

**BUILDING MATERIALS:
EMISSIONS TESTING USING THE CLIMPAQ**

Key words: Building materials, emission, pollution, air quality, CLIMPAQ, Chamber for Laboratory Investigation of Materials, Pollution and Air Quality

TABLE OF CONTENTS

1	INTRODUCTION	1
2	SCOPE	2
3	FIELD OF APPLICATION	2
4	REFERENCES	2
5	DEFINITIONS	2
6	COLLECTION, TRANSPORT AND STORING OF MATERIAL SAMPLES	3
7	METHOD OF TEST	3
7.1	Principle	3
7.2	Apparatus	3
7.3	Preparation of test specimens	4
7.4	Conditioning of test specimens	5
7.5	Testing conditions	5
7.5.1	Temperature and humidity	5
7.5.2	Air velocity	5
7.5.3	Area specific airflow rate	5
7.5.4	Test chamber airtightness	6
7.5.5	Background concentration	6
7.6	Preparing the test chamber for emission test	6
7.7	Test procedure	6
7.8	Quality control	6
7.9	Expression of results	7
7.10	Test report	7
APPENDICES		
A:	Adjustment of airflow rate and air velocity	9
B:	Airflow rate measurements	10
C:	Air velocity measurements	11
D:	Mounting of test specimens	12
E:	Airtightness	13
F:	Temperature and humidity control	14
G:	Examples of CLIMPAQ installations	15

1 INTRODUCTION

The Chamber for Laboratory Investigations of Materials, Pollution and Air Quality, CLIMPAQ, (1) is a small-scale test chamber in which samples of construction products are exposed to well defined and controlled environments. The environmental parameters such as air velocity, temperature and humidity can be varied independently within ranges typically found in indoor environments. The air from the CLIMPAQ may be analysed using a variety of methods for sensory and chemical characterisation of the emissions of pollutants from construction products. The present Nordtest Method focuses on the operation of the CLIMPAQ and details of different methods for characterisation of emissions are not included.

Laboratory investigations of the emission of pollutants from construction products to indoor air may have several purposes. It may be a matter of routine testing by manufacturers, monitoring their production or performing emission testing of new prototypes. They may also be carried out as basic research with the aim of increasing knowledge of the factors that influence the interaction between pollution sources and indoor air.

Regardless of the purpose of the measurement, the testing facility should provide low background concentrations and sufficiently stable test conditions. It is a matter of maintaining the values of a number of environmental parameters within the desired limits. In the context of emission of organic vapors from indoor surfaces the following environmental parameters are often considered or expected to be of importance:

- air temperature
- humidity
- air velocity
- vapor pressure of the compounds studied

The parameters listed above are dependent on both the design and the operation of the testing facility, which includes the test chamber, the air supply system and the monitoring and control systems.

Small environmental test chambers are being considered as the preferred tool for the qualitative and quantitative characterisation of pollutants emitted from various materials and

products (2). The advantage of small-scale chambers over large chambers is that they are cheaper and easier to construct and to operate. One obvious disadvantage is the limitation of the size of the test specimen. Furthermore, some uncertainty may be attributed to the upscaling of results to the situation in real buildings, for example due to different characteristics as regards air movements and sorption of chemical substances. However, from an inter-laboratory comparison of measurements in small chambers with volumes ranging from 0.035 to 1475 liters it was concluded that the chamber volume did not introduce any systematic differences in the test results (3).

Emission testing includes collection of test materials, transport of materials, preparation of test specimens, preparation of the test chamber, conditioning of test specimens, and finally, testing by measurements. The measurements may be performed as sensory assessments by a panel of judges exposed to the air exhausted from the test chamber and/or measurements of air pollution by chemical analysis. The CLIMPAQ is especially designed for simultaneous use of these two types of quantification methods. The CLIMPAQ is in use within the Danish Indoor Climate Labelling system (4).

2 SCOPE

This Nordtest method specifies the use of CLIMPAQ for conditioning and emission testing of construction products. A set of environmental conditions for standardised tests is presented together with the possible ranges for these conditions for more comprehensive investigations.

3 FIELD OF APPLICATION

The CLIMPAQ is a small-scale test chamber for the exposure of construction products to environments similar to the conditions during their intended use in buildings. The air from the chamber may be analysed for sensory and chemical characterisation of the emissions of pollutants from samples of construction products to the air surrounding the material. The environmental parameters such as air velocity, temperature, humidity and concentration of pollutants can be varied independently within ranges typically found in indoor environments. The present Nordtest method provides the framework for a method that may be modified in order to fit a variety of applications. It gives detailed information about the operation of the CLIMPAQ, and points out the activities that are critical in the process of emission testing. Details of different methods for sensory and chemical characterisation of emissions are not included.

The objectives of tests carried out using the CLIMPAQ can be to:

- investigate the influence of environmental parameters on the emission rate,
- rank different pollution sources with respect to their influence on indoor air quality, and
- obtain sensory and chemical emission data for the development and verification of theoretical models for the

prediction of indoor pollutant concentrations as a function of age, environmental conditions and other parameters that may vary during production and handling.

