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Testing method
for the determination of
emissions from hardcopy devices

as part of the award of the Blue Angel ecolabel
for office equipment with printing function

DE-UZ 219

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Foreword

This test method has been adapted for the implementation of the new requirements for the Basic Award Criteria of the Blue Angel ecolabel with respect to the emission behaviour (VOC, ozone, gravimetrically measurable dust, fine and ultrafine particles) of hardcopy devices (printers, copiers and multifunction devices). It is based on the test method from July 2012, the ECMA-328 standard [3] from ECMA International (European Association for Standardising Information and Communication System) and the international standards ISO 16000-9: 2012-11 for emission test chambers [4] and DIN ISO 16000-6: 2008-04 for VOC analysis [5]. The ECMA 328 Standard [3] is also available as ISO Standard (ISO/IEC 28360: 2015-08).

Consideration of these standards is an essential requirement for the application of this test method, provided they do not conflict with the test method.

The test method has been designed to enable the reliable determination of emission rates or emission amounts over a short continuous print phase, usually lasting well below one hour, using a dynamic test chamber method at a specified air exchange rate.

Since the devices themselves may have a certain level of VOC emissions that may decrease over time, the VOC emission rates must also be determined in the pre-operating mode as part of the test method.

The emission rates determined using this method should be regarded as system-specific emission rates because printers, copiers or multifunction devices only exhibit their specific emission behaviour in connection with the consumables used (e.g. toner, ink, paper).

The emission rates or emission amounts determined in the tests must not exceed the permissible limits specified in the Basic Award Criteria for the ecolabel.

It is generally assumed that the devices do not print constantly as they are not designed for this purpose and it is thus appropriate to use a utilisation factor <1 . In reality, the indoor air concentrations calculated by modelling are strongly influenced by adsorption effects on surfaces in the rooms, so that the actual concentrations will be lower than those calculated in real life situations.

The test method will be adapted as part of regular revisions.

1. Definitions

Aerosol

System of particles (solid and/or liquid) suspended in gas.

Aerosol measurement device

For the purposes of this test method, a device for determining the time-dependent particle number concentration of an aerosol within a defined particle size range and with a certain time resolution.

Accumulated particle number concentration $C_p(t)$

Time-dependent particle number concentration in a specified particle size range.

Load factor

Quotient of the volume of the test object and the volume of the empty emission test chamber.

Pre-operating phase

Experimental arrangement under normal climate conditions where the test object in the chamber is turned on and is waiting to start. The pre-operating phase links directly to the conditioning phase without having to re-open the chamber. Explanation: At the beginning of the pre-operating phase, the test object is switched on. The test object is then operated with the default factory settings according to the specifications in the Basic Award Criteria for DE-UZ 219.

Blank value

Background concentration of the measuring system (emission test chamber, sampling tube and analyser) for individual substances, as well as for TVOC and FP/UFP.

Print phase

Examination of the test object in print mode directly after the pre-operating phase without opening the chamber. The print phase begins when the first sheet starts printing and ends when the last sheet is printed.

Emission test chamber

Closed container with inlet and outlet and adjustable operating parameters (climate, air exchange rate) to determine the emissions (VOC, ozone, dust, fine and ultrafine particles) from test objects in an air flow (also see [4]).

Emission rate SER_u

This quantity gives the mass of the analyte (VOC, ozone, dust) that is emitted from a test object per unit time.

Fine particles FP

Particles with a particle diameter between 0.1 μm and 2.5 μm .

Averaged particle number concentration

Time dependent moving average of the measured particle number concentration formed over time intervals of 31 seconds.

Chamber loading

Placing a test object into the emission test chamber.

Condensation Particle Counter CPC

Instrument that measures the total particle number concentration of an aerosol within a defined particle size range.

Conditioning phase

Experimental arrangement under normal climate conditions where the test object with pre-loaded paper is in the chamber for conditioning, the power switch is in the "on" position, but the power cord is not connected to the power supply (the reason for this procedure is that the device can be moved from this status into the pre-operating phase by inserting the plug into the socket but without having to open the chamber).

Air exchange rate n

The ratio of the hourly net volume of air introduced into the emission test chamber to the free volume of the unloaded emission test chamber, which is to be determined in identical units, expressed in air exchanges per hour.

Air flow rate

Volumetric air flow rate supplied to the emission test chamber per unit time.

Air flow velocity v

Air velocity over the surface of the test object (distance: ten millimetres).

Post-operating phase

Experimental arrangement in which the test object is still in the chamber with the same air exchange rate as in the print phase, but printing has already been completed. The post-operating phase is directly linked to the print phase without opening the chamber.

Normal climate

Standard climate conditions: $23^{\circ}\text{C} \pm 2 \text{ K}$, $50 \pm 5\%$ relative humidity as per ISO 554 [6].

Ozone half-life

Time which elapses, starting from an initial ozone concentration, until the concentration has fallen to half its original value.

Particles

Small bodies suspended in air or gas having specified physical boundaries and consisting of liquid and/or solid substances.

Particle emission rate $\text{PER}(t)$

Time-dependant system-specific rate during the print phase and post-operating phase.

Particle size/particle diameter

Physical quantity to describe the physical dimension of a particle.

Note: The term particle size is often used as a synonym for particle diameter. The term particle diameter is also used to classify particles in particle size classes.

Particle loss coefficient β

Coefficient for describing particle loss in the emission test chamber.

Test object

Hardcopy device to be tested with consumables (toner or ink and paper).

Fast aerosol measuring instruments

Instruments with rapid time resolution and particle size classification.

Standard particle emission rate PER₁₀

This quantity gives the number of emitted particles during a 10-minute print phase. PER₁₀ is calculated as the test result from the measured accumulated particle number concentration.

Dust

For the purposes of this test method, the gravimetrically measurable particle fraction in an aerosol.

Toluol equivalent

Concentration of an unidentified compound evaluated from the calibration line for toluol. For GC-MS analysis, the TIC (total ion chromatogram) must be used.

Total Volatile Organic Compounds TVOCs

Total content of volatile organic compounds, i.e. the sum of the concentrations of identified and unidentified volatile organic compounds which elute from gas chromatographic separation on a nonpolar column between n-hexane and n-hexadecane, including these compounds.

TP

Number of emitted particles, TP is calculated as the test result from the measured accumulated particle number concentration based on the duration of particle emission.

Ultrafine particles UFP

Particles with a particle diameter less than or equal to 0.1 μm .

Volatile Organic Compounds VOC

General: organic compounds that are emitted from the test object and are detected in the chamber air. For the purposes of this test method: identified and unidentified organic compounds which elute from gas chromatographic separation on a nonpolar column between n-hexane and n-hexadecane, including these compounds.

Very Volatile Organic Compounds VVOC

For the purposes of this test method, identified and unidentified organic compounds which elute from gas chromatographic separation on a nonpolar column before n-hexane (e.g. ethanol, isopropanol, acetone, pentane).

2. Measuring instruments

- Emission test chamber in accordance with Section 4.1
- Instruments for climate measurement with recording capability in accordance with Section 4.4.1
- Colour mouse for determining the black value and the colour values in accordance with Section 4.4.2
- Multimeter in accordance with Section 4.4.3
- Systems, adsorbents for air sampling in accordance with Sections 4.5 and 4.6
- Capillary gas chromatograph with thermodesorption unit coupled with a mass spectrometer with an evaluation unit (see example in Section 8.6)
- Ozone analyser in accordance with Section 4.7
- Dust measurement station in accordance with Section 4.8
- Aerosol instrument in accordance with Section 4.9

3. Test objects

3.1 Selection

The client is responsible for supplying the test object for the testing. In general, a device from the current series is delivered fresh from the production process or as a prototype. The manufacturer is responsible for ensuring that the prototype does not differ from the subsequent series and that it can handle the maximum number of prints specified in 3.2 before the test. The delivery contents and the functionality and suitability of the test object for a test according to this test method will be inspected by the test laboratory. The test object will then be stored in its original packaging in a standard normal climate. This inspection should be carried out as soon as possible, but no later than ten working days after delivery.

3.2 Preparation of the test object

The control and monitoring of the test object and the printing process in the sealed test chamber is carried out from outside the chamber.

The print speeds (5% area coverage, black and 20% coverage, colour) are determined with the help of sample printouts of test pages. For this purpose, a maximum of two 10-minute test cycles is permitted. The total number of prints (by the manufacturer, the testing laboratory or by others) prior to the test using this test method is limited to a maximum of 1200 pages; this number may only be exceeded for the purpose of avoiding possible technical problems. The preparation of the test object, including any malfunctions that may occur during this process, and compliance with the criteria will be documented in the report.

The test object, filled with sufficient consumables, must be placed into the test chamber on the day before the test. It is important to ensure that the printed papers are arranged in an orderly way. If necessary, an additional collection container made out of inert material should be used.

The device must be tested using a configuration that allows a 10-minute printing time in simplex mode (single sided pages). A minimum printing time of 5 minutes must be achieved.

For those devices which cannot achieve a printing time of at least 5 minutes in simplex mode and which cannot be equipped with an additional paper tray due to their design, the test must be carried out in duplex mode (double sided printing).

The devices must be tested in the default setting (standard print quality).

3.3 Consumables

Toner and ink

For each device, the toner or ink modules supplied by the manufacturer as original equipment or the toner or ink already fitted in the device must match the type specified in the product documentation. The testing laboratory must be informed of the exact name of the toner or ink modules so that a replacement can be acquired.

Toner or ink modules will be stored in accordance with the manufacturer's instructions until the test. (After consultation with the manufacturer, they can also remain in the device.) The toner and ink will be stored under the same conditions as for the test object. The toner or ink must be provided in sufficient quantities.

Paper

The paper used for the tests must be in DIN A4 format and have a moisture content of between 3.8% and 5.6%. The weight of the paper must be within the range of 60 grams to 80 grams per square meter. The moisture content of the paper can be determined according to DIN EN 20287 (1994-06) [7].

Recommendation: By testing the paper in advance (e.g. in accordance with DE-UZ 14), the contribution made by the paper to the VOC emissions can be estimated and minimised by selecting appropriate paper.

Due to the nature of the test, the moisture content of the paper should not exceed 4%. A higher moisture content could cause condensation in the chamber during printing, which would require the use of larger chambers or higher air exchange rates.

4. Measurement in the emission test chamber

4.1 General

Emission test chambers and the requirements placed on them are described in [1, 2, 3, 4]. Depending on the volume of the test object, a chamber with an appropriate volume must be selected (see formula 1).

The volume of a test object is given by the smallest enclosing cuboid. Protruding parts such as paper trays should not be considered when determining the volume of the test object.

