Fugitive and diffuse emissions of common concern to industry sectors — Measurement of fugitive emission of vapours generating from equipment and piping leaks

ICS 13.040.40

National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Emissions fugitives et diffuses concernant les secteurs industriels - Mesurage des émissions fugitives de composés gazeux provenant d'équipements et de canalisations

Fugitive und diffuse Emissionen von allgemeinem Interesse für Industriebereiche - Messung fugitiver Emissionen von Gasen und Dämpfen aus Lecks von Betriebseinrichtungen und Rohrleitungen

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Contents

Foreword

This document (EN 15446:2008) has been prepared by Technical Committee CEN/TC 264 “Air quality”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by July 2008, and conflicting national standards shall be withdrawn at the latest by July 2008.

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This European Standard has been elaborated under a mandate of the European Commission/DG Enterprise to support essential requirements of the IPPC Directive (96/61/EC).

The horizontal approach of common concern to industrial sectors is to gather industries concerned with diffuse/fugitive emissions and to develop methods suiting their needs. The industries of three trade associations have participated: EUROFER, EUROMETAUX and CEFIC. For practical reasons the two developed measurement methods, one for dusts and the other for gases are published as two separate standards.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

A portable instrument is used to detect VOC leaks from individual sources. Any detector type is allowed, provided it meets the specifications and performance criteria contained in Clause 5. This procedure is intended to locate the leaks, and to estimate the mass emission rate from individual sources and the total emission of the industrial facility over a reporting period by using:

— EPA or user-defined correlations whenever possible;

— fixed emission factors, in all other cases.

1 Scope

This standard applies to the measurement of fugitive emissions of volatile organic compounds (VOCs) from process equipment. The leak sources include, but are not limited to, valves, flanges and other connections, pressure relief devices, process drains, open-ended valves, pump and compressor seal systems, agitator seals, and access door seals. It does not apply to instrument tubing connections.

This standard applies to all products of which at least 20 % by weight has a vapour pressure higher than 0,3 kPa at 20 °C. For the petroleum industry, this includes all light products and excludes kerosene and all heavier products.

The standard is based on the measurement of the gas concentration at the interface of a leak. This concentration is measured with a portable instrument. It is converted to a mass emission rate by use of a set of correlations. The scope of this standard includes the complete data processing, from the initial concentration measurement up to the generation of an emission report over a reporting period (which is generally one year)[1]).

This standard does not prescribe the number of potential emission points that should be screened each year nor the frequency at which these points should be screened. This sampling strategy shall indeed take into account the plant characteristics and the required level of control over fugitive emissions.

Optical methods are currently under development to ease the detection of leaks in plants and use of this standard in conjunction with these methods might be possible. In any case, measurements have to be performed according to the requirements of this standard. To enable direct quantification of total fugitive emissions based only on these methods, a subsequent revision of this standard will be needed.

2 Normative references

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

ISO 5725-2, *Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method (ISO 5725-2:1994 including Technical Corrigendum 1:2002)*

3 Terms and definitions

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

3.1
fugitive emission
emission to the atmosphere caused by loss of tightness of an item which is designed to be tight

3.2
screening
action of measuring the concentration in VOC at the interface of a potential leak source

3.3
screening Value
local VOC concentration at the surface of a leak source that indicates a VOC emission is present

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[1]) The standard aims at significantly improving the consistency of emissions reporting, however determination of the trueness of the method is not in the current scope of the TWG.

NOTE The value is an instrument reading based on a reference compound. These values are indicated in ppm(*v/v*) (abbreviated as ppm in the remainder of the text).

3.4
threshold concentration
pre-set performance target for the individual sources

3.5
reference compound
VOC substance selected to express the screening value concentration

3.6
calibration gas
VOC substance used to adjust the instrument meter reading to a known value

NOTE The calibration gas is usually the reference compound at a predefined concentration.

3.7
response factor
ratio between the actual concentration of VOC present at the location where a screening measurement is made and the observed meter reading

NOTE This ratio represents the correction that shall be applied to the meter reading to take into account that the meter has been calibrated with a calibration gas that can be different from the substance or mix of substances present in a leak.

3.8
calibration precision
degree of agreement between several measurements of calibration gas with the same known concentration

NOTE It is the ratio of the average absolute value of the difference between the meter readings and the known concentration to the known concentration, expressed in percent.