4 REFERENCES

- (1) Gunnarsen, L., Nielsen, P.A. and Wolkoff, P. "Design and characterization of the CLIMPAQ Chamber for Laboratory Investigations of Materials, Pollution and Air Quality", *Indoor Air*, 4, pp. 56–62, 1994.
- (2) Commission of the European Communities, "Guideline for the characterization of volatile organic compounds emitted from indoor materials and products using small test chambers", Report No. 8, EUR13593 EN, 1991.
- (3) Commission of the European Communities, "Determination of VOCs emitted from indoor materials and products, Interlaboratory comparison of small chamber measurements", Report No. 13, EUR 15054 EN, 1993.
- (4) Wolkoff, P. and Nielsen, P.A., "Indoor Climate Labeling of Building Materials: The Experimental Approach for a Prototype", *Characterizing Sources of Indoor Air Pollution and Related Sink Effects*, ASTM STP 1287, Bruce A. Tichenor, Ed., American Society for Testing and Materials, 1996, pp. 331–349.
- (5) Nordtest Method, "Building Materials: Emission of Volatile Organic Compounds, Chamber Method", NT Build 358, Esbo, 1990.
- (6) ISO 554, Standard atmospheres for conditioning and/or testing – Specifications.
- (7) Clausen, G., Pejtersen, J., Saarela, K., Tirkkonen, T., Tähtinen, M. and Dickson, D. "Protocol for testing of building materials", Version 1.0, 1995.

5 DEFINITIONS

Air change rate, n: the ratio of the supply airflow rate to the free volume of the ventilated space [h^{-1}].

Area specific airflow rate, q: the ratio of the supply airflow rate to the area of the tested material [$\text{m}^3 \cdot \text{h}^{-1} \cdot \text{m}^{-2}$].

Area specific emission rate, E: the release of pollutants from a unit area of the tested material to the surrounding air [$\text{mg} \cdot \text{m}^{-2} \cdot \text{h}^{-1}$].

Chamber concentration, C_c : the concentration of a specific compound or group of compounds measured in the test chamber. At steady state and when the sink effects are zero, the emitted amount of the compound is transported from the chamber by ventilation. Under given test conditions the chamber concentration depends on the emission rate and the airflow rate in the chamber. If the supply air concentration is negligible, the relation between the chamber concentration, the area specific emission rate and the area specific airflow rate of the test chamber at steady state can be expressed as:

$$C_c = \frac{E}{q} = E \frac{L}{n} \quad (1)$$

where

C_c = concentration in the test chamber [$\text{mg} \cdot \text{m}^{-3}$]

E = area specific emission rate [$\text{mg} \cdot \text{m}^{-2} \cdot \text{h}^{-1}$]

q = area specific airflow rate [$\text{m}^3 \cdot \text{h}^{-1} \cdot \text{m}^{-2}$]

L = loading factor [$\text{m}^2 \cdot \text{m}^{-3}$]

n = air change rate [h^{-1}]

Throughout this method description, the area specific airflow rate is systematically designated by the symbol q . As can be seen in Equation (1), however, the area specific airflow rate, q , equals the ratio n/L . Neither the air change rate, n , nor the loading factor, L , is suitable on its own as a parameter for scaling purposes, when test chambers and model rooms of different sizes are compared. For a given material tested under given climatic conditions the concentration of the emitted pollutant is dependent on the area specific airflow rate, $q = n/L$. Thus, it appears suitable to keep the area specific airflow rate in the test chamber equal to the area specific airflow rate in the model room.

Loading factor, L: the ratio of the area of the tested material in the model room to the volume of the model room [$\text{m}^2 \cdot \text{m}^{-3}$].

Material sample: A sample collected to represent a specific material.

Model room: a full-scale room used for determination of the area specific airflow rate to be used in the test chamber. In Nordtest, NT Build 358, (5), a model room was defined as having the dimensions $3.2 \cdot 2.2 \cdot 2.4$ m (length, width and height respectively). Model rooms with other dimensions can be used.

Supply airflow rate, Q: airflow rate expressed as the volume-flow of air entering a room or a test chamber [$\text{m}^3 \cdot \text{h}^{-1}$ or $1 \cdot \text{s}^{-1}$].

Test specimen: A piece of the material sample prepared for use in the test chamber.

6 COLLECTION, TRANSPORT AND STORING OF MATERIAL SAMPLES

Each material sample shall be selected, collected, transported and stored in a manner that allows the emission characteristics of the test specimen to be representative of the emission characteristics of the material.

During the time between the collection of a material sample and the start of conditioning or testing, an undesirable change may occur in the emission characteristics of the material. The material may, for example, be affected with respect to:

- a decrease in the residue of emittable matter
- a change in concentration gradient within the material
- contamination of the material surface by adsorption
- chemical reactions on the material surface and/or within the material.

The history of the material and the sample must be documented in the test report together with information about the circumstances under which the sample was collected. If pollutants are emitted from the material, the total residue of emittable matter in the material will be reduced, and the

concentration gradient within the material may change. The material near the surface of the specimen will have a lower concentration of emittable compounds than that farther away from the surface. Thus, if compounds are emitted from the material sample during transport there is a risk that it will not be possible to restore the concentration gradient before emission testing.

If the emission is minimised by sealing the material surfaces, the total residue of emittable matter may stay practically unchanged, and the concentration gradient will be equalised within the material. However, by conditioning the material before the start of the emission test, it is, at least theoretically, possible to restore a concentration gradient similar to the original one, but at a slightly lower level.

For these reasons, during the time between the collection of a material sample and the start of conditioning or testing, the emission from the material should be minimised and the surfaces of the material sample should be protected from chemical contamination by sealing the surfaces. Each material sample should be stored and transported separately, without contact between the surface of the sample and the ambient air. For solid materials this could be achieved by wrapping each sample in clean aluminum foil. Newly applied paint should be allowed to dry before wrapping the sample in foil. Liquid and paste products should be placed in sealed containers.

During storage and transport the temperature and the humidity should be maintained at approximately the same level as that during testing. The material samples should arrive at the testing laboratory as soon as possible after collection and packaging.

