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Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation —

Part 3: Classification system for GPACDs applied to treatment of outdoor air

Méthodes d'essai pour l'évaluation de la performance des médias et des dispositifs de filtration moléculaire pour la ventilation générale —

Partie 3: Système de classification pour les GPACD appliqués au traitement de l'air extérieur

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Foreword

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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 ISO documents 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO 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).

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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.

This document was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 195, *Cleaning equipment for air and other gases,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 10121 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.

Introduction

There is an increasing need for gas-phase filtration in general filtration applications. This demand can be expected to grow rapidly due to the increasing gaseous pollution problems in the world together with an increasing awareness that solutions to the problems are available in the form of filtration devices or, phrased more technically, gas-phase air cleaning devices (GPACD). The performance of devices relies to a large extent on the performance of the gas-phase air cleaning media (GPACM) incorporated in the device. The applications and device performance are often poorly understood by the users and suppliers of such media and devices. Media tests can be adequate to offer data for real applications if actual low concentrations (< 100 ppb) and longer exposure times (> weeks) can be used in the test, provided that the geometrical configuration, packing density and flow conditions of the small-scale test specimen are equal to those used in the real applications. Such tests are however not included in the scope of the ISO 10121 series.

ISO 10121-1 and ISO 10121-2 aim to provide laboratory test methods for GPACM and GPACD respectively. From the tests and reports produced, a person skilled in the field of molecular filtration can evaluate the performance of different products as well as comparing performance using benchmark tests for specific applications. To make these evaluations, a basic knowledge in chemistry, molecular filtration and the application at hand are necessary.

Persons not skilled in molecular filtration face challenges with increasing pollution. Annex A shows the annual average concentration of selected outdoor pollutants, the concentration differences of different urban and industrial settings as well as an example of ambient air quality guidelines. The air quality guideline is from WHO, where most countries have similar national threshold values. Due to this increasing pollution in urban areas, any building owner, facility management engineer, design engineers or maintenance personnel need to be able to evaluate GPACDs for general ventilation in buildings. Different standards classifying air filters for particle filtration (e.g. ASHRAE 52.2 and ISO 16890-1) have, together with many national standards, made a vast difference in facilitating the selection of air filters for particle filtration for general ventilation in buildings. Equivalent standards classifying molecular filtration devices, i.e. GPACDs, have not been available up to the publication of this document. This document addresses the specific case of outdoor air to buildings in cities and aim to be used in parallel with ISO 16890-1.

The ISO 10121 series consists of three parts.

— ISO 10121-1 covers three different media configurations and aims to provide a standardized interface between media suppliers and producers of air cleaning devices. It may also be used between media suppliers and end customers with regards to loose fill media properties.

— ISO 10121-2 aims to provide a standardized interface between suppliers of air cleaning devices and end customers seeking the most cost-efficient way to employ gas-phase filtration.

— ISO 10121-3 provides a classification system for the specific application of GPACDs in general, ventilation systems for cleaning of outdoor air polluted by local urban sources and/or long-range transboundary air pollution.

Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation —

Part 3: Classification system for GPACDs applied to treatment of outdoor air

1 Scope

This document establishes a classification system for GPACDs supplying single pass outdoor air to general ventilation systems using outdoor air polluted by local urban sources and/or long-distance pollution. The classification system is intended to aid in assessing molecular contamination in addition to the particulate contamination dealt with by ISO 16890-1.

This document specifies four reference pollutants, i.e. ozone, sulphur dioxide, nitrogen dioxide and toluene, used for the classification due to their relevance to the intended application. This document further specifies three duty levels that are assigned for each pollutant reflecting the typical performance range of devices intended for the application. Since selection of reference pollutants and duty levels are specific and unique to the intended application, all other applications are excluded. In particular, this document does not apply to GPACDs in recirculation applications and/or dealing with pollution from indoor sources as well as pharmaceutical, microelectronic, nuclear, homeland security and military applications.

