INTERNATIONAL STANDARD

ISO/IEC 28360

First edition
2007-09-01

Information technology — Office equipment — Determination of chemical emission rates from electronic equipment

Technologies de l'information — Équipement de bureau — Détermination des taux d'émission chimique d'un équipement électronique

Reference number
ISO/IEC 28360:2007(E)

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Contents

Page

Foreword ... iv

Introduction ... v

1 Scope ... 1

2 Conformance ... 1

3 Normative references ... 2

4 Terms and definitions ... 2

5 Acronyms, abbreviations and symbols ... 4
5.1 Acronyms and abbreviations ... 4
5.2 Symbols ... 4

6 Method overview ... 6

7 ETC requirements ... 7
7.1 Construction materials ... 7
7.2 Air tightness ... 7
7.3 Air mixing efficiency ... 7

8 Determination method ... 7
8.1 Test conditions ... 7
8.2 Handling of EUT and ETC ... 7
8.3 VOC and carbonyl compounds ... 11
8.4 Ozone ... 13
8.5 Particulate matter ... 15

9 Test report ... 16

Annex A (normative) **Print patterns** ... 18
A.1 Monochrome print pattern 5% coverage ... 18
A.2 Colour print pattern, 20% coverage ... 20

Annex B (informative) **Emission rate model for EUT using consumables** ... 21
B.1 Objective ... 21
B.2 Approach ... 21
B.3 General mass balance and concentration equations ... 21
B.4 Background SER ... 22
B.5 Emission during pre-operating phase ... 22
B.6 Emission during operating phase ... 23
B.7 Emission during post-operating phase ... 25
B.8 Special cases ... 26
B.9 Model for RAL-UZ 122 Option ... 27

Annex C (informative) **Influence of EUT filtering on SER_{O3}** ... 29

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC 28360 was prepared by Ecma International (as ECMA-328) and was adopted, under a special “fast-track procedure”, by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, in parallel with its approval by national bodies of ISO and IEC.

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Introduction

Globally, governmental agencies, academic institutions, environmental organizations and manufacturers have developed methods to determine chemical emissions from electronic equipment. These attempts however, resulted in a range of tests from which the results are not necessarily comparable, either qualitatively or quantitatively.

Following the publications of the first edition of ECMA-328 and the “Test method for the determination of emissions from Hard Copy Devices” (RAL-UZ 122), experts from the German Federal Insitute for Materials Research and Testing (BAM) and Ecma have collaborated to harmonise methods to determine the chemical emission rates from information and communication technology and consumer electronics equipment in this International Standard (second edition of ECMA-328).

In addition to stricter test procedures, this International Standard uses generalised emission formulae, and their derivations developed in Annex B, to calculate emission rates from concentrations of analytes that are measured in Emission Test Chambers.

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Information technology — Office equipment — Determination of chemical emission rates from electronic equipment

1 Scope

This International Standard specifies methods to determine chemical emission rates of analytes from information and communication technology and consumer electronics equipment during intended operation in an Emission Test Chamber (ETC).

The methods comprise preparation, sampling (or monitoring) in a controlled ETC, storage and analysis, calculation and reporting of emission rates.

This International Standard includes specific methods for equipment using consumables, such as printers, and equipment not using consumables, such as monitors and PCs. Annex A specifies monochrome and colour print patterns for use in the operating phase of EUT using *paper* consumables.

Examples of equipment under test (EUT) that do not use consumables are:

- monitors and TV sets (CRT, plasma, LCD, rear projector, beamer);
- video (VCR, DVD player/recorder, camcorder);
- SAT receiver (set-top box);
- audio units (CD player/recorder, home theatre systems, audio home systems, micro-/mini-, midi-systems, amplifier, receiver);
- portable audio (CD player, MP 3 player, radio recorder, clock radio, etc.);
- computer (desktop, tower, server), portable computers (notebooks).

Emission rates from EUT using consumables may also be determined according to additional requirements identified by “RAL-UZ 122 Option”.

Calculations use the generalised model and approximations thereof as developed in Annex B.

The emission rates determined with this method may be used to compare equipment in the same class.

Predictions of “real indoor” *concentrations* from the determined *emission rates* are outside the scope of this International Standard.

2 Conformance

Determinations of emission rates conform to this International Standard when:

1) executed using a Quality Assurance Project Plan, Quality Assurance and Quality Control as specified in ISO 16000-9;

2) tested in a controlled ETC as specified in Clause 7 and in 8.1;

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3) sampled/monitored and calculated as specified in Clause 8;

4) reported as specified in Clause 9.

For EUT using consumables, determinations according to additional requirements identified by "RAL-UZ 122 Option" herein conform to the RAL-UZ 122 Option.

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CIE 15:2004, *Colorimetry*, 3rd edition, Commission Internationale de l'Eclairage

ECMA-74, *Measurement of Airborne Noise Emitted by Information Technology and Telecommunications Equipment* (2005)

ISO 554:1976, *Standard atmospheres for conditioning and/or testing — Specifications*

ISO 13655:1996, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

ISO 16000-3:2001, *Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds — Active sampling method*

ISO 16000-6:2004, *Indoor air — Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID*

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

ISO 16017-1:2000, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling*

EN 55013:2001, *Sound and television broadcast receivers and associated equipment — Radio disturbance characteristics — Limits and methods of measurement*

RAL-UZ 122, *Test method for the determination of emissions from Hard Copy Devices*

4 Terms and definitions

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

4.1
air exchange rate, n
ratio of the volume of clean air brought into the ETC per hour [m^3/h] to the unloaded ETC volume [m^3]

4.2
air velocity
air speed [m/s] measured in the unloaded ETC

4.3
analyte
Volatile Organic Compounds, carbonyl compounds, ozone and particulate matter

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4.4
consumables
toner, ink, paper and ribbon

4.5
Emission Test Chamber
ETC
enclosure with controlled operational parameters for testing analyte mass emitted from EUT

4.6
Equipment Under Test
EUT
functional and complete, including consumables and accessories if applicable, ICT or CE equipment, from which chemical emission rates are determined as specified herein

4.7
loading factor
ratio of the EUT volume to the volume of the unloaded ETC

4.8
Hard Copy Devices
class of EUT using consumables that includes printers, (photo)copiers and Multi Functional Devices (MFD)

4.9
operating phase
phase in which the EUT is performing its intended functions

4.10
particulate matter
airborne particles

4.11
pre-operating phase
phase in which the EUT is connected to an electrical supply, which may include warming-up and energy saving modes; before the EUT is able to enter the operating phase

4.12
post-operating phase
phase following the operating phase,which may include energy saving modes

4.13
Total Volatile Organic Compounds
TVOC
sum of the concentrations of identified **Volatile Organic Compounds** and the concentrations of the converted areas of unidentified peaks using the toluene response factor

4.14
unit specific emission rate
SER
mass, in micrograms, of a specific analyte emitted per unit per hour

4.15
Volatile Organic Compounds
VOC
compounds that elute between n-hexane and n-hexadecane on an unpolar GC-column

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5 Acronyms, abbreviations and symbols

5.1 Acronyms and abbreviations

CE	Consumer Electronics
DNPH	2,4-dinitrophenylhydrazine
ETC	Emission Test Chamber
EUT	Equipment Under Test
FID	Flame Ionisation Detector
GC/MS	Gas Chromatography/Mass Spectrometry
ICT	Information and Communication Technology
MFD	Multi Functional Device
PTFE	polytetrafluoroethene
PVC	polyvinylchloride
rH	relative Humidity
SER	unit Specific Emission Rate
TVOC	Total Volatile Organic Compounds
VOC	Volatile Organic Compounds

5.2 Symbols

C_s	Average concentration [µg/m^3]
C_{bg}	Background concentration [µg/m^3]
C_{max}	Maximum ozone concentration [µg/m^3]
C_0	Initial concentration [µg/m^3]
C_{pre}	Average concentration during pre-operating phase [µg/m^3]
C_{ope}	Average concentration during operating phase and optionally during post-operating phase [µg/m^3]
H’	Ozone half-life [min]: the period of time for the ozone concentration to drop from C_{max} to $C_{max}/2$
k	Ozone decay constant, without ventilation [min^{-1}]
k’	Ozone decay constant with ventilation (k’ = k + n/60) [min^{-1}]
m_{after}	Sample filter mass [µg] after sampling

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m_{before}	Sample filter mass [µg] before sampling
m_{bg}	Sampled mass for chamber background [µg]
m_{pm}	Mass of particulate matter [µg] deposited on the filter
$m_{ref\text{-}after}$	Reference filter mass [µg] after sampling
$m_{ref\text{-}before}$	Reference filter mass [µg] before sampling
m_s	Sampled mass [µg]
m_{pre}	Sampled mass [µg] during pre-operating phase
m_{ope}	Sampled mass [µg] during operating and optionally post-operating phase
n	Air exchange rate [h^{-1}]
P	Atmospheric pressure [Pa]
SER_{bg}	Background SER [µg/h]
SER_{ope}	SER during operating and optionally post-operating phase [µg/h]
SER_{O3}	SER for ozone [µg/min]
SER_{pm}	SER for particulate matter [µg/h]
SER_{pre}	SER during pre-operating [µg/h]
T	Ambient temperature [K]
t_{ope}	Operating phase duration [h]
t_G	Sampling time during operating and optionally post-operating phase [h]
t_{pre}	Pre-operating phase duration [h]
u	Number of EUT units
V	ETC volume [m^3]
V_s	Sampled air volume [m^3]
V_{bg}	Sampled air volume [m^3] for determination of C_{bg}
V_{pre}	Sampled air volume [m^3] in pre-operating phase
V_{ope}	Sampled air volume [m^3] in operating and optionally post-operating phase

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6 Method overview

The flowchart in Figure 1 illustrates the method; clause numbers are indicated in brackets.