7 METHOD OF TEST

7.1 Principle

The principle of the test method is to assess the emission of pollutants from a test specimen, prepared from a sample of a building material, by sensory assessments and concentration measurements of the air in a test chamber. The surface of the test specimen is exposed to the chamber air which is maintained at a temperature, humidity and velocity similar to that which can be expected in the indoor environment in which the material will be used. In addition to these conditions the chamber concentration depends on the supply airflow rate in the chamber and the area of the test specimen. The test is performed with an area specific airflow rate similar to that which can be expected during the normal use of the material.

7.2 Apparatus

The CLIMPAQ is made of glass and stainless steel, and has an internal volume of 50.9 liters. The dimensions and the principal parts of the chamber are shown in Figure 1.

The CLIMPAQ can be supplied with air in two different ways. It can be placed in a room with sufficiently clean and conditioned air. In this case it may be used as a stand alone unit, drawing supply air by itself directly from the room where

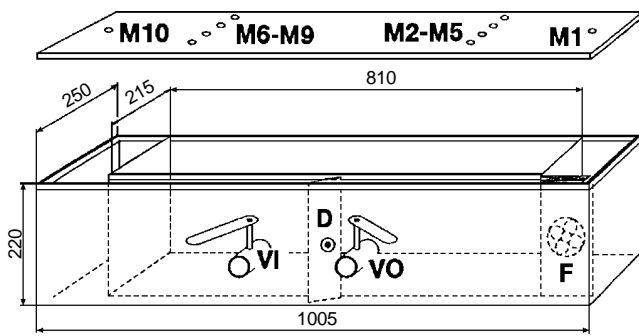


Figure 1. Sketch of the CLIMPAQ and its dimensions. The total air volume of an empty CLIMPAQ is 50.9 liters.

it is placed. Alternatively, the CLIMPAQ may be supplied with air from an external supply air system connected to the air inlet of the CLIMPAQ. The area specific airflow rate, q [$\text{m}^3 \cdot \text{h}^{-1} \cdot \text{m}^{-2}$], can be adjusted by adjustment of the supply air flow rate and by changing the material loading in the CLIMPAQ. Furthermore, the air velocity in the test chamber can be adjusted independently of the supply airflow rate by controlling the air recirculation in the test chamber. The main performance data of the CLIMPAQ are given in Table 1.

Table 1. Main performance data of the CLIMPAQ [1].

Parameter	Minimum	Maximum	Remark
Supply airflow rate	0.0003***	2.0	$1 \cdot \text{s}^{-1}$ Obtained with internal fan only
Air change rate	0.02	140	h^{-1} Volume of empty chamber = 50.9 liters
Mean air velocity *	0	0.3	$\text{m} \cdot \text{s}^{-1}$ Depends on material loading and recirculation
Material loading **	0	3.8	m^2 Max 12 double sided plates of $0.8 \cdot 0.2 \text{ m}^2$

* Measured with a hot-wire anemometer in the test zone of an empty CLIMPAQ.

** Dependent on the thickness of the test specimens.

*** Air leakage when recirculating 100 % and operating without external supply air system.

The fan, F, is used to force the supply air flow and to enable recirculation of air over the test specimens. The damper, D, enables control of the recirculation rate. The setting of the inlet valve, VI and the outlet valve, VO, influence the supply air flow rate and the air recirculation. The adjustment of the airflow rate and the air velocity comprises an iterative procedure involving adjustment of both valves, VI and VO, and the damper, D. The practical procedure for adjustment of the airflow rate and the air velocity in the CLIMPAQ is described in Appendix A.

The ten holes (diameter 10–12 mm) in the lid of the CLIMPAQ are used for measurement purposes. The holes

M2–M9 should be used for measurement of the air velocity in the test zone. The holes M1 and M10 can be used for measurement of the static pressure in the CLIMPAQ. The hole M10 may be used for injection of a tracer gas and the hole M1 can be used for sampling on adsorbent tubes. During emission testing the holes should be covered, for example by stainless steel or aluminum caps kept in place by a low-emitting tape. A diffuser can be mounted at the test chamber outlet, VO, in order to enable sensory assessment of the quality of the air exhausted from the test chamber (see Figure G1 in Appendix G). Air pollutants may alternatively be sampled on adsorbent tubes placed in the air exhausted from the test chamber, for example in the diffuser. Furthermore, the CLIMPAQ can be equipped with a dilution system which enables sensory assessments of polluted air at different concentrations (see Figure G3 in Appendix G).

7.3 Preparation of test specimens

The preparation of test specimens includes production of a number of specimens with the desired surface area, and sealing of the edges that should not be in contact with the chamber air. Test specimens prepared from flat materials can have a maximum length of 0.8 m and a maximum height of 0.2 m. Sealants may be applied in aluminum U-profiles with a maximum length of 0.8 m. The total surface area of the test specimens shall be determined in view of the desired area specific airflow rate and the supply airflow rate to the CLIMPAQ. The selection of these parameters is discussed in Section 7.5.

Test specimens should be handled in a climate approximately equal to the planned testing climate. The material samples used for production of test specimens should be of the same temperature as the ambient air. The time between unpacking and the start of conditioning should be as short as possible, see Section 7.4.

Unless otherwise specified, all edges and the reverse side of the test specimen shall be sealed with a product that does not contribute to the air pollution level in the test chamber. A low-emitting, self-adhesive aluminum tape is suitable for this purpose. In order to minimise the need for sealing the reverse sides, an even number of test specimen plates should be used, and those should be mounted in pairs with the reverse sides facing each other. In order to prevent uneven air distribution in the CLIMPAQ, all test specimens used at the same time should have the same dimensions.