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 10121-2:2013, *Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation — Part 2: Gas-phase air cleaning devices (GPACD)*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
adsorption
process in which the molecules of a *gas* (3.14) or vapour adhere by physical or chemical processes to the exposed surface of solid substances, both the outer surface and inner pore surface, with which they come into contact

[SOURCE: ISO 29464:2017, 3.5.7]

3.2
adsorbate
molecular compound in gaseous or vapour phase that may be retained by an *adsorbent* (3.3) medium

[SOURCE: ISO 29464:2017, 3.5.3]

3.3
adsorbent
material having the ability to retain gaseous or vapour *contaminants* (3.10) on its surface by physical or chemical processes

[SOURCE: ISO 29464:2017, 3.5.4]

3.4
ambient pressure
absolute barometric pressure immediately outside the test rig

[SOURCE: ISO 29464:2017, 3.5.50, modified — The word “barometric” has been added.]

3.5
adsorbate capacity
m_s
maximum amount (mass or moles) of a selected *adsorbate* (3.2) that can be contained in GAPC medium or device under given test conditions and a specific end point (termination time)

Note 1 to entry: Capacity can also be negative during *desorption* (3.11).

[SOURCE: ISO 29464:2017, 3.5.12, modified — The symbol m_s and the words “maximum” and “a specific” have been added.]

3.6
challenge air stream
test *contaminant(s)* (3.10) of interest diluted to the specified *concentration(s)* (3.9) of the test prior to filtration

[SOURCE: ISO 29464:2017, 3.5.13]

3.7
challenge concentration
concentration (3.9) of the test *contaminant(s)* (3.10) of interest in the air stream prior to filtration [*challenge air stream* (3.6)]

[SOURCE: ISO 29464:2017, 3.5.14]

3.8
challenge compound
chemical compound that is being used as the *contaminant* (3.10) of interest for any given test

[SOURCE: ISO 29464:2017, 3.5.15]

3.9
concentration
C_n
quantity of one substance dispersed in a defined amount of another

Note 1 to entry: Indices “n” denote location.

[SOURCE: ISO 29464:2017, 3.1.7, modified — The symbol C_n and Note 1 to entry have been added.]

3.10
contaminant
substance [solid, liquid or *gas* (3.14)] that negatively affects the intended use of a fluid

[SOURCE: ISO 29464:2017, 3.1.8, modified — The alternative term "pollutant" has been removed.]

3.11
desorption
process in which *adsorbate* (3.2) molecules leave the surface of the *adsorbent* (3.3) and re-enter the air stream

Note 1 to entry: Desorption is the opposite of *adsorption* (3.1).

[SOURCE: ISO 29464:2017, 3.5.21]

3.12
downstream
area or region into which fluid flows on leaving the *GPACD* (3.15)

[SOURCE: ISO 29464:2017, 3.1.11, modified — "GPACD" has been used instead of "test device".]

3.13
face velocity
volumetric air flow rate divided by the nominal *GPACD face area* (3.16)

Note 1 to entry: *GPACD* (3.15) face velocity is expressed in m/s.

[SOURCE: ISO 29464:2017, 3.1.15, modified — The alternative term "filter face velocity" has been removed; "GPACD face area" and "GPACD face velocity" have been used instead of "filter face area" and "filter face velocity".]

3.14
gas
substance whose vapour pressure is greater than the *ambient pressure* (3.4) at ambient temperature

[SOURCE: ISO 29464:2017, 3.1.28]

3.15
gas-phase air cleaning device
GPACD
assembly of a fixed size enabling the removal of specific gas- or vapour-phase *contaminants* (3.10)

Note 1 to entry: It is normally box shaped or fits into a box of dimensions between 290 mm × 290 mm × 290 mm up to approximately 610 mm × 610 mm × 610 mm or 2 ft × 2 ft × 2 ft.

[SOURCE: ISO 29464:2017, 3.5.32, modified — The box dimensions in note 1 to entry have been modified.]

