surface area of the test specimen and loading factor,
 - 3) whether the test specimen was sealed (and how) or not,
 - 4) information on air sampling (sampling tube used, volume of air sampled, vapour sampling period from the test start, the number of air samplings, etc.),
 - 5) test conditions for long-term performance test (temperature, formaldehyde-spiked supply air concentration);
- e) devices: information on the equipment and procedure (test chamber, sealing material or sealing box, formaldehyde-spiking technique, air purifier, temperature and humidity controls, air flow meter, climate chamber, air sampling devices, analytical instrument, etc.);
- f) quality control/quality assurance:
- 1) background concentration of formaldehyde,
 - 2) recovery data of formaldehyde,
 - 3) number of measurements,
 - 4) result of each analysis of air sampled, if duplicate sampling was undertaken,
 - 5) accuracy of temperature, relative humidity and air change rate,
 - 6) quality assurance report;
- g) additional details for test materials such as paints, coatings, or plastering materials:
- 1) number of test specimens,
 - 2) mass per area,
 - 3) thickness,

- 4) other observations that may influence the test results (drying conditions, storage, preservation, moisture content, surface treatment),
- 5) applied mass per area, in grams per square metre,
- 6) applied area,
- 7) applied method.

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Annex A (normative)

Sample tube test for long-term reduction performance

A.1 Principle

A.1.1 General

If a test material has a formaldehyde concentration reduction performance greater than, say, 28 days, meaning that a chamber test would take too long, a sample tube test for determining ρ_{Aa} may be applied, based on the physical sorption, chemisorption, and decomposition reaction.

The sample tube test for long-term formaldehyde concentration reduction performance is one method to estimate the sorption capacity, w_s .

NOTE In many cases, the value of ρ_{Aa} estimated by the chamber test is less than the value of ρ_{Aa} estimated by the sample tube test.

A.1.2 Formaldehyde reduction by physical sorption

The saturation mass per area, ρ_{Aa} , shall be calculated from the sorption capacity, w_s , which is measured by passing air containing formaldehyde through a glass sample tube filled with a small mass of finely ground (2 mm diameter or less) test specimen at breakthrough time.

A.1.3 Formaldehyde reduction by chemisorption and/or decomposition reaction

The saturation mass per area, ρ_{Aa} , shall be calculated from the sorption capacity, w_s , which shall be measured as specified in A.1.2.

It is possible to calculate chemisorption and/or decomposition when the chemical reaction scheme is widely known.

The composition of the chemical substance needs to be known in this case, because the molar concentration of the sorption agent employed is used in the calculation. Therefore, this method is not applicable to natural materials with unknown composition.

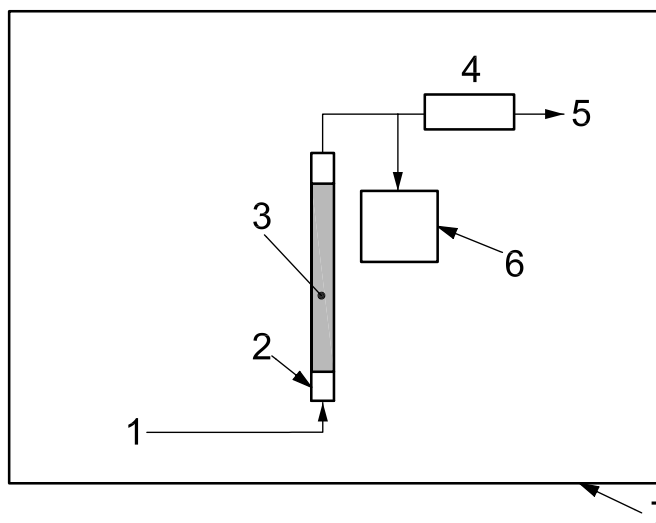
Confirmation is recommended of any calculation of long-term reduction performance by experimental data (testing).

Alternatively, evaluation by calculation of chemical reaction between sorption agent and formaldehyde may be performed.

A.2 Apparatus and materials

Usual laboratory equipment, and in particular the following.

See Figure A.1 for a typical setup.

**Key**

- 1 inlet air
- 2 sample tube
- 3 ground test specimen
- 4 air flow meter
- 5 outlet air
- 6 formaldehyde detector
- 7 climate chamber

Figure A.1 — Example of apparatus for concentration reduction performance evaluation

A.2.1 Sample tube, that fits the testing system and which can accommodate the test specimen. The sample tube is installed so that its length is vertical.

A.2.2 Supply air spiked with formaldehyde, complying with 6.4.

A.2.3 Temperature control, complying with 6.5.

A.2.4 Air flow meter, installed before the sample tube or behind the air sampling pump for measuring formaldehyde air flow. Other devices may be used if they have equal or better performance.