Wet materials shall be applied to a support made of a material selected with regard to the purpose of the test. If, for example, the test intends to study the emission from a paint itself the support should be made of a non-emitting and non-permeable material (for example a sheet of stainless steel or glass). When testing paints, one alternative is to test the support and the paint as a system. If the paint is applied, for example, on wallpaper or gypsumboard, the results may be more representative of the real building situation. In other applications the preparation may include production of test specimens consisting of several layers of different construction products.

7.4 Conditioning of test specimens

The time between the unpacking of the material samples and the start of the test is considered as a conditioning period. Unless otherwise specified: 1) conditioning should be carried out in the same climate and with the same requirements for background concentration as specified for the test, and 2) the conditioning period should be 28 ± 2 days.

7.5 Test conditions

The selection of test conditions includes selection of air temperature, humidity, air velocity and area specific airflow rate. Generally, the tested object should be in equilibrium with the temperature and the humidity of the test chamber air. The selection of test conditions depends on the objective of the test and should be agreed upon before the start of the test. The selected test conditions shall be incorporated in the Quality Assurance Project Plan.

Unless otherwise specified the test conditions should comply with the figures given below.

7.5.1 Temperature and humidity

The temperature and relative humidity in the chamber shall comply with ISO standard 554 (6) within the following limits:

Temperature	23 °C	± 1 °C
Relative humidity	50%RH	± 5 %RH

7.5.2 Air velocity

The air velocity measured in the center of each cross section between test specimens shall be 0.2 ± 0.1 m·s⁻¹.

7.5.3 Area specific airflow rate

The area specific airflow rate should be the same in the test chamber as in the selected model room. In the model room the different types of materials have different exposed areas, which means that different types of materials are ventilated with different area specific airflow rates. The desired area specific airflow rate in the CLIMPAQ is adjusted by adjusting the test specimen area and the supply airflow rate in the test chamber. The correct material area is obtained by preparing a number of material plates with the maximum length of 0.8 m and the maximum height of 0.2 m. The maximum material loading depends on the thickness of the test specimen, see Appendix D.

Guidance on how to select the area specific airflow rate is given below. During the emission test the supply airflow rate shall not deviate by more than 20 % from the selected value, and it shall not vary by more than ± 3 %.

Full-scale scenario defined by the use of a model room

The following example is based on the use of the model room defined in NT Build 358 (5), which has the dimensions

3.2 · 2.2 · 2.4 m (length, width and height respectively). Table 2 shows the areas and the loading factors for some surfaces in this specific model room.

Table 2. Loading factors for some of the surfaces in the NT Build 358 Model Room [5].

Surface	Surface area, A [m ²]	Loading factor, L [m ² /m ³]
Floor/Ceiling	7	0.42
Wall	24	1.41
Door	2	0.12
Window frames	0.2	0.012
Sealants	0.2	0.012

Once the loading factor has been selected, for example using Table 2, the next step is to select the air change rate, n, in the model room. The air change rate in normal buildings may range from about 0.5 [h⁻¹] in naturally ventilated buildings, to about 5 [h⁻¹] in mechanically ventilated buildings.

The area specific airflow rate, q, for a material is then calculated as the ratio of the air change rate to the loading factor in the model room, $q = n/L$. The area specific airflow rate should be the same in the test chamber as that calculated for the selected model room. This is achieved by a proper combination of test specimen area and supply airflow rate in the CLIMPAQ.

Selection of test specimen area and supply airflow rate in the CLIMPAQ

Equation (2) shows the relationship between the airflow rate in the CLIMPAQ and the test specimen area required to obtain the same area specific airflow rate in the CLIMPAQ as in a model room, ventilated with n air changes per hour and with a loading factor of L.

$$q = \frac{Q}{A_{ts} \cdot x} = \frac{n}{L} \tag{2}$$

where

- q = area specific airflow rate [m³ · h⁻¹ · m⁻²]
- Q = supply airflow rate in the CLIMPAQ [m³ · h⁻¹]
- A_{ts} = area of one test specimen [m²]
- x = number of test specimens to be mounted in the CLIMPAQ
- n = air change rate in the model room [h⁻¹]
- L = loading factor in the model room [m² · m⁻³]

The relationship between the supply airflow rate and the test specimen area should be calculated using Equation (2) whenever the area specific airflow rate is not explicitly studied. However, depending on the air quality quantification methods being used, there may be some limitations regarding the selection of air flow rate in the CLIMPAQ. For example, sensory assessments using the diffuser shown in Figure G1 in Appendix G require that the airflow rate through the diffuser is kept at about 0.9 l·s⁻¹ (7). Furthermore, some methods for chemical quantification may require higher concentrations than what is obtained using Equation (2) applied to a specific model room. In such cases, in order to obtain

a measurable concentration, it may be necessary to select airflow rates that deviate from the desired model room scenario.

Example of a model room scenario

Table 3 shows the area specific airflow rates corresponding to an air change rate of 2.0 h⁻¹ in the model room defined in NT Build 358 (5). The table also shows the test specimen areas that give the corresponding area specific airflow rates in the CLIMPAQ, when the supply airflow rate in the CLIMPAQ is kept at 0.9 l/s. The data in Table 3 are obtained using Equation (2).

Table 3. Area specific airflow rates corresponding to an air change rate of 2.0 h⁻¹ in the model room defined in NT Build 358 [5], and examples of supply airflow rates and test specimen areas that give the corresponding area specific airflow rates in the CLIMPAQ.