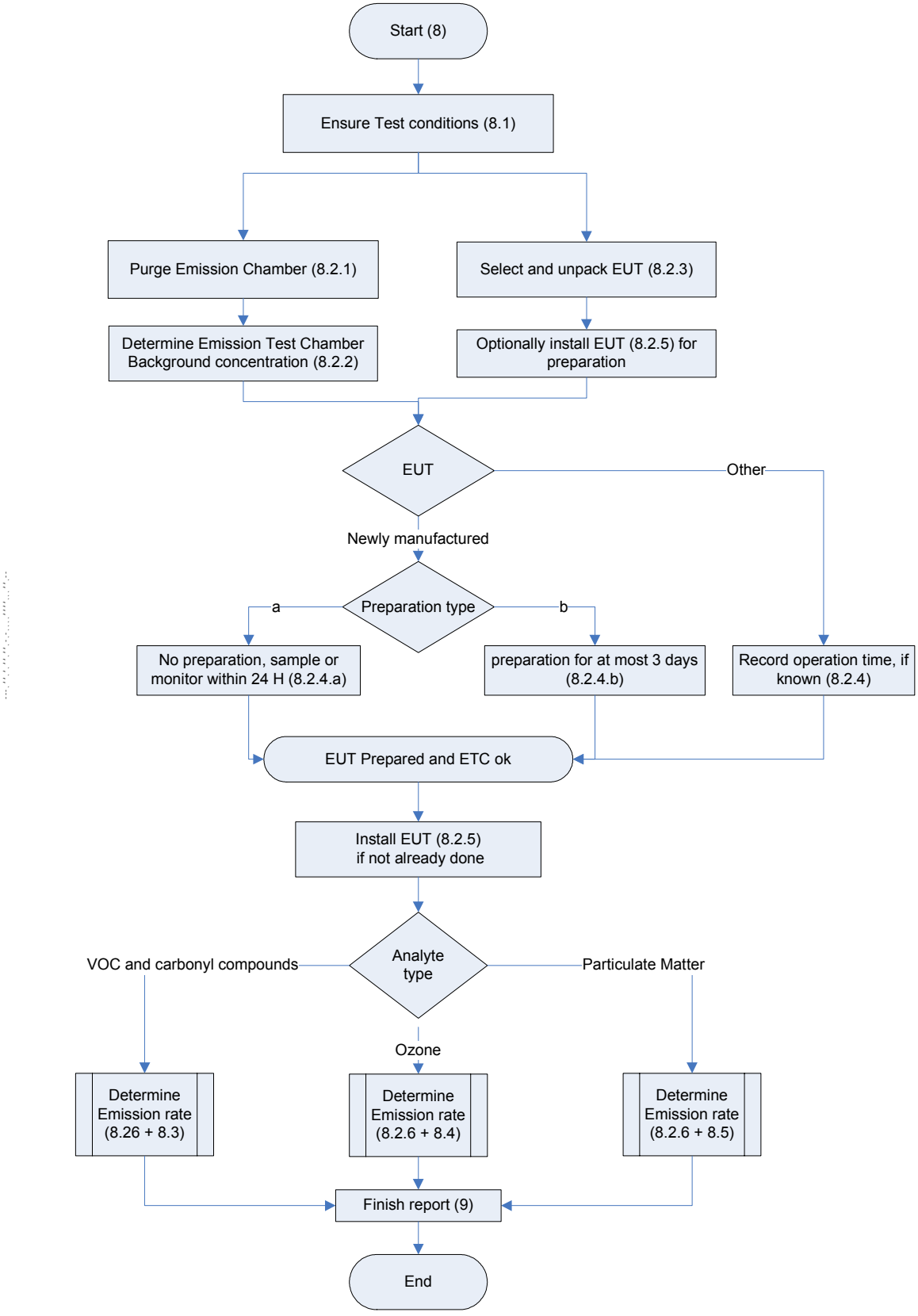

Figure 1 — Determination method overview

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7 ETC requirements

7.1 Construction materials

ETC construction materials shall comply with ISO 16000-9.

7.2 Air tightness

The ETC air tightness shall be as specified in ISO 16000-9.

7.3 Air mixing efficiency

The air mixing efficiency in the ETC shall be as specified in ISO 16000-9.

8 Determination method

For the RAL-UZ 122 Option, tests shall be executed within 10 working days after delivery of the EUT.

8.1 Test conditions

To meet the operational requirements specified herein, ETC parameters such as temperature, relative humidity and supply airflow shall be controlled and measured at regular intervals and recorded in accordance with ISO 16000-9 and shall be reported as specified in Clause 9.

8.1.1 Operating temperature and relative Humidity (rH)

Tests shall be executed at (23 ± 2) °C and (50 ± 5)% rH according to ISO 554. For EUT used in alternative climatic conditions, higher operating temperature and humidity conditions may be used as specified in ISO 554.

Consult 8.2.6.2 for special requirements on rH for EUT using consumables.

8.1.2 Air exchange rate (n)

For unloaded ETCs with a volume larger than 5 m^3, n shall be in the range from 0,5 to 2,0. For unloaded ETC's with a volume of 5 m^3 or smaller, n shall be in the range from 0,5 to 5,0.

8.1.3 Air velocity

The air velocity shall be in the range from 0,1 to 0,3 m/s.

8.1.4 Sampled air flow

The sum of sampled airflow shall be less than 80% of the inlet airflow into the ETC.

8.2 Handling of EUT and ETC

EUT shall be selected from normal manufactured batches or shall be a prototype that is representative for EUT from such batches. For determinations using the RAL-UZ 122 Option, EUT shall be stored in an air-conditioned room (23 °C, 50% rH) in its original packaging.

To ensure detection of a minimum emission within a practicable time, the ETC with capabilities as specified in 7.2 shall be selected such that the loading factor is in the range of 1:4 to 1:100.

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8.2.1 ETC purging

The selected ETC shall be unloaded and its interior walls shall be cleaned as described in ISO 16000-9.

k' shall be less than 0,0693 [min^{-1}], which corresponds to an ozone half-life of greater than 10 minutes, when n = 1.

To determine k', the ETC should be deactivated by exposure to an ozone concentration of 0,2 mg/m^3 to 0,4 mg/m^3 until a stable concentration is reached.

Thereafter, the ETC shall be purged with 4 ETC volumes of clean air.

8.2.2 Background concentrations (C_{bg})

Following purging, the C_{bg} of analyte in the unloaded ETC shall be determined and recorded.

NOTE C_{bg} may stem from e.g. emissions from the ETC itself and sampling tubes or filters.

The C_{bg} values at n = 1, shall be below the limits in Table 1.

Table 1 — Background concentrations

Analyte	Limit [µg/m³]
VOC and carbonyl compounds	2 for any analysed substance
TVOC	20
Ozone	4
Particulate matter	10

8.2.3 EUT unpacking

Emissions from packaging may influence measurements considerably; in addition packaging itself may emit VOCs that are not representative for EUTs in typical use. Therefore, the EUT to be tested shall be removed from the shipping containers and all protective shipping packaging such as spacers, film wrapping and any other shipping/packaging elements before preparation (as specified in 8.2.4).

NOTE After unpacking, installation (step 8.2.5) may precede the preparation step (8.2.4).

8.2.4 Preparation of the EUT before testing

For EUT using paper consumables, using 60 g/m^2 to 80 g/m^2 A4 paper with water content from 3,8% to 5,6%, while printing the patterns specified in Annex A.1 and A.2 as appropriate, the maximum operating time shall be determined. Thereafter, lightness (L*) and colour values (L*, a*, b*), as appropriate, shall be determined from the printouts according to CIE 15:2004 and ISO 13655.

For the RAL-UZ 122 Option no further preparation shall be executed.

Newly manufactured equipment is known to emit higher levels in the first days of use, which is not representative for the normal emissions over the intended lifetime. For newly manufactured equipment, one of the following preparatory operations shall be executed:

a) The EUT shall not be operated before testing; testing shall start within 24 hours after unpacking.

b) The EUT shall have been in operation for a maximum of three days or equivalent before the start of testing.

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For other equipment, that may have been operated longer than three days, no preparation shall be executed; in this case, the number of days that the EUT has been in operation shall be recorded, if known, otherwise "not known" shall be reported.

Treatment conditions shall be recorded in the test report.

NOTE Typical treatment conditions for types of EUT are:

PCs and ICT & CE equipment: 8 hours operation in idle mode for three days at 8 hours per day which is equivalent to 24 hours of continuous operation.