3.9
response time
time interval from a step change in VOC concentration at the input of the sampling system to the time at which 90 % of the corresponding final value is reached as displayed on the instrument readout meter

4 Measurement equipment

4.1 Specifications of equipment

1) VOC instrument detector shall respond to the compounds being screened. Detector types that may meet this requirement include, but are not limited to, catalytic oxidation, flame ionisation, infrared absorption, and photo ionisation.
2) Maximum admissible lower detection limit of the detector provided by the manufacturer shall be 10 ppm.
3) Scale resolution of the instrument meter shall be ± 5 % of the threshold concentration.
4) Instrument shall be equipped with a pump so that a continuous sample is provided to the detector. The nominal sample flow rate shall be 0,2 l/min2) to 1,2 l/min2).
5) Instrument shall be intrinsically safe for operation in explosive atmospheres.
6) Instrument shall be equipped with a probe or probe extension for sampling with a maximum outside diameter of 6,4 mm, with a single end opening for admission of the sample.

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2) Based on available equipment. Actual range is 0,25 to 1,0 l/min.

7) Instruments used for quantification of fugitive emissions shall have a minimum measurement range up to 50 000 ppm.

NOTE In case a survey is performed solely to detect leaks or verify repair quality and is not intended to be used for emission quantification purposes, these requirements do not apply.

4.2 Performance criteria

1) Instrument response factors for the individual compounds to be measured shall be less than 10.

2) Instrument response time shall be equal to or less than 5 s. The response time shall be determined for the instrument configuration to be used during screening.

3) Calibration precision shall be lower or equal to 10 % of the calibration gas value.

4) Evaluation procedure for each of these parameters is given in Annex A.

4.3 Performance evaluation requirements

1) Response factors shall be determined according to the requirements set in 6.4. In case these need to be used, the determination of the response factors should take place before actual measurements are performed.

2) Calibration precision test shall be completed prior to placing the analyser into service, and at subsequent 3 month intervals or at the next use, whichever is later.

3) Response time test is required before placing a new instrument into service for the first time. If a modification to the sample pumping system or flow configuration is made that would change the response time, a new test is required before further use.

5 Chemicals / Calibration gases

1) Monitoring instrument is calibrated in parts per million by volume [ppm(*v/v*)] of the reference compound specified in the applicable regulation when possible, or with another calibration gas.

2) Gases required for monitoring and instrument performance evaluation are:

   – zero gas (air, less than 10 ppm VOC);

   – mixture of calibration gas in air with a concentration approximately equal to the threshold concentration specified in the regulation (two different concentrations are used, usually 1 000 ppm and 10 000 ppm).

3) If cylinder calibration gas mixtures are used, the concentration in calibration gas shall be analysed and certified by the manufacturer to be within ± 2 % accuracy, and a shelf life should be certified. Cylinder standards shall be either reanalysed or replaced at the end of the specified shelf life. Alternatively, calibration gases may be prepared by the user according to any documented gas preparation procedure that will yield a mixture accurate to within + or - 2 %. Prepared standards will be replaced each day of use unless it can be demonstrated that no degradation occurs during storage.

4) Calibration may be performed using a compound other than the reference compound provided a conversion factor is determined for that alternative compound in order to convert the resulting meter readings during emission surveys to reference compound measurements.

6 Procedures

6.1 Preparation

1) At the beginning of the instrument performance evaluation test, assemble and start up the instrument according to the manufacturer's instructions for the recommended warm-up period and preliminary adjustments.

2) Perform the instrument response time test and calibration precision test provided in Annex A when required. This evaluation shall be performed at first use and after instrument maintenance.

6.2 Check and adjustment

1) Assemble and start up the VOC analyser according to the manufacturer's instructions. After the appropriate warm-up period and zero internal calibration procedure, introduce the calibration gas into the instrument sample probe.

2) Introduce the calibration gas with the highest concentration into the instrument sample probe and adjust the instrument meter readout to correspond to the calibration gas value.

3) If the meter readout cannot be adjusted to the proper value, a malfunction of the analyser is indicated and corrective action should be taken before use.

4) Check the instrument with the calibration gas with the lower concentration, according to the manufacturer’s instructions[3]). If the reading is within 10 % of the calibration gas concentration, the check is accepted. Otherwise the check procedure needs to be restarted or corrective action is required.

5) Checking of the VOC analyser as per articles 1 to 4 in clause 6.2 should be performed at least once a day, before starting the measurements. If checks are performed during the day and the reading is found to be deviating from the calibration gas concentration by more than 10 %, the instrument needs to be adjusted and re-checked, and screening values obtained since the last correct check will be discarded.

6) A last check shall be performed after the last measurement. Screening values measured since the last correct check with an instrument that is not properly adjusted will be discarded.

6.3 Individual source survey

6.3.1 Scope of survey

1) All leak sources in process service within the vapour pressure limits, as indicated in the scope of this standard, shall be screened.