The test chambers must have sufficiently sealable bushings in the wall for feeding power and control cables and they must allow aerosol measurements and the simultaneous sampling of VOC, dust, ozone and FP/UFP. The test chambers must correspond to the requirements described in [4]. This means in particular:

- High-purity air supply (low VOC, ozone, dust, FP and UFP)
- High-purity water supply
- Chamber walls made of glass or stainless steel
- Extensive avoidance of sealing materials
- Effective air mixing

The following test conditions should be observed in accordance with [4]:

- | | |
|---------------------------------------|----------------------------|
| • Temperature | 23 °C ± 2 K ¹⁾ |
| • Relative humidity | 50 % ± 5 % ¹⁾ |
| • Adjustable air exchange rate | |
| Large chamber (V > 5 m ³) | (1 ≤ n ≤ 2) ± 5 % |
| Small chamber (V ≤ 5 m ³) | (1 ≤ n ≤ 5) ± 5 % |
| • Air flow rate | 0.1 - 0.3 ms ⁻¹ |

1m³ chambers and chambers with volumes > 5 m³ (e.g. 20 m³) have proven suitable for use as emission test chambers [2]. Chambers are regarded as suitable if, in addition to complying with the above conditions, they have sufficiently low blank values for VOC, ozone and UFP/FP and dust and provide suitably long ozone half-lives.

Before using the chambers for the first time, and at regular intervals thereafter, they must be inspected to ensure that they comply with the requirements. The chamber blank values at an air exchange rate of n = 1 h⁻¹ must be less than the following values:

Individual substances	2	µgm ⁻³
TVOC	20	µgm ⁻³
Ozone	4	µgm ⁻³
Dust	10	µgm ⁻³
FP/UFP (accumulated particle number concentration)	2000	cm ⁻³

The measuring instruments suitable for emission testing in accordance with Section 4.9 may have lower detection limits and be insufficient for inspecting the chamber blank value for FP/UFP. Appropriate instruments with a suitably low detection limit for the particle number concentration must be used for inspecting the chamber blank values. The ozone half-life of the chamber must be checked at an air exchange rate of n = 1 h⁻¹. A concentration of 0.1 to 0.2 ppm must be ensured in the chamber for this purpose. If the ozone half-life is at least ten minutes, the test chamber is suitable for ozone determination. If the ozone half-life is less than ten minutes, the chamber must be cleaned in an appropriate manner until the target value stated above is achieved. If the air exchange rates is not n = 1 h⁻¹, different ozone half-lives will occur. The blank value for FP/UFP should be checked using a sufficiently sensitive measuring instrument (usually a condensation particle counter, CPC).

¹ Shortly after loading the chamber and during the print phase, it will generally not be possible to precisely maintain these climate requirements – especially the air humidity in the chamber.

The air exchange rates required for the measurement must be regularly checked and documented using an independent method, e.g. tracer gas method according to DIN EN 717-1 (2005, Annex B) [8], in an unloaded state.

4.2 Test schedule (see also 8.1 Test schedule)

To determine the blank value and for the test in the pre-operating phase, an air exchange rate of $n = 1 \text{ h}^{-1}$ should be set in the chambers. The test object, filled with enough consumables, is placed into the test chamber on the day before the test. The climate record begins with the start of the conditioning phase. The measurements of fine and ultrafine particles begin 5 to 10 minutes before the start of the pre-operating phase. The VOC measurements begin 20 minutes before the end of the pre-operating phase. The ozone concentration can also be recorded. At the end of the pre-operating phase, the air exchange rate is increased to keep the relative humidity, which will increase as a result of water release from the paper during printing, below critical values ($\leq 85\%$). Dry ventilation air may be used for this purpose.

To minimize dilution of the analytes in the chamber air, the increase in the air exchange rate must be kept to a minimum.

There must be no condensation of water in the chamber as this would lead to an undue influence on the measurement results.

At the beginning of the print phase, VOC, ozone and dust sampling should start. This continues until the end of the post-operating phase (VOCs only require one air exchange). The post-operating phase runs for a maximum period of four air exchanges (an hour at fourfold air exchange, and four hours at simple air exchange).

Dust sampling can be finalized after two air exchange periods. If testing colour printers, dust sampling must only be completed in colour mode.

Testing in monochrome mode should be carried out using the template in Section 8.3, while the template in Section 8.4 should be used for tests in colour mode.

Select the chamber size required for the test object based on the criterion for the load factor:

$$0.0025 < \frac{V_{\text{EUT}}}{V_{\text{C}}} < 0.25 \quad (1)$$

V_{EUT} : volume of the test object (EUT: equipment under test) [m^3]

V_{C} : volume of the empty test chamber [m^3]

The air exchange rate must not exceed $5 \text{ m}^3/\text{h}$ at load factors < 0.01 .

The smallest possible chamber should be used by the testing institute, since the self-adjusting concentrations are greater and thus the measurement uncertainty is reduced. Only one test object may be placed in the emission test chamber during the test. The emission test chamber must not be opened and no persons must be present in the chamber during the test. If a fault occurs (e.g. paper jam), the test must be repeated. Such problems should be largely excluded through careful preparation of the test.

4.3 Quality assurance measures

Quality assurance measures when using the test method are a necessary prerequisite for obtaining reliable emission rates. The ECMA Standard 328 [3] and ISO/IEC 28360 give an overview of these measures.

The approved test institutes are required to regularly participate in comparative tests. These comparative tests are organised by BAM Division 4.2 “Materials and Air Pollutants”.

4.4 Climate, black and colour value determination, printer control

4.4.1 Climate

For the test cycle and evaluation of the measurement results, the climate data must be recorded over the entire test procedure. For this purpose, a measuring system with an attached data logger is needed. After performing the calibration, the following measurement accuracies must be ensured as a minimum:

Temperature:	$\pm 0.5 \text{ K}$
Relative humidity:	$\pm 3.0 \%$

Section 8.5 shows an example of the climate profile during a test. For example, the device Almemo 3290-8 from Ahlborn with a calibrated probe FH A 646-R and continuous data recording can be used for this purpose.

4.4.2 Black and colour value determination

To prepare the emission tests for hardcopy devices, templates with a 5% coverage, black, and 20% coverage (5% per each colour [black, magenta, cyan, yellow]) must be printed (see Section 8.3 [9] and 8.4).

The required printing templates will be made available to recognised institutes by BAM.

The black value (L^*) and the colour values (L^* , a^* , b^*) are determined according to CIE [10] from a corresponding print-out e.g. using Colour Mouse CM2C (Savvy Systems Limited, USA). The measured black value or colour values should be noted in the test report.

4.4.3 Control EUT

The printing process can be monitored and controlled in accordance with the control capabilities specified by the manufacturer of the test object. In the pre-operating phase and print phase in particular, the operating status of the printer should be continuously documented. This can be done, for example, by measuring the electrical current consumption of the test apparatus. Multimeters (e.g. multimeter M 3850 M, Metex Corporation, in the range of 20 A, with a data logger for electronically gathering the measured values) can be used for this purpose.

Based on the current consumption as a function of time, the start and end of printing, as well as any irregularities and disturbances in operation, can be seen. Section 8.5 shows an example of the current consumption demonstrating the operational conditions.

4.5 VOC

VOC sampling must be carried out using Tenax TA followed by thermodesorption according to [5] and an analysis by GC/MSD or GC / MSD + FID. The test conditions must be chosen so that individual substances with a concentration of $\geq 1.0 \mu\text{g}/\text{m}^3$ and benzene at a concentration of $\geq 0.25 \mu\text{g}/\text{m}^3$ can be detected.

In case of doubt, positive benzene findings must be checked by a second independent sampling (e.g. using Carbotrap or activated carbon). Sampling should be carried out at least at the following times:

- a) blank value before chamber loading
- b) twenty minutes before the end of the one-hour pre-operating phase (for twenty minutes at 100 to 200 ml/min) as a double determination
- c) continuously from the beginning of the print phase up to the time at which a simple air exchange is accomplished in the post-operating phase (at 100 to 200 ml/min) as a double determination

As far as possible, all substances should be identified and individually quantified by the relative response factors determined for the internal standard from the calibration. If substances are not identifiable or the relative response factors cannot be determined, the quantification must be carried out assuming the response factor for toluene or a toluene equivalent from the identified substance class respectively.

It is permissible to use NIST or Wiley mass spectra databases if the analytes are not available as analytical standards. A match quality of at least 85% is sufficient. For a quantitative analysis, the respective standard should be purchased. The so called list of LCI values (Lowest Concentration of Interest) from the AgBB evaluation procedure [11] comprises 182 substances and thus provides an adequate set of substances for quantification. Among these substances, terpenes and most glycols, aldehyde and acids are of no relevance to the determination of emissions from printers.

A given substance is considered unidentified if the match quality is less than 85%, if there is no other identification possible or if an assignment to a class of chemical substances is not feasible. A class of chemical substances (here volatile organic substances) is defined by uniform structures, types of chemical bonding and functional groups. All substances within a class behave chemically similar.

If an unidentified substance exceeds the test value, the applicant may seek a subsequent identification (e.g. by querying component suppliers such as toner manufacturers).

To specify the TVOC value, the sum of the concentrations of all identified and unidentified substances should be calculated whose retention times are between n-hexane and n-hexadecane and whose emission rates are above the following values:

For measurements in chambers $\leq 5 \text{ m}^3$: $\text{SER}_B \geq 0.005 \text{ mg/h}$, $\text{SER}_{DN} \geq 0.05 \text{ mg/h}$.

For measurements in chambers $> 5 \text{ m}^3$: $\text{SER}_B \geq 0.010 \text{ mg/h}$, $\text{SER}_{DN} \geq 0.10 \text{ mg/h}$.

Emission rates should – according to DIN 1333:1992-02 – be rounded to 3 or 2 decimal places for the pre-operating phase and the print phase respectively. The

concentrations to be used in the subsequent calculations should be determined by subtracting the corresponding blank values from the measured values.

Note: In particular, the blind value of the Tenax pipe should be considered because it usually makes up a major part of the (total) blank value.

Calculating the emission rate during the pre-operating phase

The emission rate during the pre-operating phase can be approximately calculated with the following formula using the sample concentration in the last twenty minutes of the hour long phase:

$$SER_B = c_B * n_B * V_K \quad (2)$$

$$c_B = \frac{m_{VOC_B}}{V_P} \quad (3)$$

c_B : VOC concentration [μgm^{-3}] during the pre-operating phase

SER_B : VOC emission rate [μgh^{-1}] during the pre-operating phase

m_{VOC_B} : analysed VOC mass [μg] during the pre-operating phase

n_B : air exchange [h^{-1}] during the pre-operating phase

V_K : test chamber volume [m^3]

V_P : sample volume [m^3] during the pre-operating phase.