Hardcopy Devices: 1 to 2 hours of printing, 6 to 7 hours of pre-operation per day for three days, which is equivalent to 3 to 6 hours of printing and 18 to 21 hours in pre-operation.

8.2.5 EUT installation

8.2.5.1 EUT not using consumables

The EUT shall be installed while executing its intended function(s) as specified in ECMA-74, using suitable test signals as specified in chapter 5.2 of EN 55013:2001 or another appropriate standard or specification.

To avoid contamination, the EUT shall be installed in the middle of the ETC as fast as possible and all operators shall leave the ETC immediately thereafter.

8.2.5.2 EUT using consumables

Before installation, the EUT shall have sufficient consumables to complete the operations. In case of paper consumables, 60 g/m^2 to 80 g/m^2 A4 paper with water content from 3,8% to 5,6% shall be used.

To avoid contamination, the powered-off EUT shall be installed in the middle of the ETC as fast as possible and all operators shall leave the ETC immediately thereafter.

The EUT shall remain powered-off until the emission test, as specified in 8.2.6, requires the EUT to be powered-on.

For the RAL-UZ 122 Option, the EUT shall be installed on the day before the emission test.

The ETC shall remain closed until all sampling and or monitoring is completed.

The installation date and time shall be recorded.

Emission testing, as specified in 8.2.6, shall not begin within at least 3 air exchanges following installation.

8.2.6 EUT operation during test

The start of the operation of the EUT shall be recorded as the time t_0.

The start and duration of the operating phases shall be recorded.

8.2.6.1 EUT not using consumables

For this class of EUT, VOC and carbonyl compounds as specified in 8.3 shall be determined and ozone as specified in 8.4 should be determined while continuing to execute its intended functions as initiated during installation (see 8.2.5.1).

The used test standard or specification shall be reported, preferably by referring to a standard.

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8.2.6.2 EUT using consumables

To avoid condensation due to vaporisation of water from paper during the operating phase, incoming air with rH of at most 10% may be inserted in the ETC before the operating phase. In addition, the air exchange rate (n) may have to be increased to avoid such condensation. Increase of humidity during the operating phase also depends on the ETC volume. Condensation of water vapour (i.e. rH > 85%) on the ETC walls invalidates the test.

For this class of EUT, VOC and carbonyl compounds as specified in 8.3; ozone as specified in 8.4; and particulate matter as specified in 8.5 shall be determined while being controlled from outside the ETC.

8.2.6.2.1 Pre-operating phase

To enter the pre-operating phase, the EUT shall be powered-on and remain in this phase between 1 and 4 air exchanges.

8.2.6.2.2 Operating phase

The Hard Copy Device class of EUT shall operate at nominal speed. Operating may include colour-, and/or dual sides printing. The monochrome and colour print patterns specified in Annex A.1 and A.2 respectively shall be used for EUT using paper consumables.

Enter the operating phase by starting copying or printing. The output of the first printed page marks the start of the operating phase. It ends with the output of the last printed page.

The duration of this phase shall be at least 10 minutes and, in conjunction with other parameters such as n, ETC volume and the use of a post-operating phase, the duration shall be such that quantitative analysis is ensured.

8.2.6.2.3 Post-operating phase

The post-operating phase starts when the operating phase ends, and may last up to four air exchanges.

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8.3 VOC and carbonyl compounds

The flow chart in Figure 2 illustrates the determination method for VOC and carbonyl compounds.

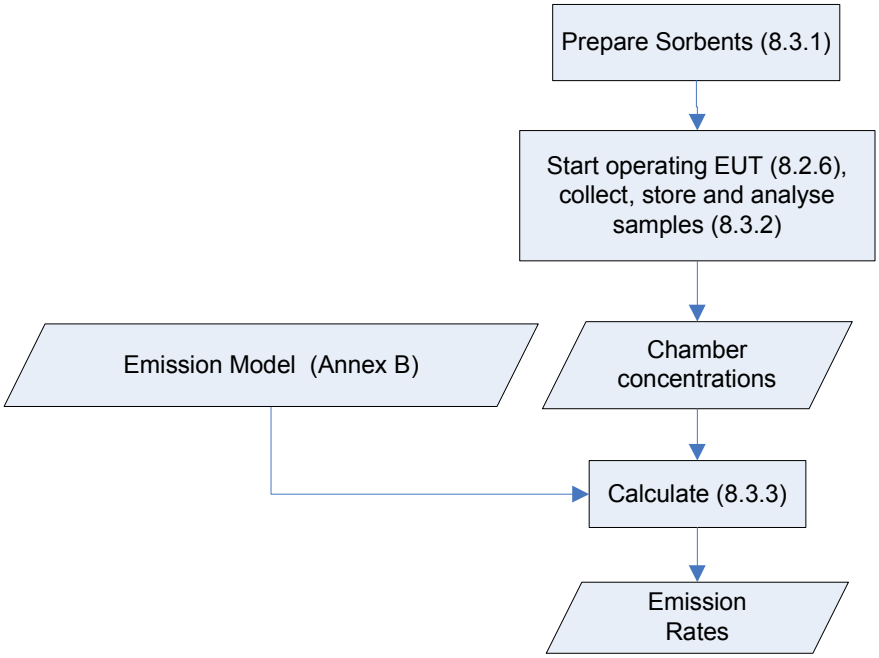

Figure 2 — Determination method for VOC and carbonyl compounds

8.3.1 Sorbents

VOC sampling and analysis shall be performed using the sorbents as specified in ISO 16017-1, with the exception of Chromosorbs and Porapacks due to their high blank values: Tenax TA™ shall be conditioned and analysed according to ISO 16000-6 to minimise the production of artefacts, especially benzene.

For the RAL-UZ 122 Option, Tenax tubes shall be spiked with an internal standard such as cyclodecane or deuterated toluene.

For carbonyl compounds, DNPH cartridges shall be used as sorbent material.

8.3.2 Sample collection

For VOC, duplicate samples shall be taken, and for carbonyl compounds one sample shall be taken.

Individual VOCs, carbonyl compounds with a concentration $\geqslant$ 1,0 µg/m^3 and, under the RAL-UZ 122 Option, benzene with a concentration $\geqslant$ 0,25 µg/m^3, shall be detected.

8.3.2.1 Sample collection from EUT not using consumables

Sampling shall start at 3 and end no later than 4 air exchanges after t_0.

In addition, Carbonyl compounds sampling shall be conducted as specified in ISO 16000-3.

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8.3.2.2 Sample collection from EUT using consumables

Sampling shall be performed during:

a) The pre-operating phase, starting at the beginning of this phase, or, under the RAL-UZ-122 Option, with a sample flow of 100 to 200 ml/min, from 20 minutes before the end until the end of the one-hour pre-operating phase; and

b) The operating phase, starting at beginning of this phase, and may continue into the post-operating phase. Under the RAL-UZ 122 Option, sampling shall continue for one air exchange in the post-operating phase, with a sample flow of 100 to 200 ml/min.

Loaded samples shall be stored and analysed as specified in ISO 16000-3 and ISO 16000-6.

Identified VOCs shall be quantified using absolute response factors, determined by calibration. Unidentified VOCs shall be quantified using the toluene equivalents as a relative response factor.

When benzene is detected, this shall be verified and quantified by analysing a sample on alternate carbonaceous sorbent such as Carbotrap/Carbopack™ type materials.

8.3.3 Emission rate calculation

This Clause specifies formulae that apply to practical situations that are special cases of the general case (as developed in Annex B).

Concentrations shall be determined, using the following equations:

$$C = \frac{m_s}{V_s} \qquad C_{ope} = \frac{m_{ope}}{V_{ope}} \qquad C_{pre} = \frac{m_{pre}}{V_{pre}} \qquad C_{bg} = \frac{m_{bg}}{V_{bg}} \tag{1}$$

8.3.3.1 EUT not using consumables

The SER for EUT not using consumables is:

$$SER = (C - C_{bg}) \cdot n \cdot V \tag{2}$$

8.3.3.2 EUT using consumables

The Background emission rates are:

$$SER_{bg} = C_{bg} \cdot n \cdot V \tag{3}$$

a) Emissions in the pre-operating phase

Assuming constant emission rates during the pre-operating phase, emission rates shall be calculated as follows.

