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

**Part 2:  
Not using-consumables**

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





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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

ISO/IEC 28360-2 was prepared by Ecma International (as ECMA-328 Part 2) 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.

This first edition of ISO/IEC 28360-2, together with ISO/IEC 28360-1, cancels and replaces ISO/IEC 28360: 2015, which has been technically revised. It also incorporates the Technical Corrigendum ISO/IEC 28360: 2015/Cor.1:2016. The main changes compared to the previous edition are as follows:

- This edition was divided into a part for electronic equipment using consumables and a part for electronic equipment not using consumables as follows:
  - Determination of Chemical Emission Rates from Electronic Equipment — Part 1 (using-consumables);
  - Determination of Chemical Emission Rates from Electronic Equipment — Part 2 (not using-consumables).

The purpose of the split was to make the description of test procedures simpler (they included considerable differences between the two equipment categories) and to facilitate users' understanding.

- This edition is fully aligned with “Test method for the determination of emission from Hard Copy Devices” (RAL-UZ 205).

A list of all parts in the ISO/IEC 28360 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

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

Following the publications of the 1st edition of ECMA-328 in 2001 and the “Test method for the determination of emissions from Hard Copy Devices” (RAL-UZ 122), experts from the BAM and Ecma have collaborated to harmonise methods to determine the chemical emission rates from ICT & CE equipment in the 2nd edition.

In addition to stricter test procedures, the 2nd edition used generalised emission formulae, and their derivations developed in Annex C, to calculate emission rates from concentrations of analytes that are measured in Emission Test Chambers.

The 3rd edition was fully aligned with the 1st edition of ISO/IEC 28360:2007 adopted under ISO/IEC JTC 1 fast track procedure and published in September 2007.

In addition, the 4th edition fixed a number of errata on ISO/IEC 28360:2007 that JTC 1/SC 28 identified.

Following the publications of the 4th edition of ECMA-328 and the “Test method for the determination of emissions from Hard Copy Devices” (RAL-UZ 122), experts from the BAM, WKI, JBMIA and Ecma have collaborated to harmonise methods to determine the Fine Particle (FP) and Ultrafine Particle (UFP) emissions from hard copy devices in the 5th edition.

The 6th edition was aligned with the 2nd edition of ISO/IEC 28360:2012, and it added a new ozone calculation method. “Test method for the determination of emission from Hard Copy Devices” (RAL-UZ 122) has been replaced by “Test method for the determination of emission from Hard Copy Devices” (RAL-UZ 171) published in January 2013. Therefore, “RAL-UZ 122 option” is replaced with “RAL-UZ 171 option” in the 6th edition.

The 7th edition of ECMA-328 is fully aligned with ISO/IEC 28360:2015.

The 8th edition was divided into a part for electronic equipment using consumables and a part for electronic equipment not using consumables as follows:

- Determination of Chemical Emission Rates from Electronic Equipment — Part 1 (using-consumables);
- Determination of Chemical Emission Rates from Electronic Equipment — Part 2 (not using-consumables).

The purpose of the split was to make the description of test procedures simpler (they included considerable differences between the two equipment categories) and to facilitate users’ understanding.

This 8th edition is fully aligned with “Test method for the determination of emission from Hard Copy Devices” (RAL-UZ 205).

This part of the Standard is Part 2.



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

## Part 2: Not using-consumables

### 1 Scope

This Standard (all parts) specifies methods to determine chemical emission rates of analyte from ICT & CE equipment during intended operation in an Emission Test Chamber (ETC).

This Standard (all parts) includes specific methods for equipment using consumables, such as printers, and equipment not using consumables, such as monitors and PC's.

Part 2 specifies the methods to determine chemical emission rates of analyte from electronic equipment not using consumables.

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

Examples of 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).