Calculating the emission rate during the print phase

The emission rate during the print phase is calculated with the following formula using the sample concentration from the start of the print phase until the time when a simple air exchange has been accomplished in the post-operating phase:

$$SER_{DN} = \frac{\frac{m_{VOC_{DN}}}{V_P} * n_{DN}^2 * V_K * t_G - SER_B * n_{DN} * t_G}{n_{DN} * t_D - e^{-n_{DN} * (t_G - t_D)} + e^{-n_{DN} * t_G}} \quad (4)$$

SER_{DN} : VOC emission rate [μgh^{-1}] determined in the print phase and post-operating phase

SER_B : VOC emission rate [μgh^{-1}] determined in the pre-operating phase

$m_{VOC_{DN}}$: analysed VOC mass [μg] during the print phase and post-operating phase

n_{DN} : air exchange [h^{-1}] during the print phase and post-operating phase

t_D : pure printing or copying time [h]

t_G : total sampling time [h]

V_K : test chamber volume [m^3]

V_P : sample volume [m^3] during the print phase and post-operating phase

The sampling and analysis methods described in Section 8.6 are suitable for a wide range of emitable compounds. A compilation of compounds which may occur in printer and copier emission tests can also be found in Section 8.6.

4.6 VVOC

VVOCs detected in the VOC sampling using Tenax should be quantified as VOCs and listed in the test report. They may also be quantified as toluene equivalents. The VVOCs should not be included in the TVOC value.

Make sure that the test results are not distorted due to "breakthrough", especially if inks used in inkjet printer inks contain volatile solvents (according to information from the applicant or in the safety data sheet). For this purpose, two Tenax pipes should be arranged in series or the Carbotrap sampling carried out for the determination of benzene should be evaluated.

4.7 Ozone

This measurement method should preferably be based on the flameless reaction of ozone with ethylene. The resultant chemiluminescence is measured photometrically. The ozone emission tests on printers and copiers should be carried out as follows:

- a) Determination of the blank value
- b) The ozone concentration can be recorded in the pre-operating phase.
- c) Ozone determination in printing / copying:

The ozone determination is performed from the beginning of the print phase to the end of the print phase. The concentration should be recorded at least every 30 seconds, preferably every 15 seconds. The ozone concentration should be recorded as a function of time in the appropriate concentration range.

The ozone production rate is determined from the increase in ozone concentration in the initial phase. Under these conditions, hardly any ozone loss due to chemical reactions with air constituents and by discharge due to air exchange occurs. In addition, the emissions during printing / copying under actual operating conditions also contribute to the increase in concentration. The relationship between mass and concentration is:

$$m = c * V \quad (5)$$

m : ozone mass [mg]
 c : ozone concentration [mg/m³]
 V : test chamber volume [m³]

The emission rate is equal to the mass increase per unit time Δt :

$$\frac{\Delta m}{\Delta t} = \frac{\Delta c * V}{\Delta t} \quad (6)$$

Δm : generated ozone mass [mg]
 Δc : change to the ozone concentration [mg/m³]

Δt : time interval considered [min]

$$SER_u = \frac{\Delta c * V * p * 60}{\Delta t * T * R} \quad (7)$$

SER_u : ozone emission rate [mg/h]

p : air pressure [Pa]

T : absolute temperature [K]

R : gas constant [PaK⁻¹], (for ozone 339.8 [PaK⁻¹])

To calculate the ozone emission rate, a time interval of two minutes should be used. The points used should be the measurement interval where the best-fit curve exhibits the greatest slope for the time interval ($c_2 - c_1 = \text{maximum}$).

Example of an ozone test instrument

Model 3010 ozone analyser (manufactured by UPM, Environmental Pollution Measurements). This device enables the continuous measurement of ozone concentration.

4.8 Dust

A gravimetric method is used to calculate the dust emission rate.

Sampling

Air sampling takes place from the beginning of the print phase to the end of the post-operating phase. Dust sampling can be finalized after two air exchange periods. During this period, air is removed from the test chamber by a pump and drawn through a glass fibre filter. The volume of air drawn through the filter is measured (in m³). Differential weighing of the filter gives the absolute dust end weight in µg. From these two values, the dust concentration in the test chamber can be calculated (in µg m⁻³) and this can then be used to calculate the specific emission rate (in µg h⁻¹).

Standard conditions for the gravimetric dust measurement

Dust filter	Glass fibre filter with holder
Sampling location	Preferably centrally on the chamber wall
Sampling flow rate	Up to 80% of the air flow rate in the chamber during the sampling phase
Sampling time:	Entire printing and follow-up time

Execution of the gravimetric dust measurement – climate correction

The glass fibre filters (test filters) used in gravimetric dust measurements must be stored prior to measurement in an air-conditioned room (weighing room) and conditioned to constant mass in the prevailing climate. Since even the smallest inevitable fluctuations in the relative humidity in the weighing room affect the weight of the glass fibre filter, at least one unloaded glass fibre filter (reference filter) must be weighed at

the same time as the test filter (tare) before dust sampling to minimise the influence of climate on the filter material by carrying out a climate correction.

Climate conditions in the weighing room

Temperature: $23^{\circ}\text{C} \pm 2 \text{ K}$

Relative humidity: $50 \% \pm 5 \%$

During dust sampling, air is drawn through the test filter. As the relative humidity of this air may differ from that in the weighing room, the test filter must be conditioned again after dust sampling to a constant weight in the weighing room.

The reference filter is left in the weighing room for the whole time and reweighed at the same time that the gross weight of the test filter (dust end weight) is determined. The mass difference determined between the first and second weighing of the reference filter is due to changing climate conditions and is subtracted from or added to the gross mass of the test filter.

Determining the absolute dust end weight of the test filter (climate correction)

$$m_{St} = (m_{MF_{brutto}} - m_{MF_{tara}}) + (m_{RF_1} - m_{RF_2}) \quad (8)$$

m_{St} : end weight of dust mass (climate corrected) [μg]

$m_{MF_{brutto}}$: mass of the conditioned test filter after dust sampling [μg]

$m_{MF_{tara}}$: mass of the conditioned test filter before dust sampling [μg]

m_{RF_1} : mass of the conditioned reference filter simultaneously weighed with test filter before dust sampling [μg]

m_{RF_2} : mass of the conditioned reference filter simultaneously weighed with test filter after dust sampling [μg]

Calculation of the emission rate and dust concentration

$$SER_{uSt} = \frac{m_{St} * n * V_K * t_G}{V_P * t_D} \quad (9)$$

$$c_{St} = \frac{m_{St}}{V_P} \quad (10)$$

SER_{uSt} : dust emission rate [$\mu\text{g h}^{-1}$]

c_{St} : dust concentration in the test chamber [$\mu\text{g m}^{-3}$]

m_{St} : end weight of dust mass (climate corrected) [μg]

n : air exchange [h^{-1}]

t_D : pure printing or copying time [min]

t_G : total sampling time [min]

V_K : test chamber volume [m³]

V_P : volume of air drawn through the glass fibre filter [m³]

Equipment example for a gravimetric dust measurement technique

Ultra-microbalance	Type UMX2/M
Pump	Müller GSA 50
Gas flow meter	Schlumberger REMUS 4 G 1.6
Glass fibre filter	Schleicher & Schuell, diameter 50 mm

4.9 Fine and ultrafine particles

The determination of the number of fine and ultrafine particles using an aerosol measuring instrument is performed in addition to the gravimetric determination of dust emission according to 4.8 and does not replace it.

4.9.1 Requirements for an aerosol measuring instrument

The requirements defined here are intended as the minimum requirements. The aerosol measurement instrument must be capable of recording the accumulated particle number concentration $C_p(t)$ within the size and concentration ranges defined below at the specified time resolution.

The preparedness of the aerosol measuring instrument must firstly be confirmed in accordance with the requirements and criteria in Section 8.9.

Particle size range

The number of particles emitted must be determined within the size range 7-300 nm, which is considered the most relevant for electrophotographic devices. The detection efficiency for particles at the lower interval size limit as specified by the instrument manufacturer must be at least 50%.

Particle number concentration range

CPCs:

The lower particle number concentration detection limit should be 1 cm⁻³ within the previously specified particle size range.

The upper particle number concentration detection limit should be at least 10⁷ cm⁻³ in the previously specified particle size range. It may be necessary to use a calibrated aerosol dilution stage with a specified dilution factor.

Fast aerosol measuring instruments:

The lower detection limit for particle number concentration should be a maximum of 5000 cm^{-3} in the size channel which is closest to the lower particle size detection limit of 7 nm.

The corresponding upper detection limit should be at least 10^6 cm^{-3} in the size channel which is closest to the upper particle size detection limit of 300 nm.

The above values are based on particle number concentrations normalised to the width of each particle size class ($dN/d\log D_P$) and a time resolution of 1 s.

Time resolution

The particle number concentration should be recorded at a frequency of at least 0.5 hertz.

Connection between the aerosol measuring instrument and emission test chamber

The hose connection between the sampling port of the emission test chamber and the aerosol measuring instrument should be made of an electrically conductive material (e.g. conductive silicone tube, stainless steel) and be as short as possible with an internal diameter of at least 4.8 mm. The hose connection should not exceed a length of 3 m. Kinks and cross-section changes as well as sharp bends in the connection should be avoided. Ideally, the connection should be rectilinear. The connecting hose should protrude at least 10 cm deep into the emission test chamber.

Quality assurance

The aerosol measuring instruments used for the test must have the following characteristics:

- device-side controlled flow rates
- automatic display of malfunctions during measurement
- export of measurement data for evaluation
- display of the individual device settings to be selected by the user
- ability to adjust or synchronise time and date

The following documents must be available for quality assurance purposes:

- Up-to-date daily measurement of the electrometer noise level for fast aerosol measuring instruments
- Detailed description of the cleaning and maintenance procedures
- Current calibration certificate, if available

4.9.2 Performing the measurement

The concentration of fine and ultrafine particles should be recorded during the pre-operating phase, print phase and post-operating phase in a storable data set.

If using CPCs, the curve of the particle number concentration during and after the print phase should be free of irregularities such as sudden step-like changes in $C_P(t)$. Any steps that may occur should not exceed a maximum acceptable level of $15,000 \text{ cm}^{-3}$. To avoid such interference, the use of a calibrated aerosol dilution stage with a

specified dilution factor (e.g. 1/1000) for the operation of the CPCs in single count mode is recommended.

Note on step-like changes in the particle number concentration in CPCs: At low concentrations, the CPC operates in single count mode. *With increasing particle number concentration, the measured signal is corrected. At high concentrations, the CPC will automatically switch to photometric mode. The concentration range in which the change occurs is dependent on the respective device. Depending on the correction algorithm used, the described irregularities may occur in this range².*

When using fast aerosol measuring instruments, very short peak-like irregularities may occur due to momentary fluctuations in the electrometer currents. However, these only have a negligible influence on the test results as a rule.

Before further evaluation, the measured values should be checked using appropriate software (e.g. the measurement instrument software from the manufacturer) with regard to malfunctions and irregularities which may occur.

The data set can be exported to an appropriate file format for further analysis.

4.9.3 Calculation of the test results

The number of emitted particles TP and the standard particle emission rate PER₁₀ are calculated as the results of the test. For this purpose, auxiliary variables will be determined as described below. The basis of the calculation is the data set from the measured accumulated particle number concentration $C_P(t)$.