1. If a sample is taken from the beginning of this phase:

$$SER_{pre} = \frac{\left(C_{pre} - C_{bg}\right) \cdot n^2 \cdot V \cdot t_{pre}}{\exp(-n \cdot t_{pre}) - 1 + n \cdot t_{pre}} \tag{4}$$

2. RAL-UZ 122 Option

$$SER_{pre} = C_{pre} \cdot n \cdot V - SER_{bg} \tag{5}$$

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b) Emissions in the operating and post-operating phase

1. General case

Emission rates in these phases shall be determined using the following general formula:

$$SER_{ope} = \frac{(C_{ope} - C_{bg}) \cdot n^2 \cdot V \cdot t_G - SER_{pre}[\exp(-n \cdot (t_G - t_{ope})) + n \cdot (t_G - t_{ope}) - 1 + (1 - \exp(-n \cdot t_{pre})) \cdot (1 - \exp(-n \cdot t_G))]}{\exp(-n \cdot t_G) - \exp[-n \cdot (t_G - t_{ope})] + n \cdot t_{ope}} \quad (6)$$

2. Special cases

Consult Annex B for more detail on special cases. If there is no post-operating phase (t_G=t_{ope}), then:

$$SER_{ope} = \frac{(C_{ope} - C_{bg}) \cdot n^2 \cdot V \cdot t_G - SER_{pre}[(1 - \exp(-n \cdot t_{pre})) \cdot (1 - \exp(-n \cdot t_G))]}{\exp(-n \cdot t_G) - 1 + n \cdot t_G} \quad (7)$$

If the post-operating phase is relatively long ($n \cdot t_G \geqslant 3$):

$$SER_{ope} = \frac{(C_{ope} - C_{bg}) \cdot n^2 \cdot V \cdot t_G - SER_{pre}[n \cdot t_G - \exp(-n \cdot t_{pre}))]}{n \cdot t_{ope}} \quad (8)$$

3. RAL-UZ 122 Option

For the RAL-UZ 122 Option the post-operating phase shall last one air exchange and the following approximate formula shall be used for the calculation of SER_{ope} (i.e. (B.28) as derived in Annex B.9):

$$SER_{ope} = \frac{C_{ope} \cdot n^2 \cdot V \cdot t_G - SER_{pre} \cdot nt_G}{\exp(-nt_G) - \exp[-n(t_G - t_{ope})] + nt_{ope}} \quad (9)$$

8.3.3.3 TVOC (RAL-UZ 122 Option)

The TVOC value shall be calculated as the sum of the concentrations of all identified and unidentified substances, eluting between n-hexane and n-hexadecane and resulting in emission rates above the following values:

- for measurements in ETCs $\leqslant$ 5 m^3: $SER_{pre} \geqslant$ 0,005 mg/h and $SER_{ope} \geqslant$ 0,05 mg/h;
- for measurements in ETCs $>$ 5 m^3: $SER_{pre} \geqslant$ 0,02 mg/h and $SER_{ope} \geqslant$ 0,2 mg/h.

8.4 Ozone

The flowchart in Figure 3 illustrates the determination method for ozone.

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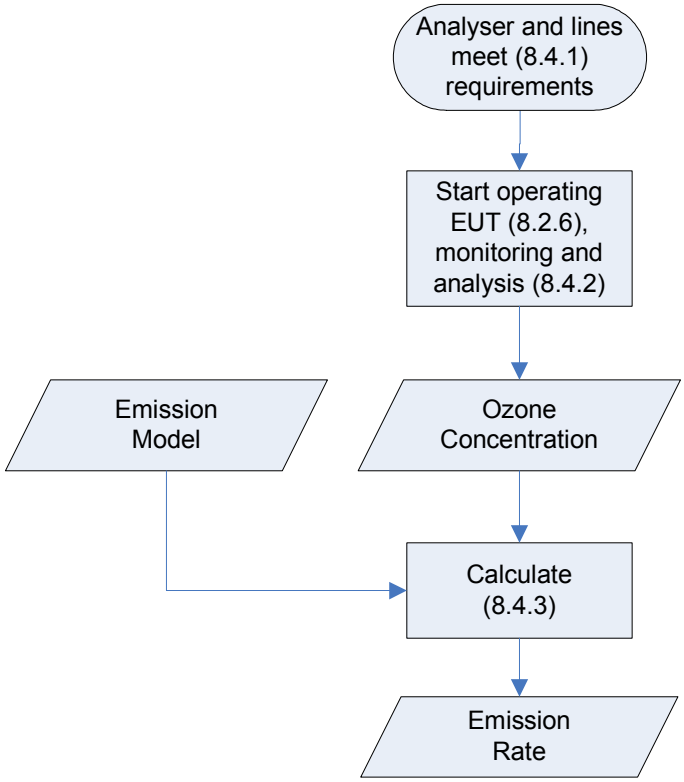

Figure 3 — Determination method for ozone

8.4.1 Analyser and sampling line requirements

Ozone analysers shall at least have:

- the capability to detect concentrations between 4 µg/m^3 and 1 mg/m^3;
- a precision of 2 µg/m^3;
- a sampling rate (may be important for small ETCs) of $\leqslant$ 2 l/min.

To prevent loss of ozone in the sampling line, it shall be of minimum length, not exceeding 4 m, and made of a flexible inert material such as PTFE.

8.4.2 Monitoring

Since ozone is an unstable molecule, it shall be monitored and analysed instantaneously at least each 30 seconds during continuous operation either for at least 10 minutes, or for as long as it takes to determine the build-up and stabilisation of ozone in the ETC.

Following the end of the operating phase, the ozone half-life (H') shall be determined from the ozone decay curve.

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8.4.3 Emission rate calculation

For analysers indicating values that are converted for the Standard Ambient Temperature and Pressure (SATP) of (273 + 25 = 298) K and 101 325 Pa (i.e. 1 atmosphere), SER_{O3} shall be calculated using the actual ETC pressure (P in Pa), the actual ETC temperature (T in K) and the gas conversion constant (R = 339,8 Pa/K), otherwise P/TR = 1 shall be used:

$$SER_{O3} = \frac{C_{max} k' VP}{TR} \text{ with } k' = k + (n/60) = \frac{\ln 2}{H'} \quad (10)$$

NOTE If the temperature and pressure in the ETC equal the SATP, P/TR is 1.

8.5 Particulate matter

The flowchart in Figure 4 illustrates the determination method for particulate matter emitted from EUT using consumables.

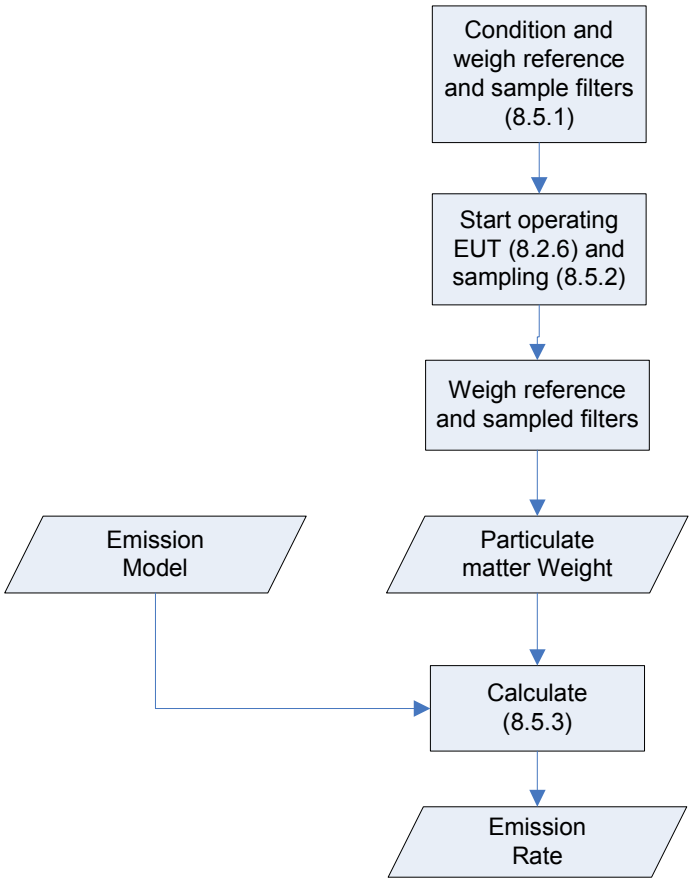

Figure 4 — Determination method for particulate matter

8.5.1 Weighing and Filter conditioning

The analytical balance, with a weighing precision of 1µg or better, shall be located in a temperature and humidity controlled room as specified in 8.1.1.

Glass fibre filters with 0,7 µm pore size, or equivalent e.g. 0,8 µm pore size PVC filters, shall be used.

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The filters shall remain in the controlled room for 48 hours. The unused reference filter and the sampling filters shall be weighed before sampling giving $m_{ref\text{-}before}$ and m_{before}.

8.5.2 Sampling

Particulate matter shall be sampled during the operating and post-operating phases of the EUT. Sampling duration shall ensure the detection of at least 5 µg/m^3 of particulate matter.

For the RAL-UZ 122 Option sampling shall start at the beginning of the operating phase and continue during the full post-operating phase that lasts 4 air exchanges.

8.5.3 Emission rate calculation

The unused reference filter and the sampling filters shall be weighted after sampling giving $m_{ref\text{-}after}$ and m_{after}.

The particulate matter mass shall be corrected with the reference filter mass difference:

$$m_{pm} = (m_{after} - m_{before}) - (m_{ref\text{-}after} - m_{ref\text{-}before}).$$

With $C_{ope} = m_{pm} / V_{ope}$, the SER_{pm} shall be calculated using the following formula:

$$SER_{pm} = \frac{C_{ope} \cdot n^2 \cdot V \cdot t_G}{\exp(-nt_G) - \exp[-n(t_G - t_{ope})] + nt_o} \quad (11)$$

For the RAL-UZ 122 Option the following approximate formula shall be used:

$$SER_{pm} = \frac{C_{ope} \cdot n \cdot V \cdot t_G}{t_{ope}} \quad (12)$$

9 Test report

The test report shall include the following, if applicable and available:

Test laboratory

- Reference to ISO/IEC 28360.
- Name and address of test laboratory.
- Name of the responsible person.
- Unique identification number of the test report.