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 Standard.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 16000-3:2011, *Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds in indoor air and test chamber air — Active sampling method*

ISO 16000-6:2011, *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 or 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*

ECMA-74, *Measurement of Airborne Noise emitted by Information Technology and Telecommunications Equipment*

EN 55013:2013, *Sound and Television Broadcast Receivers and associated equipment — Radio disturbance characteristics — Limits and methods for measurement*

### 3 Terms and definitions

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

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

#### 3.1

##### **averaged ozone concentration time series**

simple moving average of ozone concentration ( $\text{CO}_3$ ) over  $80 \pm 5$  seconds

#### 3.2

##### **air exchange rate**

$n$

ratio ( $n$ ) of the volume of clean air brought into the ETC per hour [ $\text{m}^3/\text{h}$ ] to the unloaded ETC volume [ $\text{m}^3$ ]

#### 3.3

##### **air velocity**

air speed [ $\text{m/s}$ ] measured in the unloaded ETC

#### 3.4

##### **analyte**

volatile organic compounds (VOC), carbonyl compounds and ozone

#### 3.5

##### **emission test chamber**

##### **ETC**

enclosure with controlled operational parameters for testing analyte mass emitted from EUT

#### 3.6

##### **equipment under test**

##### **EUT**

functional and complete ICT or CE equipment from which chemical emission rates are determined

#### 3.7

##### **loading factor**

ratio of the EUT volume to the volume of the unloaded ETC

#### 3.8

##### **operating phase**

phase in which the EUT is performing its intended functions in the ETC



**3.9****total volatile organic compounds****TVOC**

the sum of the concentrations of identified VOC and the concentrations of the converted areas of unidentified peaks using the toluene response factor

Note 1 to entry: This definition of “total volatile organic compounds” differs from the definition in ISO 16000-6:2011.

**3.10****unit specific emission rate****SER**

mass, in micrograms, of a specific analyte emitted per hour

Note 1 to entry: If more than one EUT is placed in the ETC, the determined SER is divided by the number of EUTs to obtain the unit specific emission rate  $SER_U$ .

**3.11****volatile organic compounds****VOC**

compounds that elute between n-hexane and n-hexadecane on a nonpolar GC-column

**4 Symbols and abbreviated terms****4.1 Abbreviated terms**

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
PTFE	Polytetrafluoroethene
PVC	Polyvinylchloride
RH	Relative humidity
SER	Unit Specific Emission Rate
TVOC	Total Volatile Organic Compounds
VOC	Volatile Organic Compounds

**4.2 Symbols**

$C_{bg}$	Background mass concentration [ $\mu\text{g m}^{-3}$ ]
$C_s$	Average mass concentration [ $\mu\text{g m}^{-3}$ ]
$C_{ope}$	Average mass concentration during operating phase [ $\mu\text{g m}^{-3}$ ]

$C_{O_3}$	Ozone concentration [mg/m <sup>3</sup> ]
$m_s$	Sampled mass [µg]
$m_{bg}$	Sampled mass for chamber background [µg]
$m_{ope}$	Sampled mass [µg] during operating phase
$n$	Air exchange rate [h <sup>-1</sup> ]
$p$	Atmospheric pressure [Pa]
$R$	gas constant [PaK-1], (for ozone: 339,8 [PaK-1])
$SER_{O_3}$	SER for ozone [µg min <sup>-1</sup> ]
$SER_u$	SER per unit [µg h <sup>-1</sup> u <sup>-1</sup> ]
$T$	Ambient temperature [K]
$u$	Number of EUTs units
$V$	ETC volume [m <sup>3</sup> ]
$V_s$	Sampled air volume [m <sup>3</sup> ]
$V_{bg}$	Sampled air volume [m <sup>3</sup> ] for determination of $C_{bg}$
$V_{ope}$	Sampled air volume [m <sup>3</sup> ] in operating phase

## 5 Conformance

Determinations of emission rates conform to this Standard (Part 2) 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](#);
3. Sampled/monitored and calculated as specified in [Clause 8](#);
4. Reported as specified in [Clause 9](#).

## 6 Method overview

The flowchart in [Figure 1](#) illustrates the method; clause numbers are indicated in brackets.