Material type	Model room		CLIMPAQ		
	Area specific airflow rate q = n/L [m ³ ·h ⁻¹ ·m ⁻²]	Supply air-flow rate Q [l·s ⁻¹]	Area of test specimens A = A _{ts} ·X [m ²]	Test specimen	
				Number x	Dimensions l-h [m·m]
Floor/ceiling	4.76	0.9	0.68	6	0.57-0.2
Wall	1.42	0.9	2.28	16	0.71-0.2
Door	16.7	0.9	0.19	2	0.48-0.2
Sealants	167	0.9	0.019	3	0.63-0.01

7.5.4 Test chamber airtightness

Unless otherwise specified the air leakage shall not exceed 10 % of the supply airflow rate. Guidance on how to check the air leakage is given in Appendix E.

7.5.5 Background concentration

The background concentration is the concentration of pollutants measured in an empty chamber operated under the same conditions as during the emission test. The background concentration shall be low enough not to interfere with the emission determinations beyond quality assurance limits. Unless otherwise specified the background concentration shall not exceed 2 µg/m³ for any VOC of interest during the emission test. When the emission test includes sensory assessments the background concentration should be determined. The concentration of pollutants in the air of the room where the CLIMPAQ is operated should not exceed the background concentration in the CLIMPAQ.

7.6 Preparing the test chamber for the emission test

The chamber is prepared for use by performing the following steps:

- 1) The chamber shall be cleaned before the start of each test. Cleaning is performed by scrubbing the inner surfaces with an alkaline detergent in hot tap water, rinsing with hot tap water and final rinsing with deionised water.

The internal fan is easily removable for these cleaning procedures. After cleaning the chamber should be closed and purged with clean air for 24 hours.

- 2) The supply airflow rate, air velocity, air temperature and humidity should be adjusted in accordance with the desired test conditions. A detailed description of the adjustment procedure is given in Appendix A–C. In order to minimise the need for a subsequent correction of the airflow rate and air velocity (see step 5 below) the adjustment may be carried out with inert substitutes of the test specimens mounted in the CLIMPAQ.
- 3) The background concentration should be measured and if the concentrations of the compounds of interest exceed the limits stated as part of the Quality Assurance Project Plan (see Section 7.8) the cleaning procedure shall be repeated. However, in some cases it may be acceptable to subtract the background concentration from the measured concentration.
- 4) The test specimens should be mounted in the CLIMPAQ according to the instructions given in Appendix D and the lid should be closed.
- 5) Check and adjust the airflow rate and the air velocity. Ensure that the tightness of the chamber is satisfactory, according to the instructions given in Appendix E.

7.7 Test procedure

The test is carried out by chemical measurements of the concentration of the compound(s) of interest, or by sensory assessments by a panel of air quality judges. The number of concentration measurements and the time interval between the measurements depend on the objective of the test. Testing of a material with an unknown emission-time curve may for example require a larger number of consecutive measurements than testing of a material with a known emission-time curve. A plan for the concentration measurements should be agreed upon prior to the start of the test. The results from previous measurements may, however, be used for revision of the succeeding part of the measurement plan. The concentration measurement should be made either in the hole M1 in the lid of the CLIMPAQ, or in the exhaust air leaving the CLIMPAQ through the outlet valve, VO.

The air temperature, humidity, the airflow rate in the CLIMPAQ and the air velocity over the test specimens should all be kept constant during the emission testing. These parameters should be measured at least in the beginning and at the end of the test period. If it has not been verified prior to the start of the emission test that the parameters can be automatically kept stable within acceptable limits, they should be continuously monitored during the test period.

Details of the air velocity measurements are given in Appendix C, and information on temperature and humidity control is given in Appendix F.

7.8 Quality control

Emission testing should be carried out using a Quality Assurance Project Plan, which should include the following items:

A **project description** should specify the objective of the test, the way the test will be conducted, what materials will be tested and who is responsible for the different parts of the project.

The **data quality objectives and the acceptance criteria** should be specified as the desired precision and accuracy of each measured parameter. The expression of results should state whether the measurements are in compliance with the data quality objectives.

Quality assurance activities, such as cleaning of the chamber, proper handling of materials and calibration and maintenance of equipment should be recorded in log books.

The steady state concentration of a pollutant in the chamber air may depend on the environmental parameters, such as temperature and humidity. Furthermore, the concentration is dependent on the airflow rate in the chamber. It is therefore important that the temperature, relative humidity and airflow rate are registered continuously. All instruments have to be calibrated at sufficient time intervals. In addition to the above mentioned parameters, extensive quality assurance activities should be involved in the process of measuring emissions, e.g. sampling organic compounds on adsorbents, subsequently analysed with gas chromatography, and air quality measurements by sensory assessments.

In order that the Quality Control activities may be carried out in a meaningful way it is necessary to make distinct definitions of a number of parameters and sub-procedures prior to the start of the project. In this context the following items should be considered:

- Strategy for the collection of material samples
 - selection of representative materials
 - packing materials and methods
 - maximum time between collection and the start of the preparation of test specimens
- Preparation of test specimens
 - method for cutting out test specimens
 - method for application of wet materials
 - selection of support materials
 - selection of materials and methods for sealing of edges
- Definition of conditioning climate and test conditions
 - area specific airflow rate
 - supply airflow rate
 - test specimen area
 - air temperature
 - humidity
 - air velocity over the test specimens
- Definition of allowable deviations from the selected conditions
- Criterion for test chamber airtightness
- Required accuracy of all the measured parameters
- Method for chemical measurements
 - measurement location
 - analytical procedure
 - instrumentation
 - maximum allowable background concentration

- Sensory assessments
 - principle of method
 - type of sensory panel
 - number of panel members
 - administration of sensory panels
 - maximum allowable background concentration
- Plan for concentration measurements
 - Time schedule
- Calibration procedures.