If a dilution step is used, $C_P(t)$ must be corrected accordingly by the dilution factor. The corrected data set and/or file with the corrected values should be clearly labelled. In this case, the corrected data set is used as the basis for the subsequent calculation.

$C_P(t)$ is shown in a graph (see for example Fig. 4.9.1) as a function of time, which should be attached to the report. The unit of the abscissa (time axis) should be [min] (minutes) or [s] (seconds).

The evaluation requires the data set of the particle number concentration $C_P(t)$ to be smoothed. For this purpose, the method of moving average³ over a time interval of 31 s is used. The smoothed data set and/or the file containing the smoothed values should be clearly labelled. In the evaluation steps described below, only the data set for the smoothed particle number concentration will be used.

Note:

Commonly used evaluation programs (e.g. EXCEL, ORIGIN, IGOR and others) provide functions for calculating the moving average.

² Richard J.J. Gilham and Paul G. Quincey: *Measurement and mitigation of response discontinuities of a widely used condensation particle counter*, Journal of Aerosol Science, Volume 40, Issue 7, July 2009, Pages 633-637).

³ see e.g. http://www.statistics4u.info/fundstat_germ/cc_moving_average.html, H. Lohninger "Grundlagen der Statistik", electronic book

Note on $C_p(t)$ as a function of time:

$C_p(t)$ may a) already decrease before the end of the print phase; b) decrease after the end of the print phase; c) remain constant or even increase for a short period after the end of the print phase before a steady decay. These characteristics are partly due to the device being tested and are also affected by the test conditions. The evaluation steps described below are equally applicable to all above types of emission versions.

Evaluation steps

1. The smoothed curve of the accumulated particle number concentration is plotted as a function of time, about 5 minutes before the print phase, during the print phase and at least for 30 minutes thereafter. The diagram is part of the report. Figure 4.9.1 shows an example which illustrates various markings used in the subsequent steps, as well as the measured course of the particle number concentration of $C_p(t)$. The abscissa (time-axis) should be given in units of [min] (minutes).

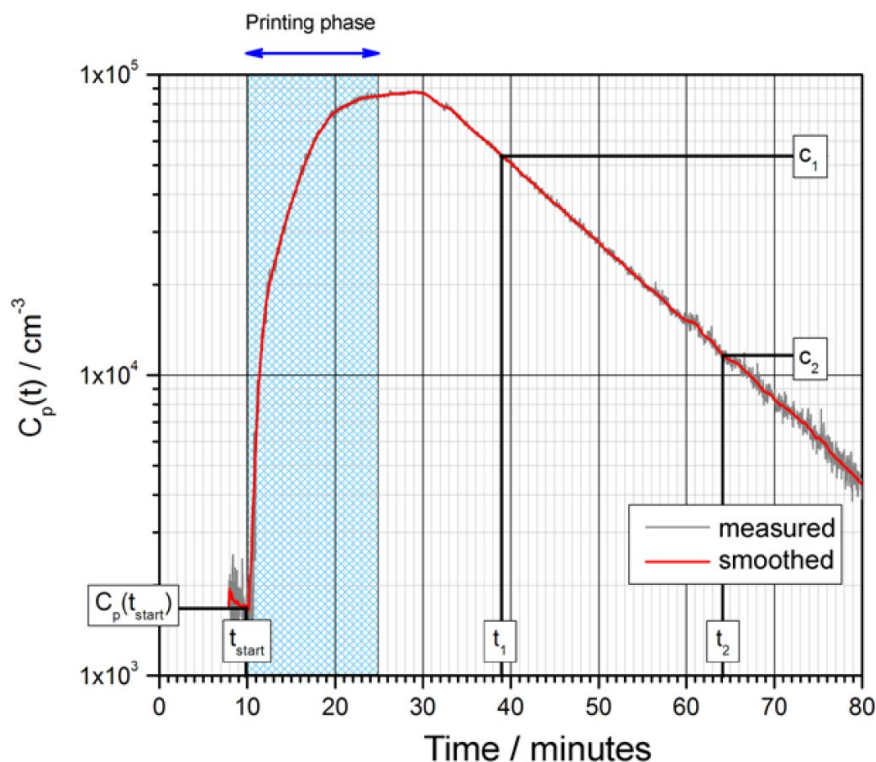


Figure 4.9.1: Particle number concentration as a function of time (example)

2. As indicated in Figure 4.9.1, the value pairs C_1 , t_1 and C_2 , t_2 should be read from the smoothed time-dependent curve of particle number concentration as accurately as possible or determined by means of a cursor. On a logarithmic scale, t_1 should be chosen within the linear descending range at least 5 minutes after the end of the print phase and t_2 at least 25 minutes after t_1 .

3. Calculation of particle loss coefficient β in units of $[s^{-1}]$:

$$\beta = \frac{\ln(c_1/c_2)}{t_2 - t_1} \quad (11)$$

Note: Time difference $t_2 - t_1$ must be calculated in the unit [s].

4. The values t_{start} and $C_p(t_{start})$ should be read from the smoothed time-dependent curve of particle number concentration (cf. Figure 4.9.1) as accurately as possible or determined by means of a cursor.
5. Δt describes the time resolution of the particle emission measurement and should be determined using the manufacturer's manual and recorded. Δt must be given in the unit [s] for the calculations.
6. $PER(t)$ $[s^{-1}]$ is calculated using Δt , β and the data set of the smoothed particle number concentration.

$$PER(t) = V_C \left(\frac{C_p(t) - C_p(t - \Delta t) \cdot \exp(-\beta \cdot \Delta t)}{\Delta t \cdot \exp(-\beta \cdot \Delta t)} \right) \quad (12)$$

$C_p(t)$: smoothed curve of particle number concentration $[cm^{-3}]$

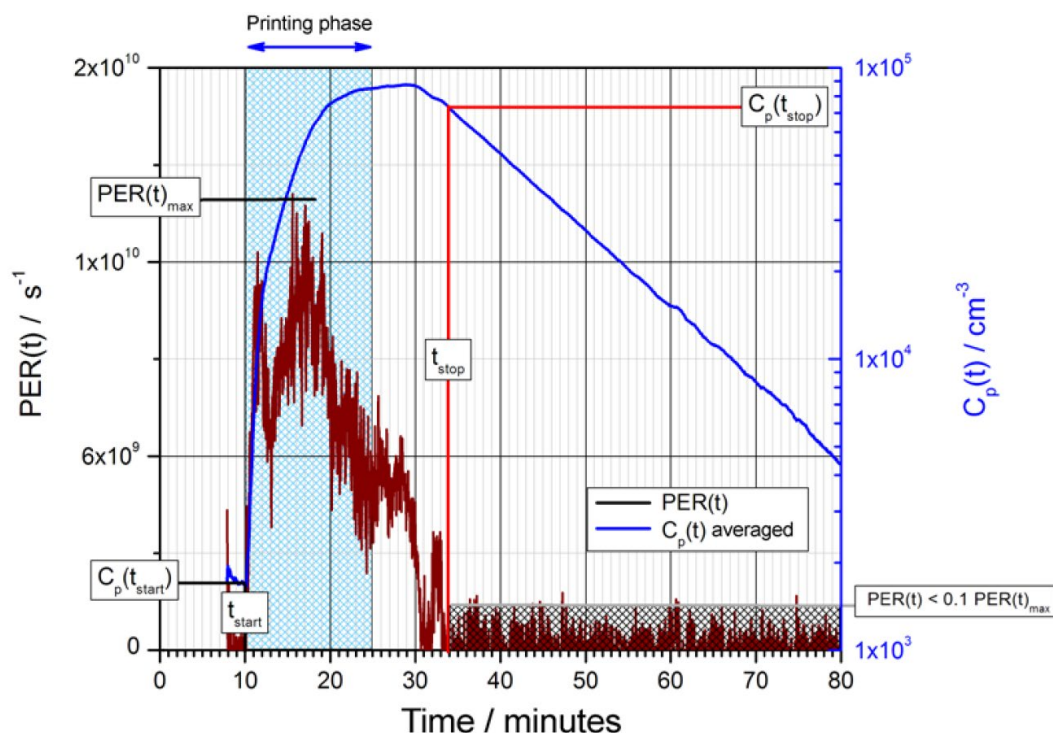
V_C : test chamber volume $[cm^3]$

Δt : time resolution of the particle emission measurement [s]. The time resolution should be 1 s.

β : particle loss coefficient $[s^{-1}]$

Note: $C_p(t)$ is usually in the unit $[cm^{-3}]$. The chamber volume V_C must be converted accordingly into the unit $[cm^3]$.

7. $PER(t)$ and the smoothed $C_p(t)$ curve will be plotted according to the example in Figure 4.9.2. The abscissa (time-axis) should be given in units of [min] (minutes). The diagram is part of the report.

Figure 4.9.2: Plotting PER(t) and $C_p(t)$ (example).

8. The values t_{stop} and $C_p(t_{\text{stop}})$ should be read from the diagram according to Figure 4.9.2 as accurately as possible or determined by means of a cursor. t_{stop} marks the point on the time axis from which PER(t) remains steady, i.e. at least over the next 10 min, below $0.1 \cdot \text{PER}(t)_{\text{max}}$. $\text{PER}(t)_{\text{max}}$ indicates the maximum value of PER(t)

Note: In some cases, the calculated emission rate PER(t) may assume negative values due to influences which cannot be considered in the calculations. Before and after the print phase, the absolute values of the negative PER(t) values should not exceed 5% of the maximum value of PER(t) below the zero line.

9. The difference ΔC_p [cm^{-3}] of the particle number concentration between the times t_{start} and t_{stop} is calculated from the data set of the smoothed particle number concentration:

$$\Delta C_p = C_p(t_{\text{stop}}) - C_p(t_{\text{start}}) \quad (13)$$

TP cannot be calculated for $\Delta C_p \leq 1000 \text{ cm}^{-3}$. In this case, the measured value TP is called “non-quantifiable” in the test report. The following calculation steps are then not needed.

10. The arithmetic average C_{av} [cm^{-3}] between the times t_{start} and t_{stop} is calculated from the data set of the smoothed particle number concentration. The index n stands for the number of measured values between time points t_{start} and t_{stop} .

$$C_{\text{av}} = \frac{\sum_{i=1}^n C_{p,i}}{n} \quad (14)$$

11. TP is calculated as follows:

$$TP = V_C \left(\frac{\Delta C_p}{t_{stop} - t_{start}} + \beta \cdot C_{av} \right) (t_{stop} - t_{start}) \quad (15)$$

ΔC_p : difference of $C_p(t)$ between t_{start} and t_{stop} , [cm^{-3}]
 C_{av} : arithmetic average of $C_p(t)$ between t_{start} and t_{stop} , [cm^{-3}]
 V_C : test chamber volume [cm^3]
 β : particle loss coefficient [s^{-1}]
 $t_{stop} - t_{start}$: emission time [s]

Note: ΔC_p and C_{av} have the unit [cm^{-3}]. β is defined in the unit [s^{-1}]. For the correct application of the formula, the chamber volume V_C must be substituted in the unit [cm^3] and the emission time $t_{stop} - t_{start}$ in the unit [s].