A.2.5 Formaldehyde detector, installed at the outlet of the sample tube. It should be able to detect formaldehyde at 0,5 % of the challenge concentration in the supply air. For example, thermal conductivity detectors or mass spectrometry may be used. Formaldehyde detectors may be applied only after calibration of their response. A DNPH tube may also be installed at the outlet of the sample tube to collect air samples at appropriate time intervals.

A.2.6 Climate chamber, in which the sample tube shall be contained. The climate chamber shall be capable of maintaining the test temperature to within $\pm 2,0$ °C.

A.3 Test conditions

A.3.1 Supply air concentration

The concentration of the supply air spiked with formaldehyde in the sample tube should be approximately equal to the WHO guideline concentration.

If that is not possible, perform this determination at relatively high formaldehyde concentrations of the order of 10 times the guideline value.

A.3.2 Temperature and relative humidity

The supply air should be dry.

Building materials for use in Europe and America shall be tested at a temperature of $23\text{ °C} \pm 2\text{ °C}$ during the test (ISO 554).

Building materials for use in Japan shall be tested at a temperature of $28\text{ °C} \pm 1\text{ °C}$ during the test.

The humidity tends to affect the result. The humidity of the supply air shall be controlled at $50\% \pm 5\%$ during the test and recorded if the test is not conducted with dry air.

Performance in reducing formaldehyde concentration by physical sorption depends on temperature. Therefore, measurement at three temperatures as specified in 7.3.2 is recommended.

A.4 Test methods

A.4.1 Sampling and pretreatment of test specimen

Grind the test specimen to form fragments that can be fitted in the sample tube, while maintaining secondary structure. Fine particles should be removed prior to the test. The test specimen shall be vacuum dried.

The secondary structure which works effectively to absorb formaldehyde is maintained as long as the particle radius is approximately 10 times that of the pore.

When dry air is supplied to the sample tube, the test specimen may be vacuum dried after grinding due to homogeneity and reproducibility reasons. In this case, absolute dryness may be assumed to be fundamental. If moist (humid) air is used for this test, the specimen may be controlled at equilibrium condition at the target humidity level.

This procedure shall not be applied to material of inhomogeneous structure.

A.4.2 Preparation of sample tubes

Weigh the ground test specimen and put it into sample tube. Use glass wool to hold the test specimen in position in the sample tube.

When the tube diameter is large, a perforated support should be installed into the inlet side in order to support the sample, to enhance diffusion of the gas. If a perforated support is not installed, non-uniform diffusion is observed in the sample tube.

A.4.3 Monitoring the formaldehyde concentration of the supply air

Prior to connecting the sample tube to the system, connect an air sampling tube or detector, and determine the formaldehyde concentration of the spiked supply air as specified.

A.4.4 Test for the formaldehyde breakthrough time

Connect the sample tube to the system, start the formaldehyde air flow. Continue the formaldehyde air flow until the outlet air contains 0,5 % of supply air concentration, and then determine the sorption capacity, w_s , (saturated formaldehyde mass per mass of sorbent) at that concentration. Consider this time as the breakthrough time, t_b .

NOTE 1 At low concentrations of formaldehyde in supply air, it can take an appreciable time for the gas to break through the tube, thus requiring a long period of time before saturation occurs. To avoid long testing times, measuring at high formaldehyde concentration is possible. However, measurement under concentrations greatly in excess of

1 000 µg/m³ decreases the reliability of the regression curve that shows the results of measurements at multiple concentrations.

NOTE 2 The sorption isotherm is given by the same procedure as specified in this subclause using a different formaldehyde concentration at the test temperature. The sorption capacity at the guideline value of 100 µg/m³ can then be estimated by using of regression curve.

If the mass of compound comprising the test specimen and details of the chemical reaction with formaldehyde are known, the concentration reduction performance can be calculated. Substantiation of the results by experimental data (testing) is always recommended.

NOTE 3 Concentration dependency can be determined by a few tests where the load masses are different. The activation energy can be determined by an Arrhenius plot through a few test results at different temperatures. A half-lifetime (the time at which performance has decreased to one-half of initial performance) can be found from the reaction velocity constant that is obtained from the concentration transition along with the time taken.

A.4.5 Expression of results

A.4.5.1 Calculation of sorption capacity

Calculate the formaldehyde sorption capacity, w_s , of the test specimen using Equation (A.1):

$$w_s = \frac{\rho_s q_s t_b}{1000 m} \quad (\text{A.1})$$

where

ρ_s is the formaldehyde concentration in the supply air;

q_s is the air flow rate;

t_b is the breakthrough time;

m is the mass of test specimen in the sample tube.