3.16
GPACD face area
nominal cross-sectional area of the *GPACD* (3.15)

Note 1 to entry: For the purpose of standardizing measurements, the nominal area is calculated using 610 mm × 610 mm for a full-size filter, 610 mm × 305 mm for a half-size filter and 305 mm × 305 mm for a quarter size filter.

3.17
heavy duty
HD
duty level (specific dose) of a *contaminant* (3.10) that corresponds to a *removal efficiency* (3.29) versus dose performance for a *GPACD* (3.15) that is used in challenging environments (e.g. heavily polluted environments)

3.18
initial dose
D_i
mass per *GPACD face area* (3.16) that reaches a *GPACD* (3.15) calculated from air flow in (volume per time), time, pollution *concentration* (3.9) (mass per volume) and GPACD face area during the test phase for determination of the *initial efficiency* (3.19)

3.19
initial efficiency
E_i
removal efficiency (3.29) of an unexposed filter or *GPACD* (3.15) calculated as soon as possible after the start of a test

Note 1 to entry: For gas-phase, this should be calculated as soon as a steady reading can be obtained.

3.20
integrated removal efficiency
E_Σ
numerically integrated fraction or percentage of a challenge *contaminant* (3.10) that is removed by a *GPACD* (3.15) over a specified time or dose period

3.21
light duty
LD
duty level (specific dose) of a *contaminant* (3.10) that corresponds to a *removal efficiency* (3.29) versus dose performance for a *GPACD* (3.15) that is used as an entry level solution, for low *concentrations* (3.9) or intermittent contamination episodes

3.22
medium duty
MD
duty level (specific dose) of a *contaminant* (3.10) that corresponds to a *removal efficiency* (3.29) versus dose performance for a *GPACD* (3.15) that is used for medium *concentrations* (3.9) of contamination

3.23
molecular contamination
contamination present in *gas* (3.14) or vapour phase in an air stream and excluding compounds in particulate (solid) phase regardless of their chemical nature

[SOURCE: ISO 29464:2017, 3.5.40]

3.24
normalised dose
D_N
mass per *GPACD face area* (3.16) that reaches a *GPACD* (3.15) calculated from air flow in (volume per time), time, pollution *concentration* (3.9) (mass per volume) and GPACD face area

3.25
normalised retentivity
R
measure of the ability of an *adsorbent* (3.3) or *GPACD* (3.15) to resist *desorption* (3.11) of an *adsorbate* (3.2) per *GPACD face area* (3.16)

Note 1 to entry: Computed as the residual capacity (fraction remaining) after purging the adsorbent with clean, conditioned air only, following challenge breakthrough and expressed per *GPACD face area* (3.16).

[SOURCE: ISO 29464:2017, 3.5.53, modified — "normalised" has been added in the term, the symbol *R* has been added, "per GPACD face area" has been added in the definition, "and expressed per GPACD face area" has been added in Note 1 to entry.]

3.26
ppb(v)
parts per billion by volume
concentration (3.9) measure normally used to record ambient levels of outdoor pollution

Note 1 to entry: Units are mm^3/m^3.

[SOURCE: ISO 29464:2017, 3.5.43, modified — "parts per billion by volume" has been moved from the definition to the admitted term.]

3.27
ppm(v)
parts per million by volume
concentration (3.9) measure normally used to record pollution levels in, e.g. work place safety

Note 1 to entry: Units are cm^3/m^3 and ml/m^3.

[SOURCE: ISO 29464:2017, 3.5.44, modified — "parts per million by volume" has been moved from the definition to the admitted term.]

3.28
pressure drop
Δp
difference in absolute (static) pressure between two points in an airflow system

Note 1 to entry: In this document, pressure drop is measured between points upstream and *downstream* (3.12) of the *GPACD* (3.15).

[SOURCE: ISO 29464:2017, 3.1.36, modified — The alternative terms "resistance to air flow“, "differential pressure" and "pressure differential" have been removed; the symbol Δp has been added; and “airflow system" has been used instead of "a system"; the original note 1 to entry has been replaced by a new one.]