12. The standard particle emission rate PER_{10} for a print phase of 10 minutes (i.e. 600 seconds) is calculated from TP using the following formula:

$$PER_{10} = TP \cdot \frac{600}{t_{print}} \quad (16)$$

The length of the print phase t_{print} must be substituted in the unit [s].

4.9.3.1 Calculation of the test result for initial burst emitters

It is not always possible to comply with the 10 minute printing phase in the procedure described above for technical reasons. One reason is that the capacity of the paper storage compartment and/or paper magazine is too small, in combination with a high printing speed. To calculate the test value PER_{10} if the printing period falls short of or exceeds the standard 10-minute period, a linear correction according to formula 16 should be used if it can be assumed that the printing phase and the particle emissions for a laser printer will be proportional. However, it is sometimes not possible to make this assumption in reality, especially in the case of so-called “initial burst” printers. These printers are characterised by the fact that the maximum particle emission rate is at the beginning of the printing job and is very pronounced. An example is shown in Figure 4.9.3. Especially in cases where, due to the technical reasons described above, the printing phase for an initial burst printer is significantly shorter than the standard 10-minute printing period, this results in a disproportionately high correction of the PER_{10} value when using formula 16.

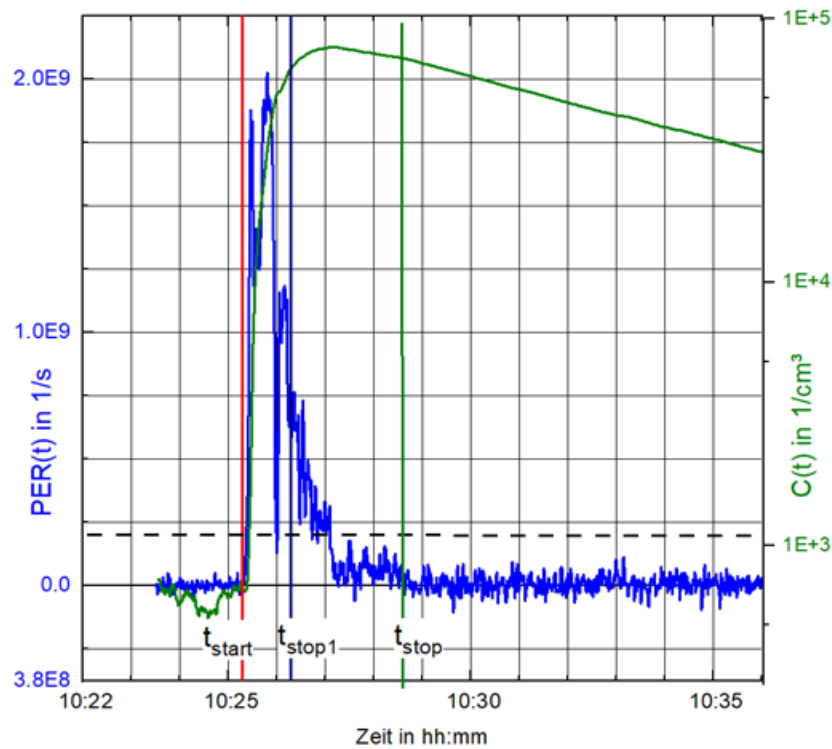


Figure 4.9.3: Curve of the particle number concentration (green) and particle emission rate (blue) for an initial burst printer (example).

Figure 4.9.3 shows an example of the particle number concentration (green curve) and particle emission rate (blue curve) for an initial burst laser printer with a printing phase of $t_{\text{print}} = 300$ seconds.

A test object is classified as initial burst emitter if its particle emission rate $\text{PER}(t)$ stays below 10% of the $\text{PER}(t)$ maximum, i.e., $0.1 \cdot \text{PER}(t)_{\text{max}}$, from 2 minutes after t_{start} . The following modification of the evaluation procedure can be applied to initial burst emitters:

- The evaluations and calculations are completed up to and including step 11.
- A second parameter TP_{IB} , should then be determined according to formula 17, where $t_{\text{stop, IB}} = t_{\text{start}} + 60$ seconds

$$\text{TP}_{\text{IB}} = V_{\text{C}} \left(\frac{\Delta C_{\text{p, IB}}}{t_{\text{stop, IB}} - t_{\text{start}}} + \beta \cdot C_{\text{av, IB}} \right) (t_{\text{stop, IB}} - t_{\text{start}}) \quad (17)$$

$\Delta C_{\text{p, IB}}$: difference of $C_{\text{p}}(t)$ between t_{start} and $t_{\text{stop, IB}}$, [cm^{-3}]
 $C_{\text{av, IB}}$: arithmetic average of $C_{\text{p}}(t)$ between t_{start} and $t_{\text{stop, IB}}$, [cm^{-3}]
 V_{C} : test chamber volume [cm^3]
 β : particle loss coefficient [s^{-1}]
 $t_{\text{stop, IB}} - t_{\text{start}}$: initial burst emission time [s]

The test value $\text{PER}_{10, \text{IB}}$ is calculated according to formula 18:

$$\text{PER}_{10, \text{IB}} = \text{TP}_{\text{IB}} + (\text{TP} - \text{TP}_{\text{IB}}) \cdot 540 / t_{\text{print}} \quad (18)$$

5. Evaluation and test report

The test report must include the full test and the complete evaluation of the test object.

In particular, the following information must be provided:

Data on the test laboratory:

- Name and full address
- Name of the responsible person

Data on the test object:

- Precise product specification, indicate if desk-top or stand-alone device, device number, print or copy speed specified by manufacturer
- Production date
- Date of receipt
- Type of packaging
- Storage time before the test
- Test date / period
- Identification of consumables used (e.g. batch numbers, type specification, identification numbers)
- Volume or external dimensions of the test object

Data on the test:

- Test date / period
- Black or colour values of prints
- Test conditions (type and size of the chamber, temperature, relative humidity, air exchange and air flow rate)
- Compliance with the condition for the load factor (see formula 1)
- Description of the aerosol measurement instrument used:
 - Manufacturer, type and serial number
 - Name and version of the software
 - Date of last calibration or maintenance
 - Currently used device settings
 - Type and dilution factor if an aerosol dilution stage was used

- Result of measures to ensure the readiness of the aerosol measuring instrument according to Section 8.9
- Start, end and duration of preparation, print phase and post-operating phase
- Printing speed during the test
- Printing mode during the test (monochrome, colour, one-sided or double-sided printing)
- Number of printed pages
- Timing and duration of air sampling, volume and volumetric flow rate of air sampling for VOCs, ozone and dust
- VOC, ozone and dust sample identifications
- Identification and location of the files with continuously recorded measurement values (climate, ozone, uncorrected and, if necessary, corrected particle number concentration)

Data on the evaluation:

- Name, CAS no. and concentration of identified VOCs, as well as the concentration of unidentified VOCs in the pre-operating phase and print phase, and the calculated emission rates; benzene and styrene must be listed separately in all cases
- TVOC value as the sum of the quantified and unidentified compounds during pre-operating phase and print phase, as well as the calculated emission rates (relevant value for the Basic Award Criteria)
- Specification of any VVOCs found with their CAS no.
- Ozone half-life of the empty chamber
- Ozone concentration and ozone emission rate calculated during printing
- Gravimetrically determined dust mass and dust emission rate determined from it
- Specification of detection and determination limits for VOCs, ozone and dust emission rates
- Diagram according to Section 4.9.3, evaluation step 1
- Diagram according to Section 4.9.3, evaluation step 7
- Test results TP and PER₁₀,

- Table of values for auxiliary variables determined in accordance with Section 4.9.3:

t_1 , t_2 , c_1 , c_2 , β , t_{start} , $C_p(t_{\text{start}})$, t_{stop} and $C_p(t_{\text{stop}})$, ΔC_p , and C_{av} ,

- For an initial burst emitter additionally test results $PER_{10, IB}$, TP_{IB} , and the following table of additional auxiliary variables determined in accordance with Section 4.9.3.1:

$C_p(t_{\text{stop}, IB})$, $\Delta C_{p, IB}$ and $C_{\text{av}, IB}$.

- Report on any malfunctions and deviations from test algorithms
- Summary of the results by the test institute with respect to the Basic Award Criteria (if necessary, an indication that the emission characteristics determined in the test only apply in conjunction with the tested type of toner and paper)
- Signature underneath the summary which must once again include the exact device identification

6. Testing institutes

The emission test may only be performed by suitable institutions.

Testing laboratories are suitable if they have the necessary apparatus, equipment and a quality management system (or are accredited for the area of such tests) and have proved their competence to carry out the tests described in this Appendix by a successful participation in relevant interlaboratory comparisons or comparative tests. The same applies to the manufacturer's testing laboratories.

Verification of compliance with these requirements may be provided to the Federal Institute for Materials Research and Testing (BAM), Division 4.2 "Materials and Air Pollutants". BAM will notify the institute concerned in writing about whether it is considered suitable to perform emission tests.

7. Literature

- 1 Entwicklung einer Prüfmethode und Untersuchungen zur Begrenzung von Emissionen aus Druckern und Kopiergeräten im Rahmen der Umweltzeichenvergabe. [Development of a test method and investigations into limiting the emissions from printers and copiers as part of the award of the environmental label] UBA Text Series 71/2003, Federal Environment Agency, Berlin, 2003
- 2 Prüfung von Emissionen aus Bürogeräten während der Druckphase zur Weiterentwicklung des Umweltzeichens Blauer Engel für Laserdrucker und Multifunktionsgeräte unter besonderer Berücksichtigung der Sicherung guter Innenraumluftqualität [Testing emissions from office equipment during the print phase to update the Blue Angel ecolabel for laser printers and multifunction devices while giving special consideration to ensuring good indoor air quality]. UBA Text Series 35/2008, Federal Environment Agency, Berlin, 2008