2) Exclusions are:
items under vacuum (since fugitive emissions from items under vacuum are non-existent).

3) General practice is also to exclude:
items not accessible (i.e. requiring special measures to be monitored, such as scaffolding, ...),
items for which monitoring would require some dismantling, e.g. of insulation,
and items for which monitoring could entail safety issues.
In petroleum refineries, items lower or equal to 50,8mm are normally excluded from sniffing measurements.

4) When specific categories of equipment are excluded from screening, emissions from these points will be based on the methodology described in 6.5, articles 5 and 6.

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[3]) Some screening measurements will be extrapolated since the calibration gas is usually at 1 000 ppm and 10 000 ppm.

6.3.2 Screening procedure

1) Place the probe inlet at the surface of the point of equipment where leakage could occur.

2) Move the probe along the interface periphery while observing the instrument readout.

3) If an increased meter reading is observed, slowly sample the interface where leakage is indicated until the maximum meter reading is obtained.

4) Leave the probe inlet at this maximum reading location for approximately twice the instrument's response time, record the results as screening value (ppm).

5) Care should be taken to minimize the effect of the wind when the wind speed exceeds 0,5 m/sec, particularly when working in elevation.

6) Examples of the application of this general technique to specific equipment types are described below and illustrated in Chapter 3 of Reference 1:

   - Valve stem: Leaks can occur at the interface between the seal and the stem or the seal and the stuffing box. Place the probe at the interface where the stem exits the packing and sample the stem circumference. Repeat for packing gland nose.

   - Flange and other connection (including valve bonnet, valve flanges and body flanges of equipment): Place the probe at the outer edge of the flange-gasket interface and sample the circumference of the flange or connection.

   - Pump or compressor seal: Place the probe at the interface of the seal with the shaft and sample the circumference, maintaining the probe tip within 1 cm of the shaft-seal interface. A spacer can be used to avoid direct contact of the probe tip with rotating parts.

   - Pressure relief device: For those devices discharging to atmosphere, place the probe inlet at approximately the centre of the exhaust area to the atmosphere. This measures leakage through the normal pressure relief discharge path. No other leakage path is normally expected on these devices.

      - Process drains: For open drains, place the probe inlet as near as possible to the centre of the area open to the atmosphere. For covered drains, locate probe at the surface of the cover and move around the periphery.

      - Open-ended lines or valves: Place the probe inlet approximately at the centre of the opening to the atmosphere.

      - Access door seals: Place the probe inlet at the surface of the door seal interface and move around the periphery.

6.4 Determination of the mass emission rate

6.4.1 Response factor

1) Response factors should be used whenever possible to correct the screening value indicated by the instrument for differences in response between the vapour being measured and the gas used for calibration. These may be provided by equipment manufacturers either as single values or per strata of concentration.

2) For pure chemicals, response factors corresponding to the measured concentration strata provided by the instrument manufacturer shall be used. If not available, response factors shall be determined by measurement of samples of the vapour to be screened having a known composition. Alternatively, response factors can be approximated by analogy with similar chemical species.

3) For chemical mixtures, a theoretical calculation of the response factor of the mix can be used as an alternative to direct measurement. This calculation shall be based on a reasonable approximation of the stream composition and on the response factors provided by the equipment manufacturer (or determined by the user) for each individual component. The calculation method is provided in Annex B.

4) Depending on the instrument, the response factors of streams present in most refinery or petrochemical units will usually be in the range of 0,5 to 1,3. In this case the use of response factors is optional[4]).

6.4.2 Correlation

1) Screening values (in ppm) corrected by response factors as required in 6.4.1 shall be converted into leak rates (in kg/h per leak) by using correlations. Several sets of correlations are available. The most frequently used sets of correlations are these published by the US EPA, namely the SOCMI correlations (developed for the Chemical industry) and the Petroleum Industry correlations. These are described in Annex C.

2) Until verification of the resulting emission calculations with data obtained through other reliable methods is available, it is recommended to use SOCMI correlations for applications in the Chemical industry and Petroleum Industry for applications in the Petroleum industry, including distribution and storage facilities.

3) Alternatively, user-defined correlations can be used provided these are developed according to the guidelines detailed in Reference 1 found in the bibliography of this standard.

4) Even if the use of dilution probes allow the measurement of very high concentrations, in most instances screening values are measured to a maximum which is lower or equal to 100 000 ppm. Using screening values up to 100 000 ppm is recommended whenever it is feasible.