EUT description

- Manufacturer.
- Type, brand name and serial number of EUT, and for EUT using consumables: if tabletop or floor-mounted.
- Print or copying time according to manufacturer's information.
- Identification number (model number) and lot number of consumables used.
- History of the EUT and of the consumables (date of production, date of arrival to the test laboratory, date and time of unpacking, storage time, environmental storing conditions before test).

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- Types of packaging.
- External dimensions.
- Number of hours the equipment has been used while energised during manufacture and testing.

Test conditions and methods

- Date of test.
- Description of the test apparatus and methods used (ETC, clean air system, environmental control system, sample collection, analytical instrumentation, standard generation and calibration).
- ETC test conditions (T, rH, n).
- Background concentrations (C_{bg}).
- Equipment loading factor.
- Type, start time and duration of preparation for newly manufactured equipment; for other equipment, the number of days in operation before test, if known; “not known” otherwise.
- Sampling methods used (sorbent(s) used, volume sampled, sampling start time and duration).
- Start and duration of pre-operating, operating and post-operating phases.
- Test specification for intended functions.
- Printing speed during test and number of printed pages.
- Lightness and/or colour values (L*, a*, b*) from printout.
- Ozone half-life of the unloaded ETC.
- Detection limits of VOC, carbonyl compounds, ozone- and particulate matter.
- Disturbances of - and deviations from test methods.

Emission rate determination

- Identification of the formulae used to determine specific emission rates from measured ETC concentrations.

Results

- Name, CAS-number and concentration of identified VOCs, formaldehyde and other carbonyl compounds in pre-operating phase and operating phase and calculated emission rates.
- Concentration of unidentified VOCs in pre-operating phase and operating phase and calculated emission rates.
- TVOC value calculated based on the response factor of toluene as specified in ISO 16000-6, for the RAL-UZ 122 Option.
- Maximum ozone concentration and calculated ozone emission rate.
- Ozone half-life following the operating phase.
- Mass of sampled particulate matter and calculated emission rate.

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Annex A
(normative)

Print patterns

A.1 Monochrome print pattern 5% coverage

Annex A.1 illustrates the monochrome pattern, that it is not to scale, with 5% black coverage; tests of EUT using paper consumables as specified in this International Standard shall be executed using the pattern at http://www.ecma-international.org/publications/standards/Ecma-328.htm.

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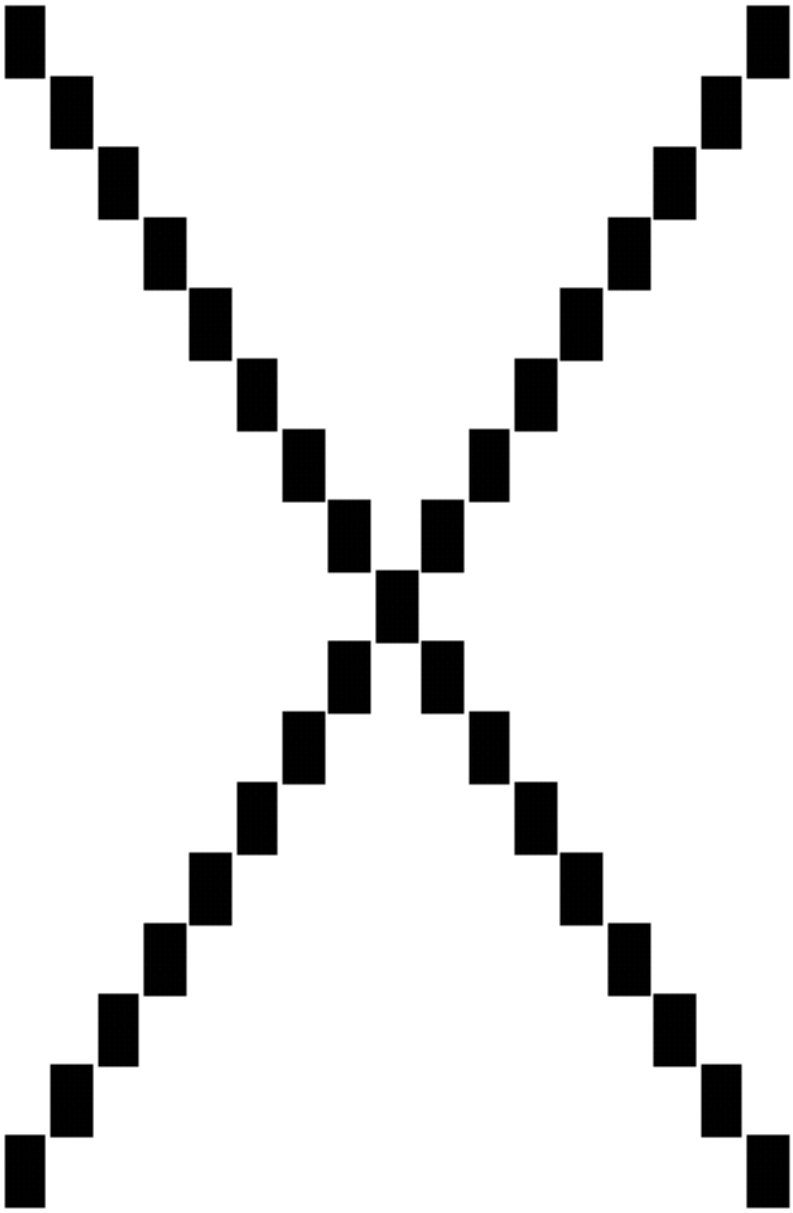

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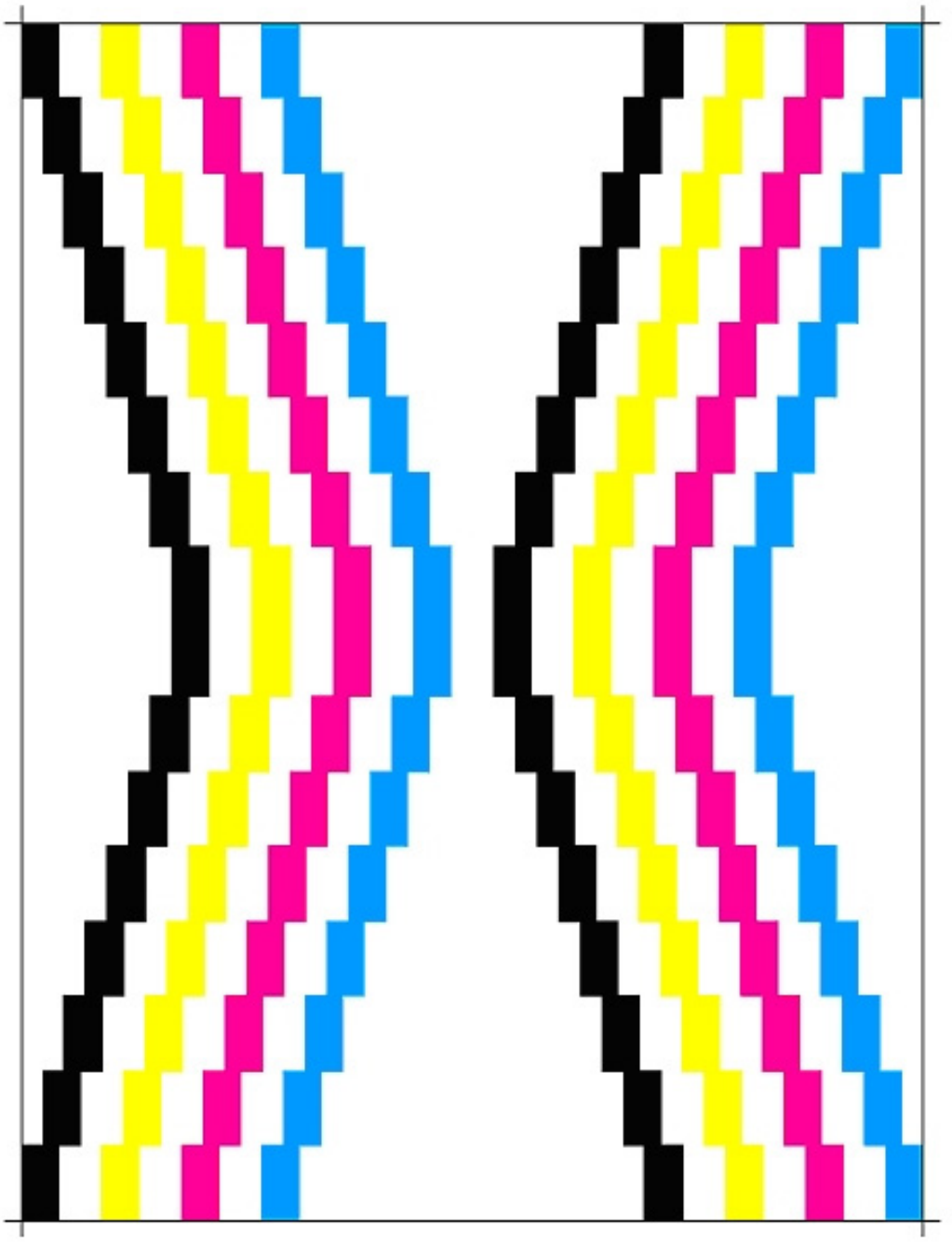
A.2 Colour print pattern, 20% coverage

Annex A.2 illustrates the colour pattern, that it is not to scale, with 20% colour coverage (5% for black, magenta, cyan and yellow); tests of EUT using paper consumables as specified in this International Standard shall be executed using the pattern at http://www.ecma-international.org/publications/standards/Ecma-328.htm.