- 3 ECMA-Standard 328, 7th edition / 2015 Detection and measurement of chemical emissions from electronic equipment, www.ecma-international.org
- 4 DIN ISO 16000-9: 2012-11 Bauprodukte - Bestimmung der Emission von flüchtigen organischen Verbindungen (VOC) - Teil 1: Emissionsprüfkammer-Verfahren; [Building products - Determination of emissions of volatile organic compounds (VOCs) - Part 1: Emission test chamber method].
- 5 DIN ISO 16000-6: 2008-4 Innenraumluftverunreinigungen. Teil 6: Bestimmung von VOC in der Innenraumluft und in Prüfkammern. Probenahme auf TENAX TA, thermische Desorption und Gaschromatographie/MSD bzw. FID [Indoor air pollution. Part 6: Determination of VOCs in indoor air and in test chambers. Sampling on TENAX TA, thermodesorption and GC/MSD or FID].
- 6 ISO 554, Edition: 1976-07 Normalklimate für die Konditionierung und / oder Prüfung; Anforderungen [Standard atmospheres for conditioning and/or testing — Specifications]
- 7 DIN EN 20287, Edition: 1994-09 Papier und Pappe - Bestimmung des Feuchtegehaltes - Wärmeschrankverfahren (ISO 287:1985); Deutsche Fassung EN 20287: 1994 [Paper and cardboard - Determination of moisture content - oven method (ISO 287:1985); German version EN 20287: 1994].
- 8 DIN EN 717-1, Edition:2005-01, Wood-based panels - Determination of formaldehyde release - Part 1: Formaldehyde emission by the chamber method
- 9 DIN 33870, Edition: 2001-01 Informationstechnik - Büro- und Datentechnik - Anforderungen und Prüfungen für die Aufbereitung von gebrauchten Tonermodulen schwarz für elektrophotographische Drucker, Kopierer und Fernkopierer [Information technology - Office machines - Requirements and test methods for the recycling of used toner cartridges for black electro-photographic printers, copiers and fax machines].
- 10 CIE Document No.15, Colorimetry, 2004
- 11 AgBB: Committee for Health-related Evaluation of Building Products / Ausschuss zur gesundheitlichen Bewertung von Bauprodukten: Health-related Evaluation Procedure for Volatile Organic Compounds Emissions (VOC and SVOC) from Building Products. Umweltbundesamt / Federal Environment Agency (UBA). http://www.umweltbundesamt.de/produkte/bauprodukte/dokumente/AgBB-Bewertungsschema_2015.pdf

Further reading

J. Rockstroh, O. Jann, O. Wilke, W. Horn: Development of a reliable test method for laser printers, copiers and multifunctional devices in emission test chambers, Gefahrstoffe-Reinhaltung der Luft (Hazardous substances, air pollution control), (2005), 65, p. 71 – 80.

O. Jann, J. Rockstroh, O. Wilke: Influence of emissions from hardcopy devices to indoor air quality, Proceedings of Indoor Air 2005, Beijing, Vol.2, 2123 – 2128.

S. Seeger, O. Wilke, M. Bücken, O. Jann: Time- and size-resolved characterization of particle emissions from office machines with printing function, *Healthy Buildings*, (2006), 2, p. 447 – 450.

T. Schripp, M. Wensing, E. Uhde, T. Salthammer, C. He, L. Morawska: Evaluation of ultrafine particle emissions from laser printers using emission test chambers, *Environ. Sci. Technol.*, (2008), 42, p. 4338 – 4343.

M. Wensing, T. Schripp, E. Uhde, T. Salthammer: Ultra-fine particles release from hardcopy devices: Sources, real-room measurements and efficiency of filter accessories, *Sci. Total Environ.*, (2008), 407, p. 418 – 427.

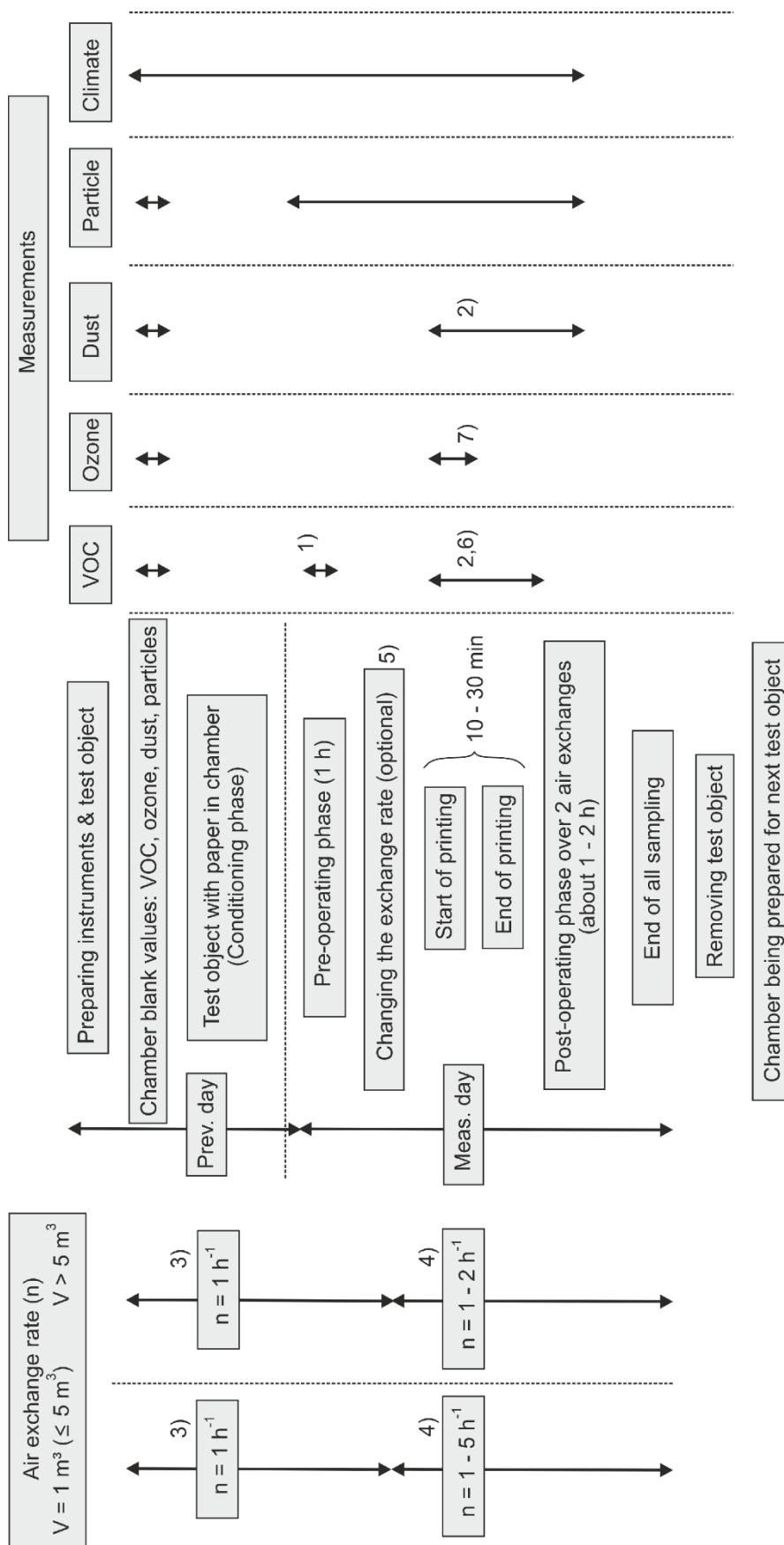
M. Barthel, S. Seeger, M. Rothhardt, O. Wilke et. al.: Measurement of Fine and Ultrafine Particles from Office Devices during Printing in order to Develop a Test Method for the Blue Angel Ecolabel for Office-Based Printing Devices, Final report, project UFO-PLAN 3708 95 301, UBA text 74/ 2013, published on the UBA website under UBA texts on the link: <https://www.umweltbundesamt.de/publikationen/UBA-Texte-74/2013>

M. Barthel, V. Pedan, O. Hahn, M. Rothhardt, H. Bresch, O. Jann, S. Seeger. 2011. XRF-analysis of fine and ultrafine particles emitted from laser printing devices. *Environ Sci Technol* 45:7819–25.

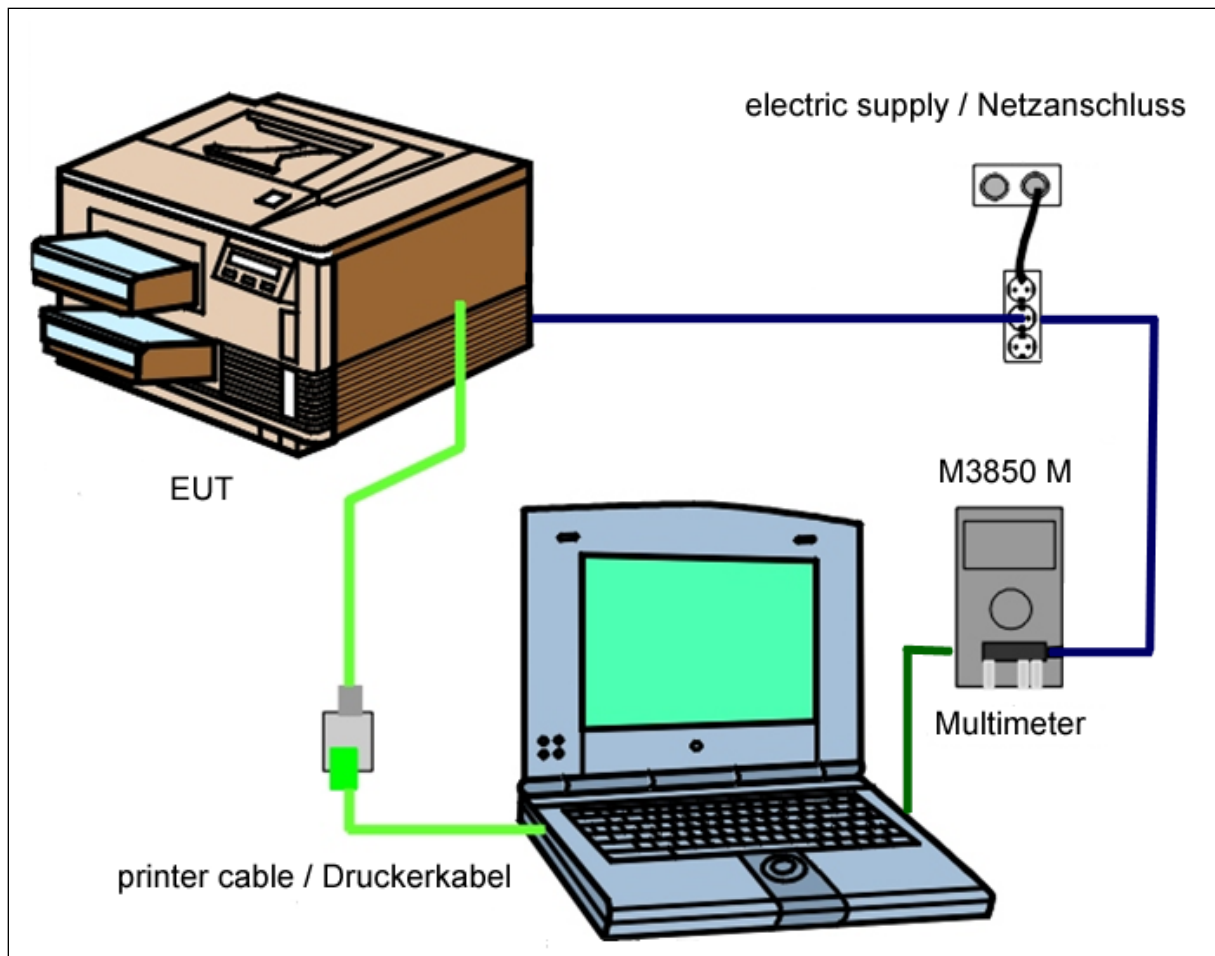
Proceedings of the 22nd WaBoLu Indoor Air Symposium 2015, Volume 154: *Drucker, Gerüche und mehr... [Printers, odours and more]*, W. Puchert, H.-J. Moriske (Publisher), Verein für Wasser-, Boden- und Lufthygiene e.V., ISBN 978-3-932816-83-3 (CD-ROM)