5) For screening values exceeding the range of measurements (most frequently 100 000 ppm), a fixed emission factor (so-called "pegged" factor) is used. For US-EPA correlations, pegged factors are provided in Annex C corresponding to a maximum reading of 100 000 ppm. If measurements are made to a maximum that is lower than 100 000 ppm, another fixed ("pegged") emission factor shall be used to calculate emissions corresponding to all screening values above 10 000 ppm (also provided in Annex C). If measurements are made to a maximum that is higher 100 000 ppm, the correlation shall be used for all data that are within the measurement range of the equipment, and pegged values at 100 000 ppm shall be used for values beyond the data range of the equipment.

6) VOC emissions corresponding to screening values below the detection limit of the instrument can be excluded from the calculation.

7) Determination of background concentration can be used to adjust the screening value, provided that it will be executed as described in the EPA documentation.

6.4.3 Speciation

Speciation of the emissions per chemical for mixed streams can be done by using the weight ratio of each chemical in the stream.

6.5 Determination of the total emission over a specified period of time

1) Total mass emission over a reporting period shall be taken as the average between the total emission rate at the beginning of the reporting period and the total emission rate at the end of the reporting period, multiplied by the duration of the reporting period.

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[4]) In refineries and some petrochemical installations, the chemical composition of many streams is not known precisely because it depends on the feedstock quality and on the operating parameters.

2) Total emission rate at the beginning or at the end of the reporting period shall be based on the measurement most representative of the emission from each item respectively at the beginning or at the end of the period.

3) For items that were screened during the reporting period, the most representative measurement for the beginning of the reporting period shall be taken as the first measurement made during the reporting period.

4) For items that were screened during the reporting period, the most representative measurement for the end of the reporting period shall be taken as the last measurement made during the reporting period.

5) For items that were not screened during the reporting period, the most representative measurement for the beginning and the end of the reporting periods shall be based on the most recent measurement available.

6) Emission rates from sources never screened shall be based on the initial average screening value from similar sources. If these are not available, the average factors corresponding to the relevant correlations shall be used. These average factors are provided in Annex C for US-EPA correlations.

7) Plant operator is best placed to decide on grouping of sources for the purpose of using average emission values for similar sources. Grouping based on finer criteria will require more data input (hence demonstrate a more detailed management of emissions) and enable the development of marginally lower emission calculations.

8) After a repair is executed sufficient time should be allowed for stabilisation under operating conditions before a valid screening value can be measured5)).

9) Emissions during the period in which equipment is depressurised are assumed equal to zero and can be proportionally deducted from the total emission of the equipment during the reporting period.

NOTE A software package is available at CEN to verify that the data handling and emission quantification embedded in the tool used by a reporting entity corresponds to the requirements of this standard.

7 Precision

7.1 General

The precision parameters are calculated according to ISO 5725-2 based on a round robin test involving four laboratories measuring 108 points twice. All labs were using FID apparatus and used response factors as appropriate.

7.2 Repeatability

During this test, a repeatability standard deviation of 34,5 % was found on screening measurements (in ppm). The repeatability standard deviation of the total mass flow (in kg/Year) was 24,5 %.

7.3 Reproducibility

During this test, a reproducibility standard deviation of 46,5 % was found on screening measurements (in ppm). The reproducibility standard deviation of the total mass flow (in kg/Year) was 40,5 %.

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5) No defined timing should be imposed to ease planning of the repair and re-measurement activities. A period of 2 weeks is often recommended.

8 Report

Emission reports shall include the following information:

- scope of the report (facility, type and size of equipment measured, streams, purpose, reporting period);
- results expressed in mass per year (indicating how this mass is specified: as reference compound equivalent, carbon equivalent, actual composition of emission …);
- characteristics of instrument used;
- response factors that have been used. In case these are provided per concentration strata by the manufacturer, these values should be provided. Source of information for response factors. Substances for which response factor is unknown shall be indicated.
- value of the threshold concentration;
- which correlation is used;
- which pegged value is used;
- max. ppm used in correlations;
- number of components measured during the reporting period;
- number of components measured in a previous reporting period;
- number of components never measured;
- handling of equipment not measured;
- grouping of equipment in case average leak rates are derived from plant data.

Annex A
(normative)

Evaluation procedure of instrument performance parameters

A.1 Response time test procedure

Introduce zero gas into the instrument sample probe. When the meter reading has stabilised, switch quickly to the specified calibration gas. Measure the time from switching to the time where 90 % of the final stable reading is attained. Perform this test sequence three times and record the results. Calculate the average response time.

A.2 Calibration precision test

Make a total of three measurements by alternately using zero gas and the specified calibration gas. Record the meter readings. Calculate the average algebraic difference between the meter readings and the known value. Divide this average difference by the known calibration value and multiply by 100 to express the resulting calibration precision as a percentage.