3.29
removal efficiency
E
fraction or percentage of a challenge *contaminant* (3.10) that is retained by a GPAC medium or device at a given time

Note 1 to entry: Removal efficiency is also known simply as “efficiency”.

[SOURCE: ISO 29464:2017, 3.5.26, modified — The symbol E has been added.]

3.30
residence time
relative time that an increment of fluid [or *contaminant* (3.10)] is within the boundaries of the medium volume

[SOURCE: ISO 29464:2017, 3.5.52, modified — Notes to entry have been removed.]

3.31
retentivity
m_r
measure of the ability of an *adsorbent* (3.3) or *GPACD* (3.15) to resist *desorption* (3.11) of an *adsorbate* (3.2)

Note 1 to entry: Computed as the residual capacity (fraction remaining) after purging the adsorbent with clean, conditioned air only, following challenge breakthrough.

[SOURCE: ISO 29464:2017, 3.5.53, modified — The symbol m_r has been added.]

3.32
very light duty
vLD
removal efficiency (3.29) versus dose performance for a *GPACD* (3.15) that reaches less than 50 % efficiency at the *LD* (3.21) dose

4 Symbols and abbreviated terms

C_u	upstream concentration (ppb, ppm) measured at a position *X* mm before the device
C_d	downstream concentration (ppb, ppm) measured at a position *Y* mm after the device
E_i	initial removal efficiency (%) for the device measured at a low (< 1 ppm) challenge concentration during the initial efficiency test
E_0	initial removal efficiency (%) for the device measured at a high (> 1 ppm) challenge concentration during the challenge test
E_c	removal efficiency (%) for the device measured at the challenge concentration selected during the capacity test
E_{td}	efficiency recorded at stop time according to the classification level (%)
Q	flow used in test (normally the rated flow for the tested device) (m^3/h) measured at a position *Z* mm after the device, see ISO 10121-2
R	normalised retentivity (g/m^2)
v_f	face velocity (m/s) calculated from flow and cross-sectional area of device
T_u	temperature upstream (ºC)
T_d	temperature downstream (ºC)
φ_U	relative humidity upstream
φ_D	relative humidity downstream
D	dose (g)
ASHRAE	American Society of Heating Refrigerating and Air-conditioning Engineers
FID	flame ionization detector
PID	photo ionization detector
TVOC	total volatile organic compounds

NOTE TVOC is a common way to refer to a larger mix or organic pollutants present either indoors or outdoors.

5 Classification system for outdoor air

5.1 General

To express filtration performance in an easy to digest way for the target group of non-specialists, e.g. building and ventilation personnel, a classification using the following three measures shall be used:

a) the initial removal efficiency E_i of pollution at start;

b) a performance duty level (light, medium, heavy);

c) the integrated removal efficiency E_{Σ} calculated for the associated duty level.

Four reference pollutants are selected and shall be used on the basis of their occurrence as outdoor air pollutants. The duty levels are selected to reflect the typical performance range of devices intended for the application and are specified for each of the four reference pollutants. The actual tests for initial efficiency and integrated removal efficiency are performed in sequence where the removal efficiency is recorded against the upstream dose calculated from concentration, device face area and air flow. The different terms used in the classification are described in 5.2 to 5.9 and Figure 1 in 5.8 explains how the different terms are connected.

5.2 Test setup and test parameters

The classification test is made up of four single tests using applicable subclauses of ISO 10121-2 including ISO 10121-2:2013, 5.4 since the fixed air flows and pollutants selected in the simplified benchmark setup do not match the scope of this document. The initial efficiency determination is performed according to ISO 10121-2:2013, 6.3 but with the pollutants and concentrations specified in Table 2 and Table 3. The test for removal efficiency versus dose is performed according to ISO 10121-2:2013, 6.4 with the addition of the calculation of dose and by comparing the removal efficiency at different dose levels to determine if the test is finished or should go on. A retentivity determination performed according to ISO 10121-2:2013, 6.5 may be optional or compulsory. Generation parameters are specified in Table 1, Table 2 and Table 3. It is also important to ensure that the GPACD is sealed well during the test to make sure that actual GPACD performance is being tested.