8. Explanations and examples

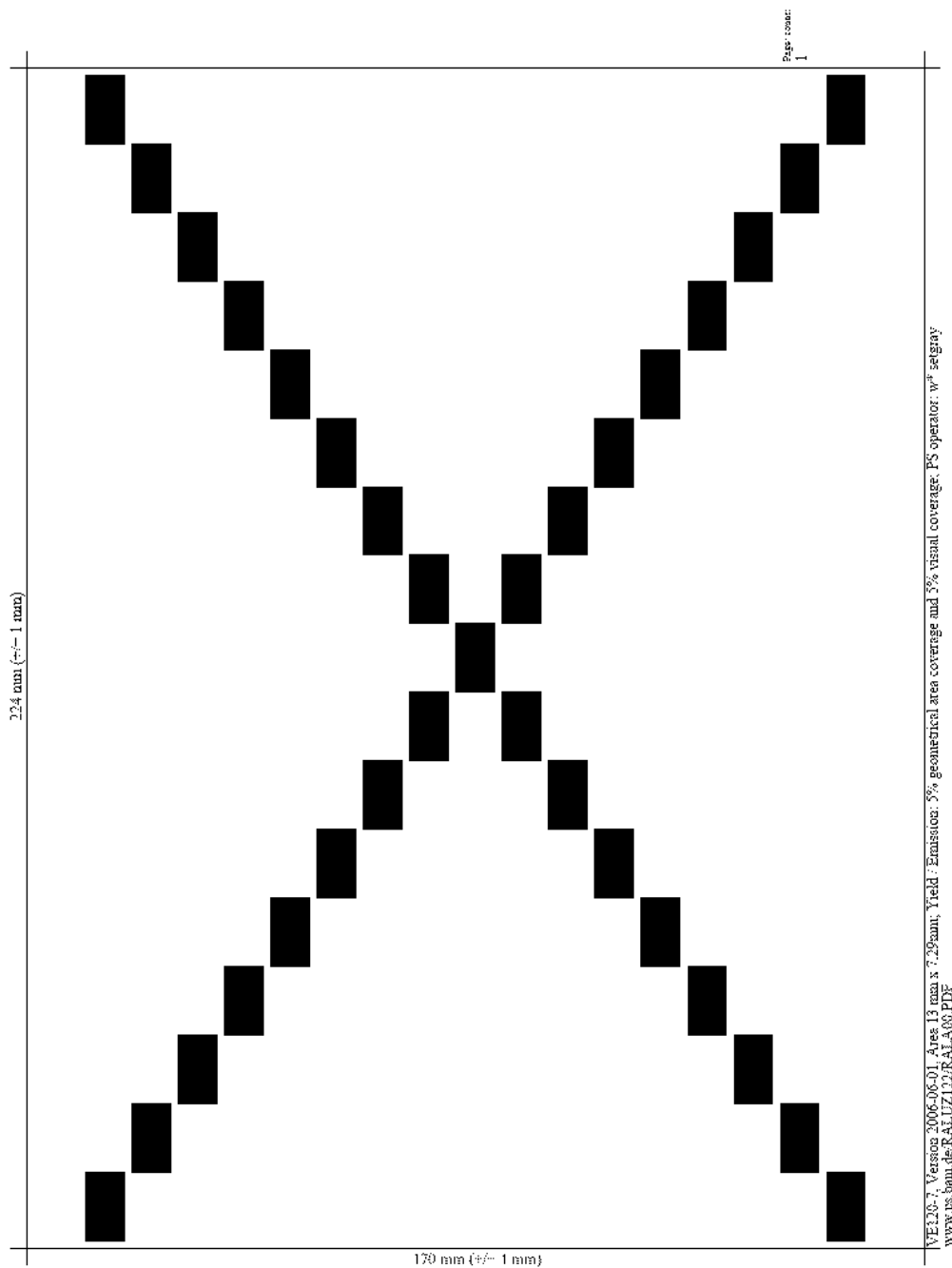
8.1 Test schedule



8.2 Setup for test devices

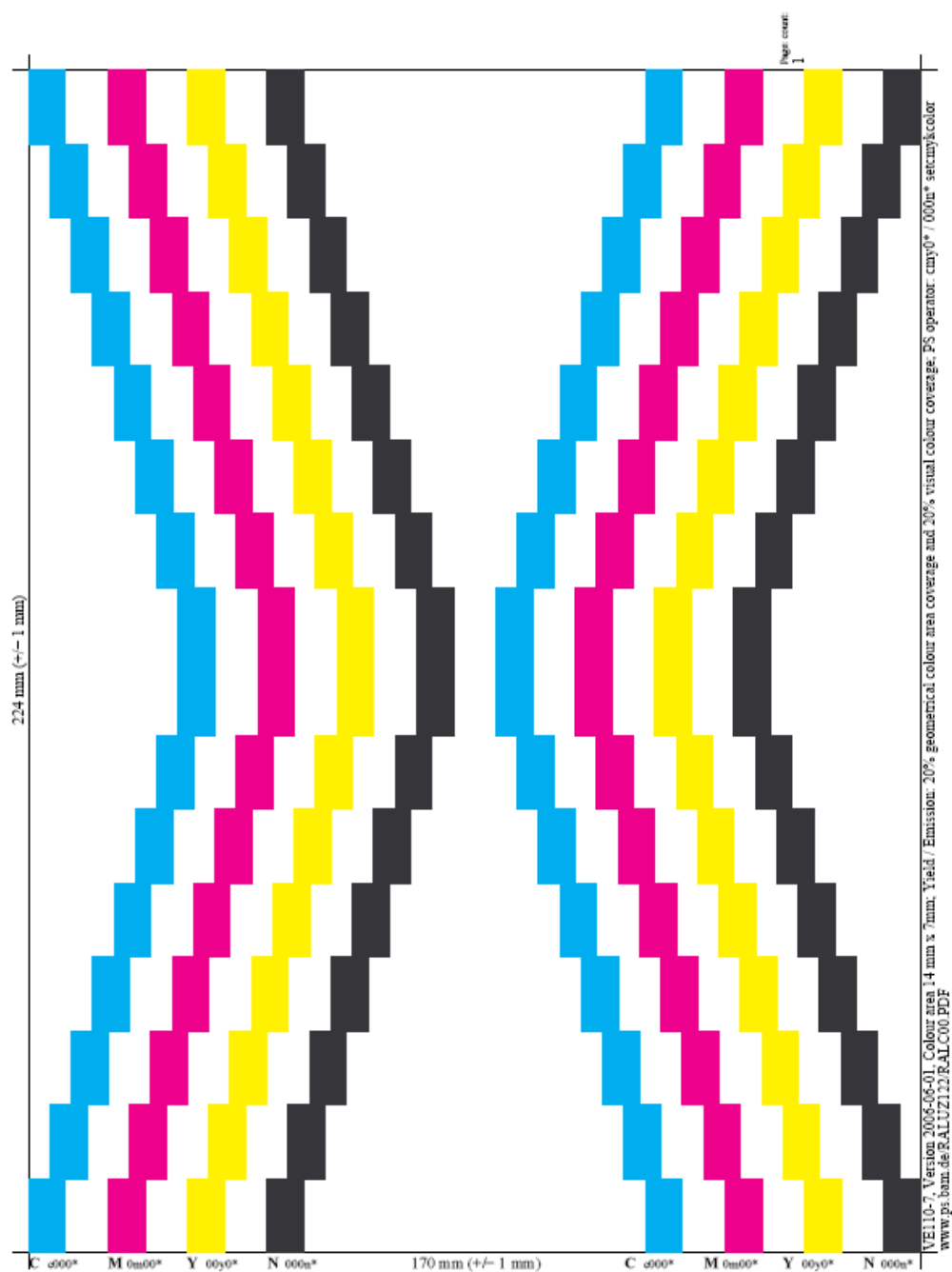


8.3 Template for 5% coverage, black (see DIN 33870 [9])



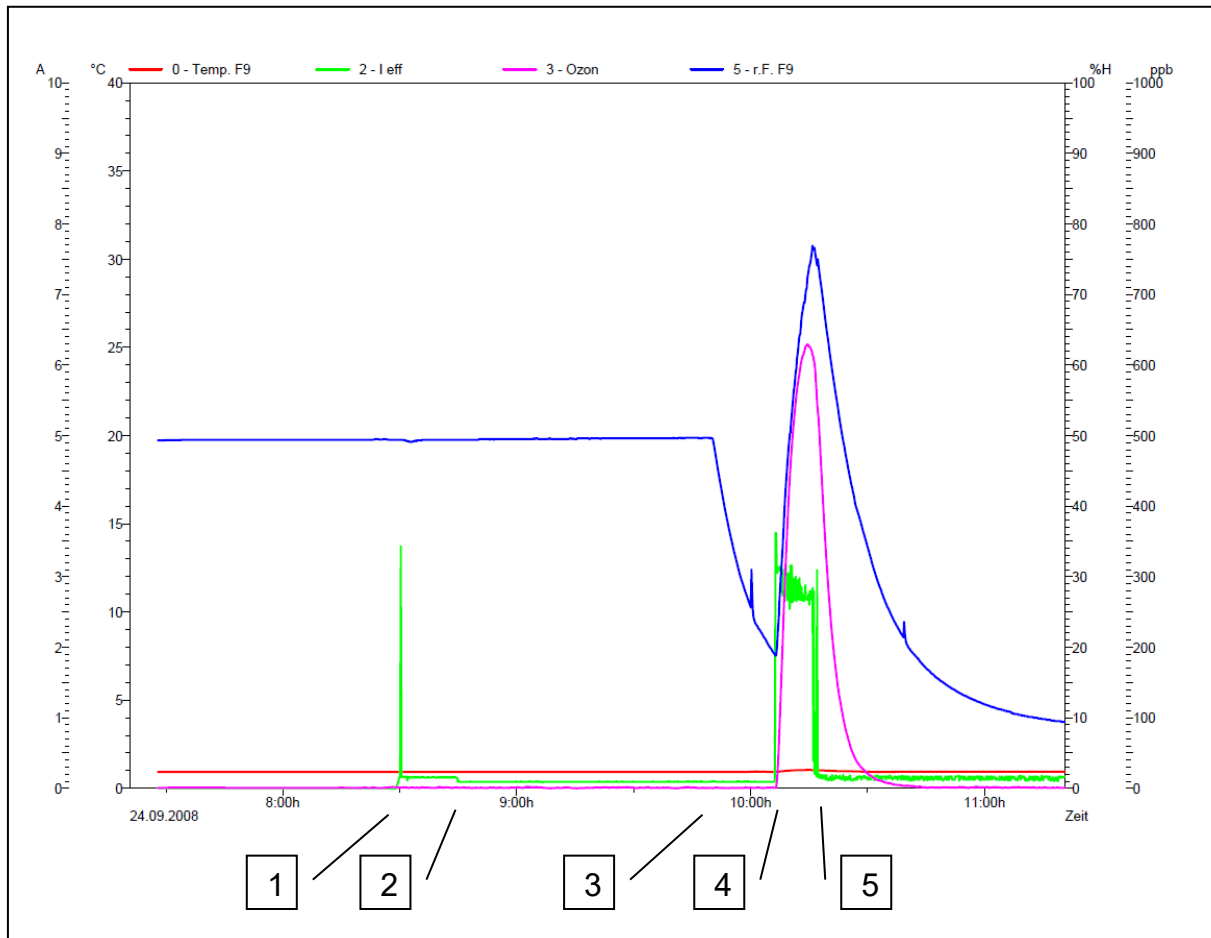
The templates are available in a ZIP file for DE-UZ 219, Appendix folder