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Annex B
(informative)

Emission rate model for EUT using consumables

B.1 Objective

This Annex develops a generalised formula to calculate emission rates from VOC, carbonyl compounds and particulate matter concentrations sampled in an ETC.

NOTE This Annex has been developed with Hard Copy Devices in mind therefore “printing phase” denotes the operating phase.

B.2 Approach

By sampling over a period of time averaged concentrations are acquired.

Emission rates must be calculated from these average concentrations. The average concentrations during printing can be described by 4 different regions as shown in Figure B.1. During printing, there are two regions: m1 for printing, and m2 for the decay of the initial concentration (C_0) and background concentration built up during the pre-operating phase. m3 represents the concentration decay from C_{max} during the post-operating phase, and m4 is the concentration build-up during the post-operating phase from pre-operating and background emission.

The following is assumed:

- The emission rates are constant.
- The emission rates during the post-operating and operating phases are equal.
- No energy saving modes apply during the pre- and post-operating phase.

Cases, where the above assumptions do not apply, are outside the scope of this International Standard.

B.3 General mass balance and concentration equations

The following mass balance is valid for an ETC containing an emission source with a SER:

$$\frac{dC}{dt} = \frac{SER}{V} - nC \qquad \text{(B.1)}$$

Integrate (B.1) to obtain C:

$$C = \frac{SER}{n \cdot V}[1 - \exp(-n \cdot t)] + C_0 \exp(-n \cdot t) \qquad \text{(B.2)}$$

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B.4 Background SER

With SER = SER_{bg} and C_0 = 0 in (B.2), the background concentration is:

$$C_{bg} = \frac{SER_{bg}}{n \cdot V}[1 - \exp(-n \cdot t)] \quad \text{(B.3)}$$

For $n \cdot t \geq 3$, (B.3) reduces to (equilibrium): $SER_{bg} = C_{bg} \cdot n \cdot V$ (B.4)

To simplify, SER_{bg} may be substituted by $C_{bg} \cdot n \cdot V$ (from B.4) in derived formulae below, as has been applied for the formulae in Clause 8.

B.5 Emission during pre-operating phase

Assume the emission model as shown in Figure B.1. During the pre-operating phase, there are two constant emission sources; one originates from the background of the ETC, and the other originates from the EUT in the pre-operating phase.

SER = SER_{bg} + SER_{pre} in (B.1) yields:

$$\frac{dC}{dt} = \frac{SER_{bg} + SER_{pre}}{V} - nC \quad \text{(B.5)}$$

$$C_{pre} = \frac{SER_{bg} + SER_{pre}}{n \cdot V}\left[1 - \exp(-n \cdot t)\right] + C_0 \exp(-n \cdot t)\Big] \quad \text{(B.6)}$$

Because the concentration at the beginning of the pre-operating phase (C_0) equals the background concentration C_{bg}, (B.6) becomes:

$$C_{pre} = \frac{SER_{pre}}{n \cdot V}\left[1 - \exp(-n \cdot t)\right] + \frac{SER_{bg}}{n \cdot V}\right] \quad \text{(B.7)}$$

The total measure for mass of sampled VOCs is equal to the product of the averaged concentration and sampling time ($C_{pre} \cdot t_{pre}$), and can be obtained by integrating (B.7) from $t=0$ to $t=t_{pre}$:

$$C_{pre} \cdot t_{pre} = \int_0^{t_{pre}} \left\{ \frac{SER_{pre}}{n \cdot V}\left[1 - \exp(-n \cdot t_{pre})\right] + \frac{SER_{bg}}{n \cdot V} \right\} dt = \frac{SER_{pre}}{n^2 \cdot V}[n \cdot t_{pre} + \exp(-n \cdot t_{pre}) - 1] + \frac{SER_{bg}}{n \cdot V} t_{pre} \quad \text{(B.8)}$$

Rearrange (B.8) for SER_{pre}:

$$SER_{pre} = \frac{C_{pre} \cdot n^2 \cdot V \cdot t_{pre} - SER_{bg} \cdot n \cdot t_{pre}}{n \cdot t_{pre} + \exp(-n \cdot t_{pre}) - 1} = \frac{(C_{pre} - C_{bg}) \cdot n^2 \cdot V \cdot t_{pre}}{n \cdot t_{pre} + \exp(-n \cdot t_{pre}) - 1} \quad \text{(B.9)}$$

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B.6 Emission during operating phase

During the operating phase the concentration build-up originates from EUT operation and the background concentration only. C_{ope}. Integration of (B.1) with SER = SER_{bg} + SER_{ope} yields:

$$C_{ope} = \frac{SER_{ope} + SER_{bg}}{n \cdot V}\left[1 - \exp(-n \cdot t)\right] + C_0 \exp(-n \cdot t)\Big] \quad \text{(B.10)}$$

NOTE In (B.10) Co is equal to the concentration at the end of the pre-operating phase (C_{pre}) determined in (B.7).

In Figure B.1, the terms from m1 to m4 denote the product of average concentration, stemming from a source, and the time period of the phase under consideration. Integrating equation (B.10) over time from zero to the end of printing (t_{ope}), yields m1 and m2.

$$m1 = \int_0^{t_{ope}} \frac{SER_{ope} + SER_{bg}}{n \cdot V}\left[1 - \exp(-n \cdot t)\right] dt = \frac{(SER_{ope} + SER_{bg}) \cdot [n \cdot t_{ope} + \exp(-n \cdot t_{ope}) - 1]}{n^2 \cdot V} \quad \text{(B.11)}$$

$$m2 = \int_0^{t_{ope}} \left[C_0 \exp(-n \cdot t)\right] dt = \frac{C_0 n \cdot V[1 - \exp(-n \cdot t_{ope})]}{n^2 \cdot V} \quad \text{(B.12)}$$

m1: Concentration area over time during printing

m2: Concentration area over time which decays from C_0 due to air exchange

m3: Concentration area over time which decays from C_{max} to the equilibrium concentration of pre-operating and background concentration

m4: Concentration area over time during pre-operating phase.

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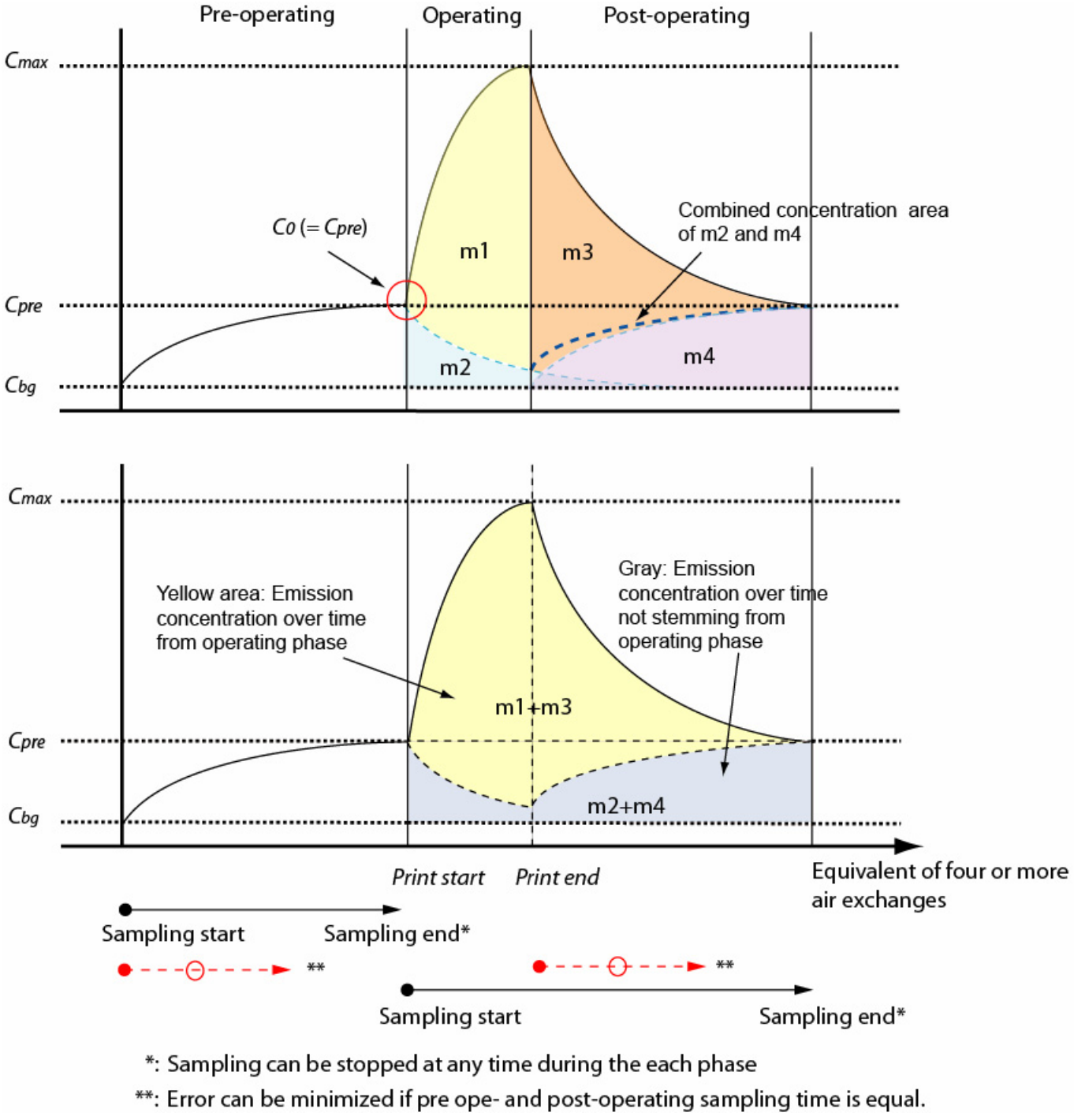