7.9 Expression of results

In addition to the obtained emission data the report should include information about the environmental parameters, i.e. temperature, humidity, air velocity as well as the airflow rate and the total area of the test specimens, together with an evaluation of the compliance with the data quality objectives.

Chemical measurements

The results should include the measured chamber concentrations and the area specific emission rates calculated using Equation (1).

Sensory measurements

Several sensory methods are described. At present it is not possible to recommend one particular method. One way to characterise emission from materials is by exposure-response relationships between the concentration of pollutants and a quantitative estimate of e.g. acceptability or intensity based on sensory assessments. Determination of sensory threshold is another way of characterising emissions from materials. A dilution system may be used for determination of exposure-response relationships and sensory thresholds. If the results are obtained using a dilution system together with the CLIMPAQ the rate of dilution shall be reported. The report should also include the measured air quality parameters.

7.10 Test report

The test report should include the following information:

- a) Name and address of the testing laboratory
- b) Identification number of the test report
- c) Name or other identification of the tested object
- d) Name and address of the organisation or person who ordered the test
- e) Purpose of the test
- f) The circumstances and conditions under which the material samples have been stored and transported
- g) Information about the procedure of test specimen preparation
- h) Description of the tested object

-
- i) The time interval between collection of the material sample and the test
 - j) The environmental parameters for the conditioning and testing atmosphere
 - k) Date and period of the test
 - l) Identification of the measurement methods, test equipment and the instruments used
 - m) Identification of the person(s) responsible for the measurements
 - n) Test results
 - o) Date and signature
for newly produced materials also
 - p) date of manufacture
 - q) production number
and for test specimen taken from materials that have been installed in buildings
 - r) age of the material
 - s) surface treatment.

APPENDIX A

PROCEDURE FOR ADJUSTMENT OF THE AIRFLOW RATE AND THE AIR VELOCITY

A step by step procedure for adjustment of the airflow rate and the air velocity is given below. The procedure indicates only the methodology for adjustment while details of the measurement methods needed are given in subsequent appendices. Section A.1 can be used for a "stand alone" CLIMPAQ, i.e. a chamber that is not connected to a supply air system, but takes the supply air directly from the room where it is placed. In section A.2 a procedure for adjustment of a CLIMPAQ with an external supply air system is presented. The symbols VI, VO, D and F are defined in Figure 1 in the body of the report.

A.1 "STAND ALONE" CLIMPAQ

Preparing the CLIMPAQ for use:

1. Mount the test specimens or inert substitutes of test specimens in the CLIMPAQ.
2. Mount the lid on the CLIMPAQ.

Adjustment for maximum supply airflow rate and minimum recirculation:

3. Open both valves, VI and VO, completely.
4. Close the damper, D, completely.
5. Turn on the internal fan, F.

Adjustment of the supply airflow rate:

6. Adjust the air outlet valve, VO, until the supply airflow rate in the CLIMPAQ is correct. Note that when the CLIMPAQ is operated as a "stand alone" chamber, there will be a negative static pressure of about 10 Pa in the test zone (measured in hole M1 in the lid of the CLIMPAQ). The inlet valve, VI, should be completely open, in order to minimise the negative pressure in the chamber.

Adjustment of the air velocity:

7. Adjust the damper, D, until the air velocity in the test zone of the CLIMPAQ is correct.

Iterations:

8. Check the supply airflow rate. Repeat steps 6–8 until the airflow rate and the air velocity are equal to the desired values.

A.2 CLIMPAQ WITH EXTERNAL SUPPLY AIR SYSTEM

For a CLIMPAQ that is operating with an external supply air system, i.e. with a supply air fan connected to the CLIMPAQ via the air inlet valve, VI, the following steps can be used for adjustment. The procedure can be used for supply airflow rates above $0.5 \text{ l}\cdot\text{s}^{-1}$ and it is suitable to let the supply air system provide a constant static pressure of about +25 Pa at the inlet valve of the CLIMPAQ.

Preparing the CLIMPAQ for use

1. Mount the test specimens or inert substitutes of test specimens in the CLIMPAQ.
2. Mount the lid on the CLIMPAQ.
3. Open both valves, VI and VO, completely.
4. Close the damper, D, completely.
5. Turn on the internal fan.
6. Adjust the outlet valve, VO, until the airflow rate in the CLIMPAQ is correct.
7. Adjust the damper, D, until the air velocity in the test zone of the CLIMPAQ is correct.
8. Check the supply airflow rate. Adjust the valve, VO, until the airflow rate is correct.
9. Check the static pressure in the chamber using hole M1. Compensate for 50 % of the difference between the measured value and the desired pressure, by adjusting the inlet valve, VI. For example, if the measured pressure is +15 Pa and the desired pressure is +5 Pa, the valve VI should be adjusted until the measured pressure is +10 Pa.

It may be suitable to operate the chamber at about 5–10 Pa overpressure, in order to prevent polluted air from entering the chamber by leakage. Note that there will be a pressure drop between M1 and M10 when test specimens are placed in the chamber.

Iterations:

10. Check the supply airflow rate. Repeat steps 8–10 until the airflow rate and the static pressure are equal to the desired values.
11. Check the air velocity in the test zone of the CLIMPAQ. If necessary, repeat steps 7–11.