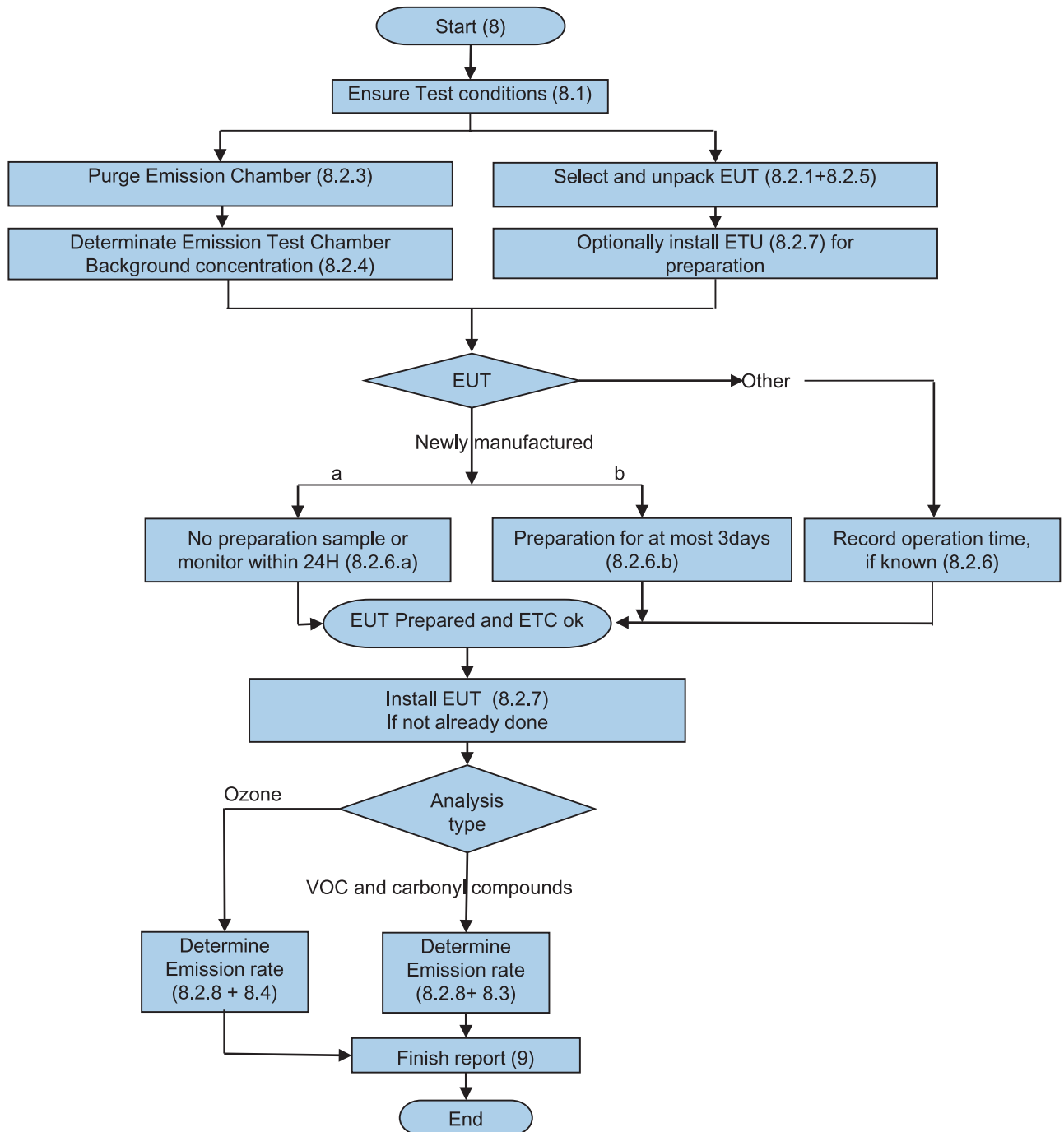


Figure 1 — Determination method overview

## 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

### 8.1 Test conditions

#### 8.1.1 General

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](#).