Figure B.1 — Representation of concentration change during printing and post operating phase

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B.7 Emission during post-operating phase

The concentration built-up from the operating phase (C_{max}) decreases with the air exchange in the post-operating phase. But emissions from background level to the level at the end of the pre-operating phase increase. Obtain C_{max} in Figure B.1 from (B.10) for $t = t_{ope}$:

$$C_{\max} = \frac{(SER_{ope} + SER_{bg})}{n \cdot V}[1 - \exp(-n \cdot t_{ope})] + C_0 \exp(-n \cdot t_{ope}) \tag{B.13}$$

Similar to (B.2), the concentration during the post-operating can be written as:

$$\underbrace{C_{post} = \frac{(SER_{pre} + SER_{bg})}{n \cdot V}[1 - \exp(}_{\text{Term due to emissions in post operating phase}} \underbrace{-n \cdot (t - t_{ope}))] + C_{\max} \exp[-n \cdot (t - t_{ope})]}_{\text{Concentration reached at } C_{max} \text{ decreased by air exchange}} \tag{B.14}$$

m3 in Figure B.1 is obtained by integrating the second term of (B.14) over time from t_{ope} to t_G.

$$m3 = \int_{t_{ope}}^{t_G} \left\{ \frac{(SER_{ope} + SER_{bg})}{n \cdot V}[1 - \exp(-n \cdot t_{ope})] + C_0 \exp(-n \cdot t_{ope}) \right\} \cdot [\exp(-n \cdot (t - t_{ope})] dt$$

$$= [\exp(-n(t_G - t_{ope})) - 1] \cdot \left\{ \frac{SER_{ope} + SER_{bg}}{n^2 \cdot V}[\exp(-n \cdot t_{ope}) - 1] - \frac{C_0}{n} \exp(-n \cdot t_{ope}) \right\} \tag{B.15}$$

Similarly, m4 can be found by integrating the first term of (B.14):

$$m4 = \int_{t_{ope}}^{t_G} \frac{(SER_{pre} + SER_{bg})}{n \cdot V}[1 - \exp(-n \cdot (t - t_{ope}))] dt$$

$$= \frac{(SER_{pre} + SER_{bg})}{n^2 \cdot V}[n(t_G - t_{ope}) + \exp(-n(t_G - t_{ope})) - 1] \tag{B.16}$$

The average concentration (C_{ope}) during sampling in the operating and post-operating phase is:

$$C_{ope} = \frac{m1 + m2 + m3 + m4}{t_G} = \frac{m_{ope}}{V_{ope}} \tag{B.17}$$

Insert m1, m2, m3 and m4 in (B.11), (B.12), (B.15), and (B.16) to obtain C_{ope} and rearrange for SER_{ope}:

$$SER_{ope} = \frac{C_{ope} \cdot n^2 \cdot V \cdot t_G - SER_{pre}[\exp(-n(t_G - t_{ope})) + n(t_G - t_{ope}) - 1]}{\exp(-nt_G) - \exp[-n(t_G - t_{ope})] + nt_{ope}}$$

$$- \frac{SER_{bg}[\exp(-nt_G) + nt_G - 1] + Co \cdot n \cdot V[1 - \exp(-n \cdot t_G)]}{\exp(-nt_G) - \exp[-n(t_G - t_{ope})] + nt_{ope}} \tag{B.18}$$

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The initial concentration C_0 can be determined from the emission during the pre-operating phase:

$$C_0 = \frac{SER_{pre}}{n \cdot V}\left[1 - \exp(-n \cdot t_{pre})\right] + \frac{SER_{bg}}{n \cdot V} \tag{B.19}$$

If the air exchange rates in the pre-operating and operating phase differ, n can be replaced by n_{pre}:

$$C_0 = \frac{SER_{pre}}{n_{pre} \cdot V}\left[1 - \exp(-n_{pre} \cdot t_{pre})\right] + \frac{SER_{bg}}{n_{pre} \cdot V} \tag{B.20}$$

(B.18) can be simplified using (B.19), where n is equal in the pre-, post- and operating phases:

$$SER_{ope} = \frac{C_{ope} \cdot n^2 \cdot V \cdot t_G - SER_{pre}[\exp(-n(t_G - t_{ope})) + n(t_G - t_{ope}) - 1 + (1 - \exp(-n \cdot t_{pre})) \cdot (1 - \exp(-n \cdot t_G))] - SER_{bg} \cdot n \cdot t_G}{\exp(-nt_G) - \exp[-n(t_G - t_{ope})] + nt_{ope}} \tag{B.21}$$

(B.21) is the general case formula used in the main text.

NOTE It is advised to use the same sampling time during pre-operating (t_{pre}) and post-operating (t_G-t_{ope}) if the emission behaviour of the EUT is unknown (one or more energy modes in addition to save energy mode). In that case, (B.21) can be reduced to:

$$SER_{ope} = \frac{C_{ope} \cdot n^2 \cdot V \cdot t_G - SER_{pre}[n(t_G - t_{ope}) - \exp(-nt_G) + \exp(-n \cdot (2t_G - t_{ope}))] - SER_{bg} \cdot n \cdot t_G}{\exp(-nt_G) - \exp[-n(t_G - t_{ope})] + nt_{ope}} \tag{B.22}$$

B.8 Special cases

Case 1 Pre-operating phase is relatively long ($nt_{pre} \geqslant 3$), and post-operating phase relatively long ($nt_G \geqslant 3$), (B.21) can be reduced to:

$$SER_{ope} = \frac{C_{ope} \cdot n^2 \cdot V \cdot t_G - SER_{pre} \cdot [n(t_G - t_{ope}) - \exp(-n \cdot t_{pre})] - SER_{bg} \cdot n \cdot t_G}{nt_{ope}} \tag{B.23}$$

and if $nt_{pre} \geqslant 3$, (B.23) can be reduced to:

$$SER_{ope} = \frac{C_{ope} \cdot n^2 \cdot V \cdot t_G - SER_{pre} \cdot [n(t_G - t_{ope})] - SER_{bg} \cdot n \cdot t_G}{nt_{ope}} \tag{B.24}$$

and if background concentration is neglected, (B.24) can be reduced to:

$$SER_{ope} = \frac{C_{ope} \cdot n^2 \cdot V \cdot t_G - SER_{pre} \cdot [n \cdot (t_G - t_{ope})]}{nt_{ope}} \tag{B.25}$$

Case 2 Pre-operating phase is relatively long ($nt_{pre} \geqslant 3$), and the air exchange rate during the pre-operating and operating phases are equal (n_{pre}=n), (B.21) can be reduced to:

$$SER_{ope} = \frac{C_{ope} \cdot n^2 \cdot V \cdot t_G - SER_{pre}[\exp(-n(t_G - t_{ope})) + n(t_G - t_{ope}) - \exp(-n \cdot t_G)] - SER_{bg} \cdot n \cdot t_G}{\exp(-nt_G) - \exp[-n(t_G - t_{ope})] + nt_{ope}} \tag{B.26}$$

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B.9 Model for RAL-UZ 122 Option

The model developed in earlier chapters of this annex, and the model for the RAL-UZ 122 Option only differ by the definition of the emission rate during the operating phase.

The emission rate during the operating phase can be thought to be composed of SER_{ope} and SER_{pre}, as described in the following model.

Figure B.2a presents the situation where equilibrium has been reached in the pre-operating phase. In Figure B.2b no equilibrium has been reached in the pre-operating phase, but it is assumed that the EUT enters an energy save mode during the pre-operating phase, so that a quasi-equilibrium is attained at the end of the pre-operating phase.

Emission is defined as: the area under the concentration curve, expressed by m1'+m3' in Figure B.2, which can be seen as the increase in concentration due to printing.