APPENDIX B

AIRFLOW RATE MEASUREMENTS

The ventilation rate in the CLIMPAQ can be measured by the use of an airflow meter connected to the air inlet or the air outlet of the chamber. An alternative method, based on tracer gas measurements, may also be used. Tracer gas measurements can be conducted either as concentration decay measurements or as constant concentration measurements. The tracer gas can be injected into the CLIMPAQ using hole M10 and the tracer gas concentration should be measured in the exhaust air at the outlet valve VO. For identification of the locations of M10 and VO, see Figure 1 in the body of this report.

The air velocity measured, for example with a hot-wire anemometer, in a straight tube connected to the air inlet or the air outlet of the CLIMPAQ, will provide a signal that may be translated into the air flow rate in the CLIMPAQ. The relationship between the measured air velocity in the tube and the airflow rate needs to be established by a calibration

procedure repeated over the range of interest, for example using simultaneous tracer gas measurements. Note that the "air velocity tube" needs to be sufficiently long to provide a well defined velocity profile and thus minimise the inaccuracy of the measurement. Since the diameter of the tube is small the geometry of the velocity probe will influence the measured values. The obtained translation curve is therefore valid only for the probe used during the calibration.

The quite small time constant (minutes) for the ventilation of the CLIMPAQ needs special considerations if the concentration decay method is chosen. A tracer gas analyser with a time constant small enough not to affect the results is needed. The constant concentration method can be used only if it is possible to make a sufficiently low and known tracer gas injection. The tracer gas methods may be relatively complicated and time consuming.

APPENDIX C

AIR VELOCITY MEASUREMENTS

The velocity of the air over the test specimens can be measured using, for example, a hot-wire anemometer. The holes (M2-M9) in the lid of the CLIMPAQ make it possible to check the air velocity in different parts of the chamber. The air velocity shall be checked in the center of the cross section between the test specimens. The anemometer should be calibrated for the vertical orientation of the probe. It is important that all the holes in the lid of the CLIMPAQ are sealed during the air velocity measurements.

Comment: The emission rates may depend on the mass transfer coefficient and, thus, on the boundary layer conditions. In general, the development of the boundary layer is dependent on both the air velocity over the surface and the geometry, e.g. the distance between the test specimens.

APPENDIX D

MOUNTING OF TEST SPECIMENS

Place the plane test specimens vertically, parallel to the long side of the CLIMPAQ. The test specimens can be kept in place using guides at each end of the chamber. Sealants applied in U-profiles should be placed on the bottom of the CLIMPAQ, parallel to the long side of the CLIMPAQ.

The distance between the chamber wall and the test specimen, and the distance between each test specimen should be equal. The absolute value of the distance depends on the thickness of the specimens and the number of specimens. The distance between each test specimen should not be smaller than 10 mm at any point.

APPENDIX E

AIRTIGHTNESS

In order to minimise the leakage of air between the CLIMPAQ and the ambient air, the silicone rubber foam gasket that is used for sealing the lid should be clean and undamaged. The lid should be tightened and kept in place by the accessory rubber straps (o-rings). Furthermore, the holes in the lid need to be properly sealed, for example using caps made of stainless steel or aluminum, kept in place by a low-emitting tape.

The tightness can be checked either

- by comparing the exhaust airflow rate to the supply airflow rate, or
- by measurement of the decay of a tracer gas, i.e. the supply airflow rate, with the outlet valve entirely closed and the CLIMPAQ operated at a significant overpressure.

APPENDIX F

TEMPERATURE AND HUMIDITY CONTROL

The temperature is controlled by controlling the supply air temperature, the temperature in the room in which the CLIMPAQ is placed and the internal heat load in the CLIMPAQ. It should be noted that the internal fan constitutes an internal heat load of about 8 W, which results in a temperature increase of approximately 1–4 °C, depending on the airflow rate in the CLIMPAQ. If desired, the temperature may be increased further by adding a heat load in the plenum below hole M10 (see Figure 1, Section 7.2).

The humidity in the CLIMPAQ is controlled by the humidity of the supply air. If the CLIMPAQ is operated as a "stand alone" chamber this means that the humidity should be controlled in the space where the CLIMPAQ is located. If the CLIMPAQ is supplied with air from an external system, the humidity is controlled by the humidity of the supply air only.

In order to prevent moisture condensing on the interior surfaces of the CLIMPAQ, the dew point temperature of the supply air should not exceed the surface temperature of the interior walls. If the CLIMPAQ is not thermally insulated this can be obtained by keeping the dry bulb temperature of the ambient air well above the dew point temperature of the supply air to the CLIMPAQ.

The temperature and the humidity should be measured using any of the holes M1–M9. However, if the material being tested acts as a heat load or humidity source, the average temperature and humidity should be measured using hole M1.

APPENDIX G

EXAMPLES OF CLIMPAQ INSTALLATIONS

The CLIMPAQ can be operated either with or without supply air from a separate supply air system. If the CLIMPAQ is operated without special supply air arrangements it is called a "stand alone" chamber. This case requires special consideration of the background contamination of the air of the room in which the CLIMPAQ is located, since the chamber is supplied with room air. If the CLIMPAQ is operated with an external supply air system, it is possible to supply the chamber with conditioned and cleaned air. Furthermore, it is possible to operate the CLIMPAQ with a slight positive

pressure, in order to prevent contaminated air from entering the chamber by leakage.

Figure G1 shows an example of a "stand alone" CLIMPAQ, and Figure G2 shows CLIMPAQs operating with supply air from an external supply air system. Figure G3 and G4 shows a CLIMPAQ equipped with a dilution system which enables sensory assessments of the polluted air at different concentrations. The concentration of pollutants in the diffuser can be adjusted by diluting the air exhausted from the test chamber with unpoluted supply air.