#### 8.1.2 Operating temperature and relative humidity (RH)

Tests shall be executed at  $(23 \pm 2) ^\circ\text{C}$  and  $(50 \pm 5) \% \text{ RH}$  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.

#### 8.1.3 Air exchange rate ( $n$ )

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

#### 8.1.4 Air velocity

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

#### 8.1.5 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

#### 8.2.1 Selection and storage of EUT

EUT shall be selected from normal manufactured batches or shall be a prototype that is representative for EUT from such batches.

#### 8.2.2 Loading Factor

To ensure detection of a minimum emission within a practicable time, the ETC with capabilities as specified in [Clause 7](#) shall be selected such that the loading factor is in the range of 1:4 to 1:100.

#### 8.2.3 ETC purging

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

The ozone half-life, the period of time for the ozone concentration ( $C$ ) to drop from  $C$  to  $C/2$ , shall be greater than 10 minutes, when  $n = 1$ .

To determine the ozone half-life, the ETC should be deactivated by exposure to an ozone concentration of  $0,2 \text{ mg/m}^3$  to  $0,4 \text{ mg/m}^3$  for at least ten minutes or until a stable concentration is reached.

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

### 8.2.4 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
VOC and carbonyl compounds	2 [ $\mu\text{g}/\text{m}^3$ ] for any analysed substance
TVOC	20 [ $\mu\text{g}/\text{m}^3$ ]
Ozone	4 [ $\mu\text{g}/\text{m}^3$ ]

### 8.2.5 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 [8.2.6](#)).

NOTE After unpacking, installation (step [8.2.7](#)) may precede the preparation (step [8.2.6](#)).

### 8.2.6 Preparation of the EUT before testing

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:

- The EUT shall not be operated before testing; testing shall start within 24 hours after unpacking.
- The EUT shall have been in operation for a maximum of three days or equivalent before the start of testing.

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.

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.

### 8.2.7 EUT installation

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 55013:2013 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.

## 8.2.8 EUT operation during test

### 8.2.8.1 General

VOC and carbonyl compounds shall be determined as specified in 8.3 and ozone should be determined as specified in 8.4 while continuing to execute its intended functions as initiated during installation (see 8.2.7).

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

### 8.2.8.2 Recording of EUT operation

The start of the operating phase shall be recorded as the time  $t_0$ .