A.4.5.2 Calculation of saturation mass per area

Calculate the saturation mass per area, ρ_{Aa} , using Equation (A.2):

$$\rho_{Aa} = w_s \rho_A \quad (\text{A.2})$$

where ρ_A is the surface density of the sorptive material, calculated as its mass per surface area.

Annex B (normative)

System for quality assurance and quality control

B.1 General

Chamber testing for evaluating the concentration reduction performance of formaldehyde by sorptive building materials shall be conducted within the framework of a quality assurance project plan (QAPP). The QAPP shall contain a project description, data quality objectives and acceptance criteria, quality assurance and quality control (QA/QC) approaches and activities, and QA/QC audits.

B.2 Project description

A brief description shall include what materials are to be tested, how the testing is to be conducted, and who is responsible for various project activities. The project experimental design shall contain the necessary information for this portion of the QAPP.

B.3 Data quality objectives and acceptance criteria

This section of the QAPP defines the precision, accuracy, and completeness desired for each parameter being measured.

B.4 QA/QC approaches and activities

See Reference [5].

The types of QA/QC activity that can be specified in the QAPP include establishment of a system of records or notebooks to ensure proper operation of equipment and recording of data, such as:

- a) sample log to record receipt, storage, and disposition of materials,
- b) HPLC standards preparation log to document preparation of all organic compound substances,
- c) permeation tube log to record mass loss data for all permeation tubes,
- d) calibration logs to contain environmental systems calibration data,
- e) instrument maintenance logs to document maintenance and repairs of all equipment,
- f) materials testing logs in which to record all pertinent information for each test, including sample details, sample identification (ID) number, and HPLC run ID number,
- g) DNPH tube cleanup and solvent extraction log and QC validation of DNPH tubes,
- h) separate electronic log to document location and content of electronically stored data,
- i) manuals governing operation of all equipment used by the project.

QC activities are carried out by project staff in a routine, consistent manner to provide necessary feedback in operation of all measurement systems. Such activities can include:

- 1) routine maintenance and calibration of systems;
- 2) daily recording of HPLC calibration accuracy and precision (i.e. control charting);
- 3) timely monitoring of the percentage recovery of the internal standard that was added to all samples;
- 4) collection and analysis of duplicate samples;
- 5) QC checking of organic collection sorbent tubes;
- 6) periodic analysis of audit gases supplied by an independent source.

B.5 QA/QC audits

Finally, the QA/QC programme shall include periodic audits by QA personnel to evaluate compliance with QAPP protocols.

Annex C (informative)

Example measurements of construction materials

C.1 Testing conditions

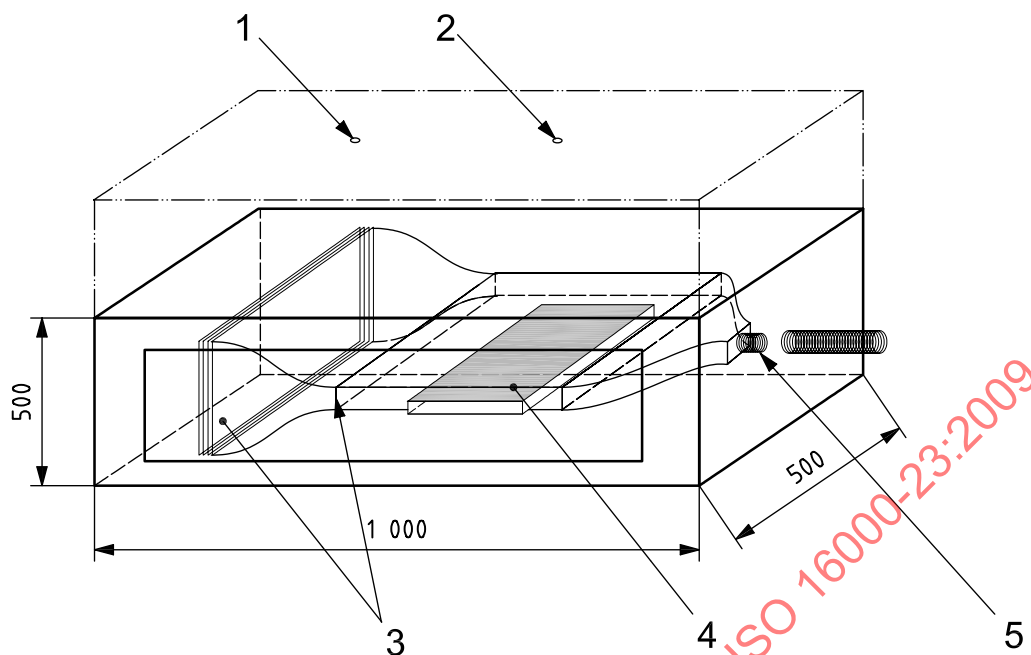
Testing conditions were set up as shown in Table C.1. The materials tested are shown in Table C.2. A boundary-layer-type small test chamber was used for the measurements, of which Figure C.1 shows an outline. This experiment was carried out with the quotient of the air flow rate to the surface area of the test specimen set to 0,23 and also 1,33.