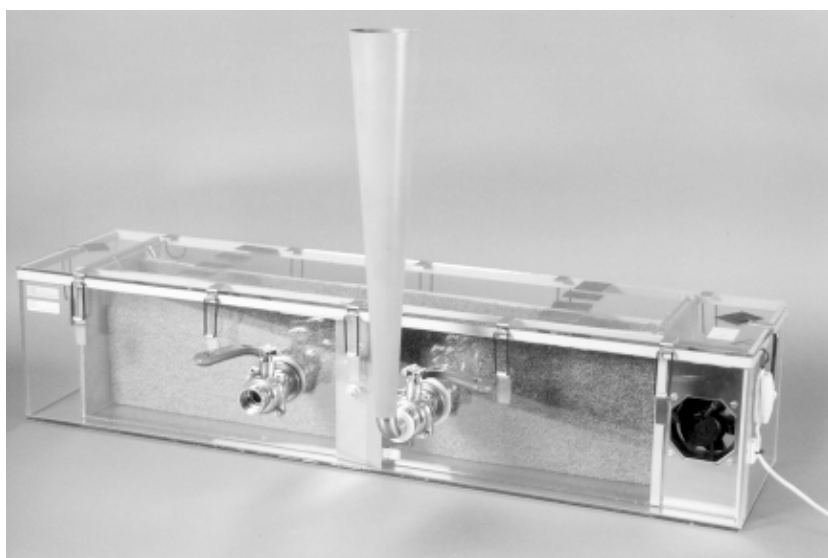


Figure G1. A "stand alone" CLIMPAQ supplied with air directly from outside the chamber. A diffuser [7] for sensory assessment of the air exhausted from the chamber is mounted at the chamber outlet.



Figure G2. CLIMPAQs supplied with air from an external supply air system.

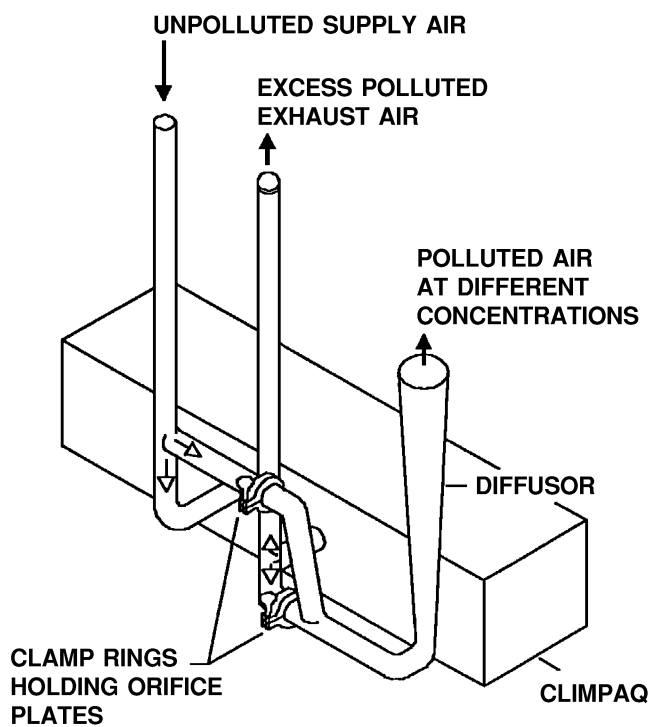


Figure G3. Sketch of a CLIMPAQ equipped with a system for dilution of the polluted air exhausted from the chamber with unpolluted supply air. The degree of dilution can be adjusted by changing two orifice plates held by the two clamp rings shown in the figure.

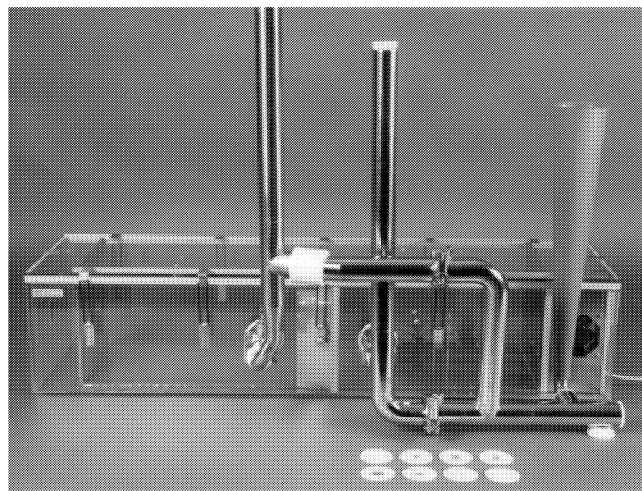


Figure G4. Photo of a CLIMPAQ equipped with a system for dilution of the polluted air exhausted from the chamber with unpolluted supply air.

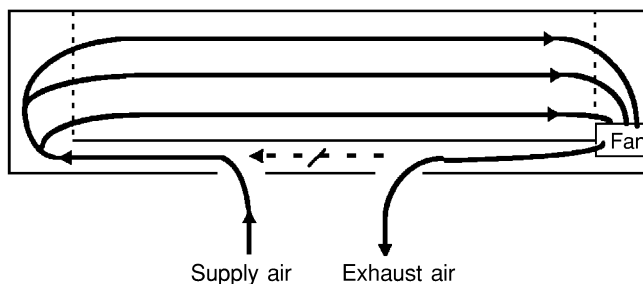


Figure G5. Sketch showing the air flow patterns in the CLIMPAQ. The dashed arrow represents the recirculated air flow.