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

## 8.3 VOC, carbonyl compounds

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

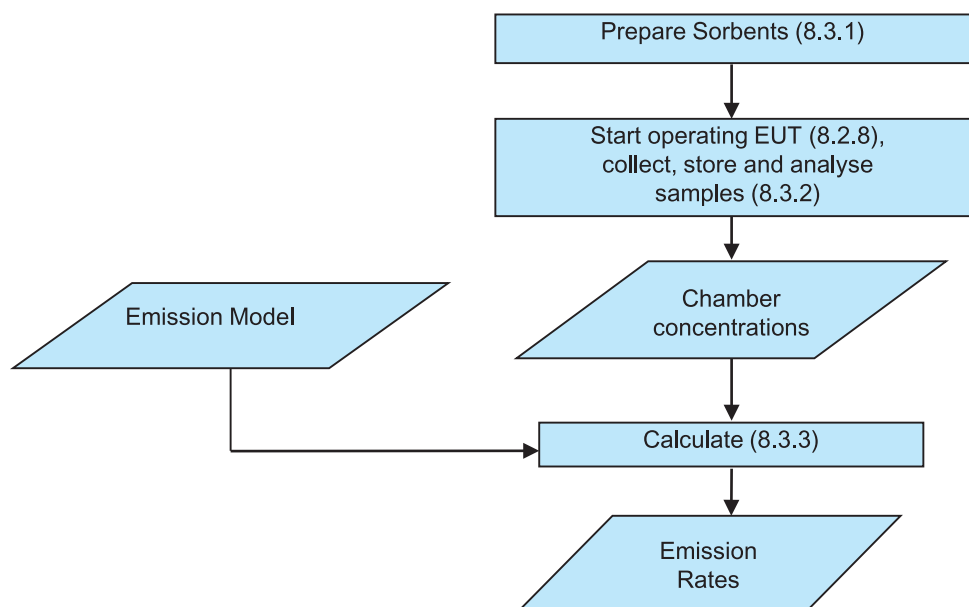


Figure 2 — Determination method for VOC, carbonyl compounds

### 8.3.1 Sorbents

VOC sampling and analysis shall be performed using the sorbents as specified in ISO 16017-1, with the exception of Chromosorb and PoraPak 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 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 at least one sample shall be taken.

Individual VOCs, carbonyl compounds with a concentration  $\geq 1,0 \mu\text{g}/\text{m}^3$  shall be detected.

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.

### 8.3.3 Emission rate calculation

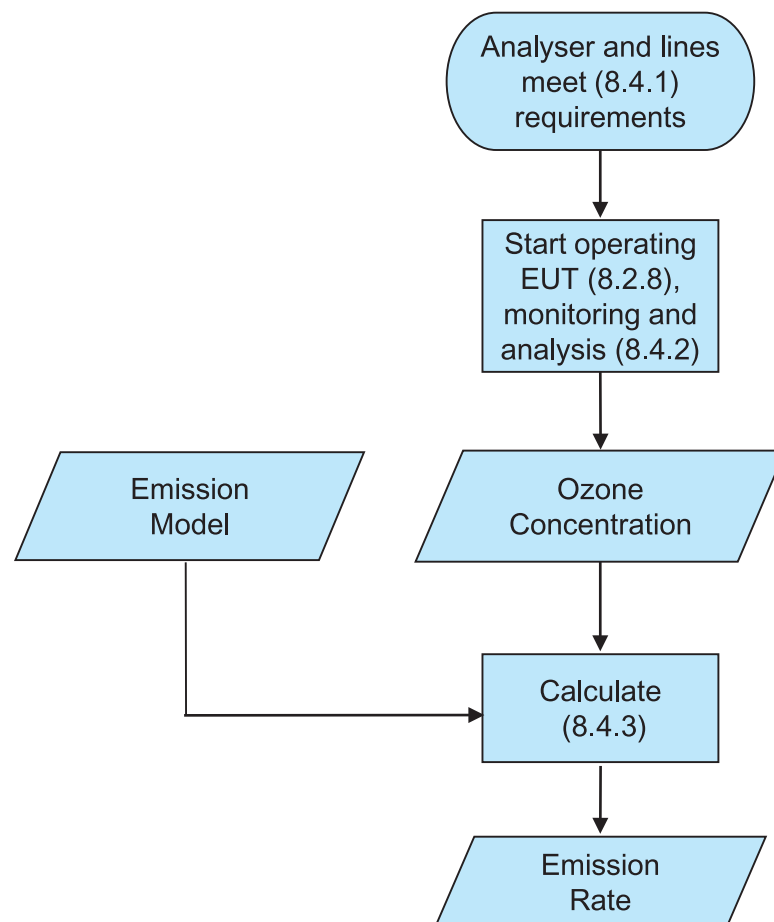
This Clause specifies formulae that apply to practical situations that are special cases of the general case. Concentrations shall be determined, using the following equations:

$$C_s = \frac{m_s}{V_s} \quad C_{ope} = \frac{m_{ope}}{V_{ope}} \quad C_{bg} = \frac{m_{bg}}{V_{bg}} \quad (1)$$

$$SER_u = \frac{(C_{ope} - C_{bg}) \cdot n \cdot V}{u} \quad (2)$$

## 8.4 Ozone

The flowchart in [Figure 3](#) illustrates the determination method for ozone.



**Figure 3 — Determination method for ozone**

### 8.4.1 Analyser and sampling line requirements

Ozone analysers shall at least fulfil the following requirements:

- The capability to detect concentrations between 4 µg/m<sup>3</sup> and 1mg /m<sup>3</sup>;
- A precision of 2 µg/m<sup>3</sup>;
- A sampling rate (may be important for small ETCs) of ≤2 l/min.