Table C.1 — Testing conditions

Inner test chamber volume	0,6 m × 0,6 m × 0,06 m	
Outer test chamber volume	1,0 m × 0,8 m × 0,5 m	
Surface area of test specimen	0,15 m ²	
Loading factor	0,38 m ² /m ³	
Temperature	23 °C ± 1 °C	28 °C ± 1 °C
Relative humidity	50 ± 5 % RH	50 ± 5 % RH
Air change rate	0,5 /h	0,5 /h, 0,09 /h
Air flow rate/surface area of test specimen: q/A	1,33	0,23, 1,33
Inner test chamber average air velocity	0,1 m/s	0,1 m/s
Mass transfer coefficient determined using water vapour	15,5 m/h	15,5 m/h

Table C.2 — Testing materials

Symbols	Building materials
HGB	Formaldehyde-reducing gypsum board
RW	Formaldehyde-reducing rock wool acoustic board

**Key**

- 1 inlet
- 2 outlet
- 3 mesh
- 4 test material
- 5 fan

Figure C.1 — Test chamber**C.2 Assembly procedure**

Before the test, the boundary-layer-type small test chamber was dismantled, the test chamber and its fittings (screws, etc.) washed, and a bake-out performed using a large oven at 260 °C.

After cooling, the boundary-layer-type small test chamber was assembled in a thermostatic oven, the system was run for about an hour, and after confirming the temperature and humidity had stabilized, the specimen was introduced to the boundary-layer-type small test chamber. After ventilating the room until it was judged that the test chamber had reached a stable temperature, supply air containing formaldehyde was passed through and after a time had passed when it was judged that the concentration was steady, sampling was performed.

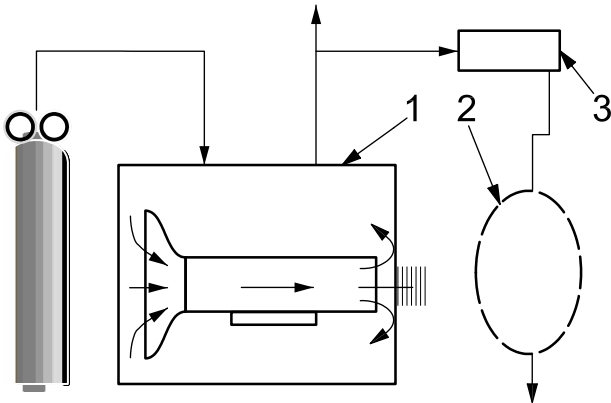
C.3 Sampling procedure and analytical conditions

Figure C.2 shows the series of flows for chemical sampling centered on the boundary-layer-type small test chamber. Air containing formaldehyde was supplied to the small outer chamber at a ventilation frequency of 0,5 times per hour. Polytetrafluoroethylene tubing was used for all pipes.

The specimen was set up in the test chamber, and after the concentration of formaldehyde in the test chamber stabilized, collection pipes were connected, and the necessary mass drawn in with an external pump. Table C.3 shows the sampling conditions for formaldehyde.

However, these conditions change depending on the specimen and the objective of the test. To maintain the accuracy of the data, the collection mass is increased for measurements of specimens expected to adsorb a large mass.

Table C.4 shows the analytical conditions for formaldehyde.



- Key**
- 1 test chamber
 - 2 pump
 - 3 adsorbent

Figure C.2 — Measurement system

Table C.3 — Sampling conditions

Sampler	Waters Sep-Pak® DNPH-Silica Cartridge (short type) ^a
Air flow rate	0,5 l/min
Sampling volume	15 l
^a Example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.	

Table C.4 — Analytical conditions (HPLC)

HPLC	Agilent HP1100® series ^a
Column	ZORBAX XDB-C18® ^a
Mobile phase	water + acetonitrile = 40 + 60
Oven temperature	40 °C
Injection volume	10 µl
Detector	UV 360 nm
^a Example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.	

C.4 Measurement

Table C.5 and Figure C.3 show the results of the test. For a supplied formaldehyde concentration of approximately 100 µg/m³, the decrease in concentration in the small chamber indicates an ability to decrease the formaldehyde concentration. The ability of test specimen RW to reduce the formaldehyde concentration was small compared to that of test specimen HGB.