The SER_{ope} is:

$$SER_{ope} = \frac{C_{ope} \cdot n^2 \cdot V \cdot t_G - (SER_{pre} + SER_{bg}) \cdot [\exp(-nt_G) + nt_G - 1] - C_0 \cdot n \cdot V[1 - \exp(-n \cdot t_G)]}{\exp(-nt_G) - \exp[-n(t_G - t_{ope})] + nt_{ope}} \quad \text{(B.27)}$$

The initial concentration (C_0) is the same as in equation (B.19) or (B.20).

If the initial concentration is equal to the pre-operating equilibrium concentration (C_0=SER_{pre}/(n*V)) and n is equal in the pre-, post and operating phases (i.e. (B.19) holds), then (B.27) can be reduced to:

$$SER_{ope} = \frac{C_{ope} \cdot n^2 \cdot V \cdot t_G - SER_{pre} \cdot nt_G - SER_{bg} \cdot n \cdot t_G}{\exp(-nt_G) - \exp[-n(t_G - t_{ope})] + nt_{ope}} \quad \text{(B.28)}$$

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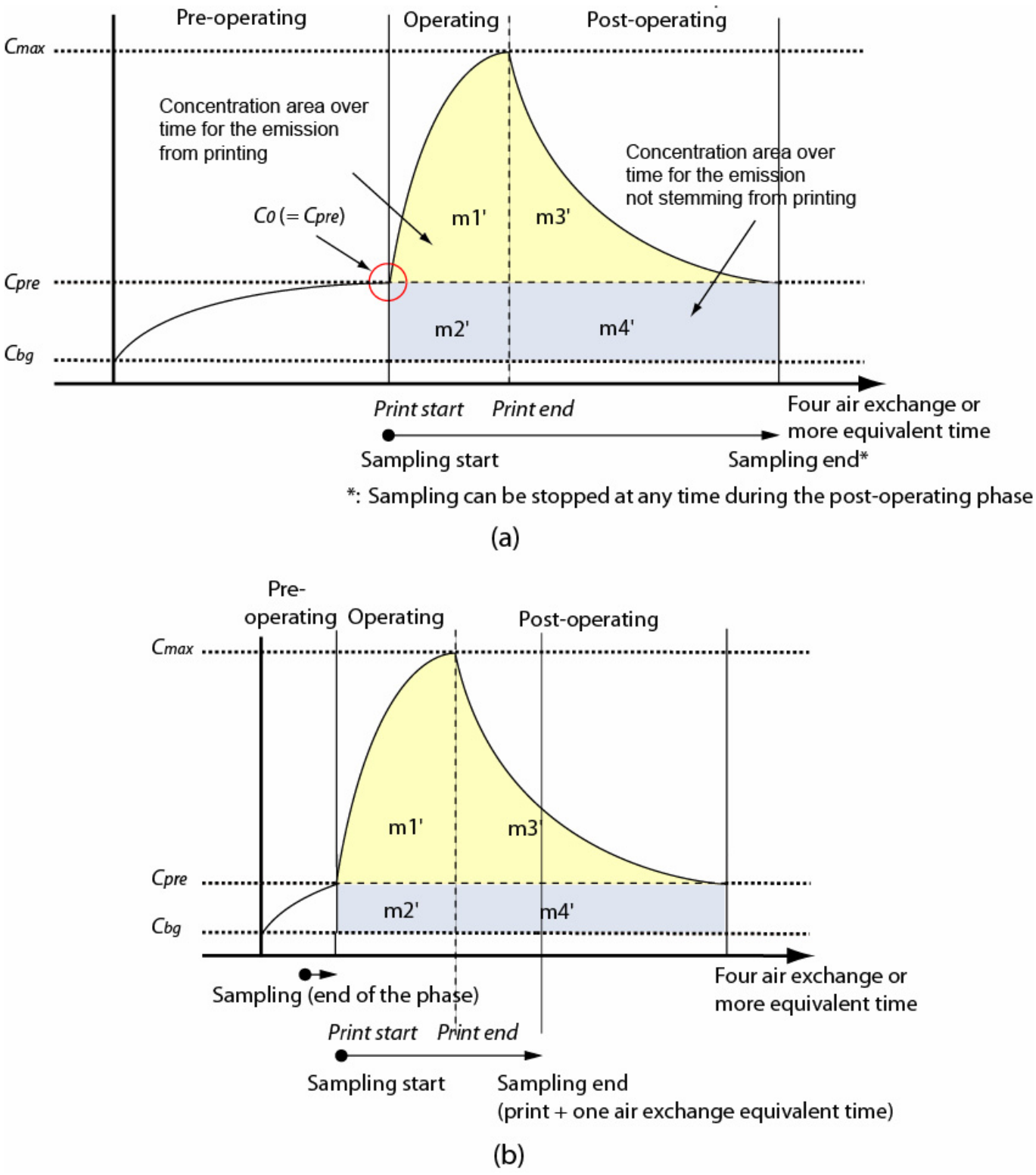

Figure B.2 — Model for equilibrium and constant C_o (a) and (b) RAL-UZ 122 Option model

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Annex C
(informative)

Influence of EUT filtering on SER_{O3}

This Annex describes the determination of the ozone emission rate for a EUT, when the effect of the ozone filtering capacity of the EUT in the operating phase is taken into account.

In 8.4 the ozone emission rate, SER_{O3}, is calculated from C_{max}, k, and V as follows:

$$\mathrm{SER}_{O3} = \frac{C_{max} k' V P}{T R} \quad \text{with} \quad k' = k + (n/60) = \frac{\ln 2}{H'} \tag{C.1}$$

When the equilibrium ozone concentration C_{max} in the ETC is attained, additional ozone may be injected in the ETC until the concentration, C_{peak}, is the greater of C_{max} + 0,2 mg/m^3 or 3C_{max}. The subsequent ozone decay is measured during operation of the EUT until the ozone concentration in the ETC returns to C_{max}.

Then, the ozone emission rate, SER_{O3}, is:

$$SER_{O3} = \frac{C_{max} k'' V P}{T R} \quad \text{with} \quad k'' = k + (n/60) + B \quad \text{and} \quad B = F \frac{Q}{V} \tag{C.2}$$

Where:

- B Ozone filtering capacity of the EUT;
- F Ozone filtering factor of the EUT (no filtration: F = 0; complete filtration: F = 1);
- Q Volumetric flow of air, expelled from the EUT [m^3/min].

If an ozone filter is present in the EUT, then the ozone filtering factor (F) must be determined by measuring ozone concentrations and volumetric flows at the exhaust of the EUT with and without ozone filter, using the following formula:

$$F = \frac{\left(Q_a C_a - Q_p C_p\right)}{Q_a C_a}$$

Where:

- Q_a Flow without ozone filter [m^3/min]
- C_a Ozone concentration without ozone filter [µg/m^3]
- Q_p Flow with ozone filter [m^3/min]
- C_p Ozone concentration with ozone filter [µg/m^3]

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NOTE The ozone filtering factor thus denotes how much ozone is removed from the filtered ozone flow in comparison to the total amount of ozone present in the flow before entering the filter. No filtration: F = 0; complete filtration = 1.

If more exhaust ports are present in the EUT, where ozone filtered air exits, then ozone-filtering capacities (Bi) should be summed, before substituting these in (C.2).

Furthermore:

$$k'' = \frac{\ln 2}{H''}$$

where:

- *H"* Ozone half life [min], time for the ozone concentration to fall to $(C_{peak} - C_{max})/2$;
- C_{peak} Highest ozone concentration value, reached at the end of the time when extra ozone is injected.

The ozone emission / generation rate can be calculated from (C.1) or (C.2) by using *k'* or *k"* respectively, c_{max}, *V*, *p* and *T*.

The applicability of (C.1) and (C.2) is illustrated in Figure C.1.

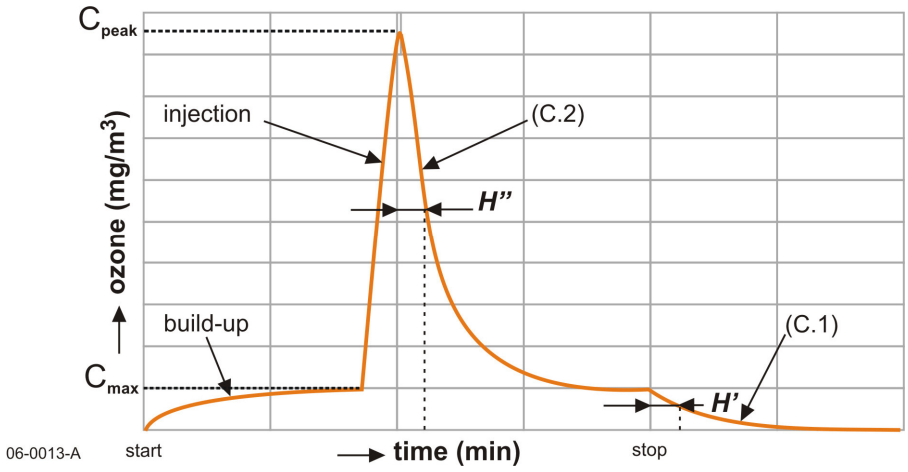

Figure C.1 — Application of equations (C.1) and (C.2)

"Start" and "stop" refer to the beginning, respectively the end of the operating phase.

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