A.3 Response factor determination test

Adjust the instrument with the reference compound as specified in the applicable regulation. For each organic species that is to be measured during individual source surveys, obtain or prepare a known standard in air at a concentration of approximately 80 % of the applicable threshold concentration unless limited by volatility or flammability. In these cases, prepare a standard at 90 % of the standard saturation concentration, or 70 % of the lower explosive limit, respectively. Introduce this mixture to the analyser and record the observed meter reading. Introduce zero air until a stable reading is obtained. Make a total of three measurements by alternating between the known mixture and zero air. Calculate the response factor for each repetition and the average response factor.

Annex B
(normative)

Calculation of response factor for mixtures

The response factor of a mixture can be based on the response factor of each individual component through the equation:

$$RF\mathrm{m} = 1 / (X1/RF_1 + X_2/RF_2 + \ldots + X_\mathrm{n}/RF_\mathrm{n}) \qquad \text{(B.1)}$$

where:

RFm	is the response factor of the mixture;
$X_1, X_2, \ldots \mathrm{Xn}$	is the mole fraction of the various constituents in the mixture;
$RF_1, RF_2, \ldots RF_\mathrm{n}$	are the response factors of the various constituents in the mixture.

Annex C
(normative)

Correlation between screening values and emission rates

The correlations between screening values and emission rates referred to as per article 1 in 6.4.2 are in the form:

$$ER = A\,(SV)^{B} \qquad \text{(C.1)}$$

where:

ER is the emission rate, in kg/h;

SV is the screening value, in ppm.

Tables C.1 and C.2 provide the values for *A* and *B*. These tables also include the pegged values at 10.000 ppm and 100.000 ppm referred to as per article 5 in clause 6.4.2, and the average emission factors determined by the US EPA that are mentioned in clause 6.5.6. Average emission factors are default values intended to be used when no screening value is available. Average emission factors for heavy liquid are not included in tables C.1 and C.2 since emissions from heavy liquids are not in the scope of this standard.

Table C.1 – US EPA SOCMI correlation parameters and factors

Source	**Service**	***A***	***B***	**Pegged value at 10.000 ppm (kg/h)**	**Pegged value at 100.000 ppm (kg/h)**	**Average factor (kg/h)**
Valve	Gas	$1,87 \times 10^{-6}$	0,873	0,024	0,110	0,00597
Valve	Light liquid	$6,41 \times 10^{-6}$	0,797	0,036	0,150	0,00403
Pump seal[6]	Light liquid	$1,90 \times 10^{-5}$	0,824	0,140	0,620	0,0199
Connector	All	$3,05 \times 10^{-6}$	0,885	0,044	0,220	0,00183

Additional average emission factors are available for the following components:

compressor seals (gas service): 0,228 kg/h

relief valves (gas service): 0,104 kg/h

open ended lines (all services): 0,0017 kg/h

sampling connections (all services): 0,015 kg/h

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[6] Also valid for compressor seals, pressure relief valves and agitator seals.

Table C.2 – US EPA Petroleum Industry correlation parameters and factors

Source	**Service**	***A***	***B***	**Pegged value at 10.000 ppm (kg/h)**	**Pegged value at 100.000 ppm (kg/h)**	**Average factor (kg/h)**	**Average factor for Marketing Terminal Equipment (kg/h)**
Valve	Gas	$2{,}29 \times 10^{-6}$	0,746	0,064	0,140	0,0268	0,000013
Valve	Light liquid	$2{,}29 \times 10^{-6}$	0,746	0,064	0,140	0,0109	0,000043
Pump seal	All	$5{,}03 \times 10^{-5}$	0,610	0,074	0,160	0,114	0,00054
Connector	All	$1{,}53 \times 10^{-6}$	0,735	0,028	0,030	0,00025	0,000042
Flange	All	$4{,}61 \times 10^{-6}$	0,703	0,085	0,084	0,00025	0,000042
Open end	All	$2{,}20 \times 10^{-6}$	0,704	0,030	0,079	0,0023	0,00013
Other[7])	All	$1{,}36 \times 10^{-5}$	0,589	0,073	0,110	see below	0,00013

Additional average emission factors are available for the following components:

compressor seals (gas service):	0,636 kg/h
relief valves (gas service):	0,160 kg/h
sampling connections (all services):	0,015 kg/h

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[7]) for *A* and *B* coefficients includes loading arms, pressure relief valves, stuffing boxes and vents.

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[3] SMT Project SMT4-CT97-2158, Valve Stem Leak-Tightness Test Methodologies – EU Commission DGXII, 25 October 2000

[4] IMPEL, Diffuse VOC emissions, December 2000

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