Ozone concentrations of the data points used to determine the maximum  $\Delta C_{O_3}$  shall not be rounded to the nearest whole ppb ( $1,963 \mu\text{g}/\text{m}^3$ ) by data processing of the analyser because rounding may cause errors in the determination of the  $\Delta C_{O_3}$ .

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 20 seconds for at least the first 6 minutes of the operating phase to determine the maximum  $\Delta C_{O_3}$  as specified in 8.4.3. In addition, data points before and/or after the first 6 minutes of the operating phase shall be sampled so that the averaged ozone concentration time series can be calculated as specified in 8.4.3.

### 8.4.3 Emission rate calculation

The ozone emission rate is derived from the increase in ozone concentration during the first 6 minutes after  $t_0$ . In this period of the operating phase ozone loss by chemical reactions with air constituents and by discharge due to air exchange is comparatively small. Therefore, the increase of ozone concentration with time is approximated as linear.

By taking formula (3) in this period

$$\frac{\Delta m}{\Delta t} = \frac{\Delta C_{O_3} \times V}{\Delta t} \quad (3)$$

where

$\Delta m$  is the emitted ozone mass [mg];

$\Delta C_{O_3}$  is the change of ozone concentration [ $\text{mg}/\text{m}^3$ ];

$\Delta t$  is the time interval [min];

the emission rate of ozone shall be calculated by formula (11):

$$SER_{O_3} = \frac{\Delta C_{O_3} \times V \times p \times 60}{\Delta t \times T \times R} \quad (4)$$

A time interval  $\Delta t$  of two minutes and the maximum  $\Delta C_{O_3}$  shall be applied in formula (11). The data points recorded in 6 minutes from the start of the operating phase shall be used to determine the maximum  $\Delta C_{O_3}$ . This is the case when the averaged ozone concentration time series exhibits the greatest slope for the two minute time interval ( $C_{O_3}(t + 2) - C_{O_3}(t) = \text{maximum}$ ). The Averaged ozone concentration time series is created with the Simple Moving Average over  $80 \pm 5$  seconds.

**NOTE** Theoretically, a time interval of the data points at the start of the operating phase gives the maximum  $\Delta m/\Delta t$  leading to the true emission rate. However, deviations of measured ozone concentration curves from the theoretical curve occur due to fluctuations of ozone data caused by incompleteness of air mixing in the chamber and effects of electric noises of ozone analysers, especially in larger chambers. The deviations make it difficult to determine an ozone emission rate according to the theory. Effects of electric noises can be reduced significantly by using the averaged ozone concentration time series. In addition,  $\Delta t$  of 2 minutes is selected and the determination of the maximum  $\Delta C_{O_3}$  for 6 minutes is conducted to minimize the effects of remaining fluctuations.

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),  $SER_{O_3}$  shall be calculated using the



actual ETC pressure ( $p$  in Pa), the actual ETC temperature ( $T$  in K) and the gas conversion constant ( $R = 339,8 \text{ Pa/K}$ ), otherwise  $p/TR = 1$  shall be used:

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

## 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.
- History of the EUT (date of production, date of arrival to the test laboratory, date and time of unpacking, storage time, environmental storing conditions before test).
- 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).
- Statement on the compliance to Quality Assurance items.
- Name and storage location of the raw data measurement files.
- Name and storage location of the ASCII-export data files.
- ETC test conditions ( $T$ ,  $RH$ ,  $n$ ).
- Background concentrations ( $C_{bg}$ ).
- 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 operation.
- Test specification for intended functions.
- Ozone half-life of the unloaded ETC.

- Detection limits of VOC, carbonyl compounds and ozone.
- Disturbances of - and deviations from test methods.

**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 operating phase and calculated emission rates.
- TVOC value calculated based on the response factor of toluene as specified in ISO 16000-6.
- Maximum change of ozone concentration for 2 minutes and calculated ozone emission rate.