8.4 Template for testing colour devices, 20% coverage



The templates are available in a ZIP file for DE-UZ 219, Appendix folder

8.5 Example for climate, electric power consumption and ozone concentration during a test



Loading on the previous day is not indicated!

- 1 Start of pre-operating phase (8:30 hours)
- 2 Energy saving mode starts
- 3 Air exchange altered, reducing humidity
- 4 Print phase starts
- 5 Print phase ends, post-operating phase starts

8.6 Example of a proven VOC test method (cf. [2], [5])

Sampling tubes: Tenax TA (tube length 178 mm, OD 6 mm, 4 mm ID, 200 mg Tenax TA (60-80 mesh) with glass wool plugs); sampling volume > 1.0 l (100 ml/min). Prior to sampling, the Tenax tubes must be spiked with the internal standard dissolved in methanol.

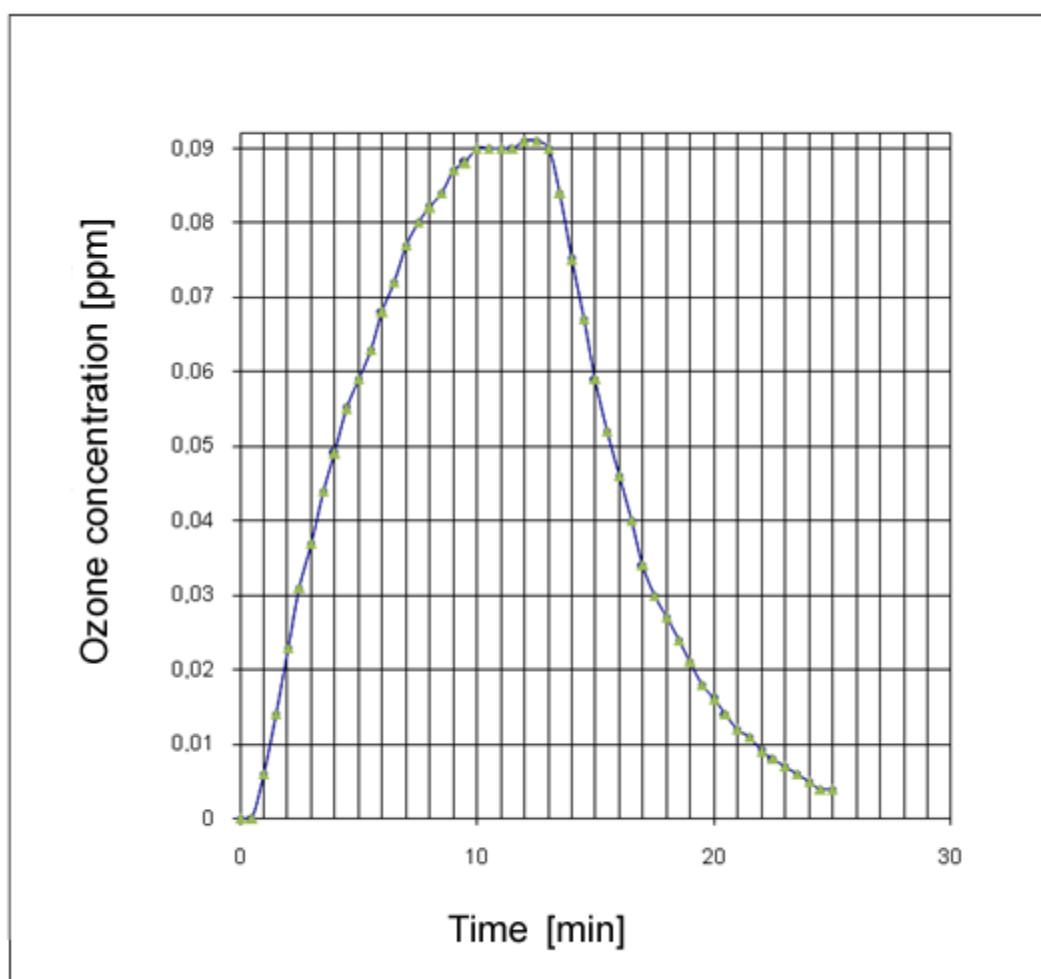
The calibration is carried out by drawing (spiking) the calibration substances, dissolved in methanol, onto a Tenax tube and rinsing it with a litre of synthetic air or nitrogen (purity 5.0) to simulate a sampling process while the methanol which remained on the Tenax after spiking is desorbed.

Analysis system

Thermodesorption / Gerstel TDS 2 cold feeding system / KAS-3 (programme: 40 – 280 °C with 40 K min⁻¹, keeping at 280 °C for 5 min / cryofocussing at -150 °C, heating at 10 Ks⁻¹ to 290 °C / He flow 35 ml min⁻¹)

HP 5890 II GC + HP 5972 MSD (HP 1 column; 60 m, 0.25 mm, 0.25 µm, temperature programme 40 °C for 4 min, 5 K min⁻¹ to 140 °C, 10 K min⁻¹ to 240 °C, 25 K min⁻¹ to 290 °C, keeping for 3 min / MSD: scan 25-400: 1.9 scans / sec; 300 °C, NBS - 75K - database).

8.7 Example for ozone concentration during print phase



8.8 Technical information about the aerosol measurement instruments

Particle size range

The lower detection limit of the particle size is the smallest particle diameter at which the counting efficiency of an aerosol measurement device is 50%.

The corresponding upper detection limit is the highest particle diameter at which the counting efficiency of an aerosol measurement device is 50%.

Particle number concentration range

The lower detection limit of the particle number concentration is the concentration which can be distinguished from the measured background concentration with a statistical probability of 95% (due to the device-specific error-count rate). The error count rate is a count rate which is not caused by particles.

8.9 Preliminary measures to ensure the readiness of aerosol measurement instruments

This appendix describes the mandatory measures to ensure the readiness of aerosol measurement instruments. The measures described here should be performed in addition to periodic maintenance.

8.9.1 Rapid aerosol measurement instruments

Setting up the instrument

1. The aerosol measurement instrument and the connecting hoses are checked for cleanliness.
2. The aerosol measurement instrument is placed so that the connection with the emission test chamber has a maximum length of 3 m and is as straight as possible.
3. Time and date of the aerosol measurement instrument, software and laboratory clock are synchronised when the data provided differ by more than 1 second from each other.

8.9.1.1 Preparation for measurement

The following steps should be carried out in sequence:

1. All operating parameters (air temperature, voltage, internal pressure and flow rates) are checked.
2. A reset (zeroing) is performed according to the manufacturer's instructions after instrument warmup (first check). Electrometer current offsets and RMS values are recorded and checked for compliance with the manufacturer's specifications.

3. After another period of 30 minutes, step 2 is repeated (second check). Electrometer offsets from the first and second checks may not differ by more than ± 10 fA. Compliance with this requirement is mandatory and must be stated in the test report. Instruments which do not comply with this requirement must be maintained in accordance with the manufacturer's specifications and cleaned before use.
4. The HEPA filter is removed from the aerosol inlet of the aerosol measurement instrument.
5. The sampling flow rate of the aerosol measurement instrument is checked. An internal flow meter should preferably be used for this purpose. Otherwise, an externally calibrated flow meter must be used. The measured flow rate of the aerosol measurement instrument must not deviate by more than $\pm 10\%$ from the specified set point in the calibration certificate.
6. The aerosol measurement instrument is connected to the sampling port of the emission test chamber.
7. The particle background concentration is measured in the emission test chamber. The background concentration must not exceed the specified values in Section 4.1.
8. The correct function of the measuring instrument is confirmed in the test report.

8.9.2 CPCs

For the measurement of total particle number concentration, only those CPCs that use isopropanol or butanol as a working fluid may be used. The following steps should be carried out before a measurement.

Preparation for the measurement

1. The CPC is placed into an operational state in accordance with the operating instructions supplied by the manufacturer. The fluid reservoir on the CPC is filled with enough working fluid for the measurement. If the CPC has an excess reservoir, this should be checked and emptied in order to avoid malfunctions during the measurements.
2. The CPC is switched on and runs through the warm-up process according to the manufacturer's instructions.
3. Time and date of the CPC, software and laboratory clock are synchronised when the data provided differ by more than 1 second from each other.
4. The CPC is checked in accordance with the manufacturer's specifications to ensure it functions correctly.
5. The sampling flow rate of the CPC is checked. An internal flow meter should preferably be used for this purpose. Otherwise, an externally calibrated flow meter must be used. The measured flow rate of the aerosol measurement

instrument must not deviate by more than $\pm 10\%$ from the set point specified in the calibration certificate.

6. If a HEPA filter (filter efficiency $\geq 99.99\%$) is connected to the CPC, it is checked whether the particle count concentration is near to the lower detection limit. If particle number concentrations $> 1 \text{ cm}^{-3}$ are indicated over a period of 1 min – after any leaks between the HEPA filter and aerosol inlet have been eliminated – the CPC is faulty.
7. The particle number concentration in ambient air outside the test chamber is measured with the CPC. The measurement readings should clearly exceed 1 cm^{-3} . Other aerosol sources with sufficiently high particle count concentrations may also be used for this test. A zero readout as described under Point 5 indicates that the CPC is faulty.
8. The correct function of the measuring instrument is confirmed in the test report.
9. The CPC is connected to the sampling port of the emission test chamber via a conductive material (e.g. conductive silicone tube, stainless steel) with a maximum length of 3 m.
10. The background particle concentration in the emission test chamber is measured and must not exceed the values specified under 4.1.