NOTE Bypass leakage for example defined in EN 1886.

Table 1 — Generation parameters, measurement frequency and demands on accuracy during test

Parameter	Generation parameters	Unit	Range	Absolute accuracy	Permissible oscillation during test	Measurement frequency
C_u	given in Table 2 and Table 3	ppb(v)	5 000 to 100 000	±1,5 %	±3 %	5 min, 1 h, 4 h, 12 h[a, b]
C_d	n.a.	ppb(v)	100 to 100 000	±1,5 %	n.a.	< 2 min[b]
T_U	23	°C	n.a.[c]	±0,5 °C	±0,5 °C	same as C_d
T_D	n.a.				n.a.	
φ_U	50	%	n.a.[c]	±1 %	±3 %	same as C_d
φ_D	n.a.				n.a.	
Q, air flow rate	rated air flow	m³/h	n.a.	±5 %	±3 %	same as C_d
v_f, face velocity	If rated air flow not given use 2,54[d]	m/s	n.a.			
Residence time	Determined by v_f and filter depth	s	n.a.	n.a.	n.a.	n.a.
GPACD face area for full, half and quarter size[e]	n.a.	mm	610 × 610 610 × 305 305 × 305	n.a.	n.a.	n.a.

Table 1 *(continued)*

Parameter	Generation parameters	Unit	Range	Absolute accuracy	Permissible oscillation during test	Measurement frequency

[a] Upstream concentration needs, at a minimum, to be measured before and after an individual test sequence.

[b] The time between consecutive downstream measurements should be less than 2 min to allow for sufficient resolution in Formula (2). Furthermore, the time for the summation increment delta between two efficiency determinations in Formula (2) shall also be less than 2 min.

[c] Useful ranges of T and φ are 15 °C to 45 °C and 30 % to 95 % respectively.

[d] The air flow used in the test shall be the rated air flow as per the GPACD label. If the rated air flow is missing from the label, an air flow corresponding to a face velocity of 2,54 m/s should be used.

[e] GPACD face area defines a nominal size but actual minimum size of GPACD to be tested may be down to 590 mm × 590 mm, 590 mm × 285 mm and 285 mm × 285 mm.

5.3 Initial removal efficiency

The initial efficiency is a good measure of the performance of a new product, especially since the initial efficiency can be advantageously measured at a low concentration close to real outdoor concentration level.

5.4 Dose concept

The air flow in (volume per time), time, pollution concentration (mass per volume) and GPACD's face area can be used to calculate the upstream normalised dose D_N (mass per specimen face area) that reaches a GPACD. This classification uses a number of specific doses or duty levels; LD, MD and HD (g/m^2) related to GPACD face area and specific concentrations to ensure that the same dose per GPACD area is used in all classification determinations. These are specified in Table 4. This also makes it possible to classify all products regardless of performance. In addition, the dose concept reflects a real-life scenario since the dose, if allowed to enter the building, is the actual stress experienced by building occupants.

5.5 Classes, duty levels and dose

Three duty levels and one entry level are assigned for each pollutant. The duty levels are related to the performance needed in different locations depending on typical pollutant concentrations, but it is not in the scope of this document to relate a specific duty level to a certain place or city size. Furthermore, the definitions of typical low, medium and high concentrations and acceptable levels in a location may also vary depending on local country regulations. The duty levels are expressed as a series of normalised dose levels of pollution D_N (g/m^2) relating mass of challenge to GPACD face area. The criterion to be awarded a certain duty level (except for the lowest entry level) is that the removal efficiency shall be above 50 % when the dose during the test reaches the duty level. The classes are described below.

— Very light duty corresponds to an entry level classification without a demand for a specific performance. A GPACD having a removal efficiency below 50 % at the LD dose is therefore denoted "vLD".

— Light duty corresponds to a removal efficiency versus dose performance for a GPACD that is used as an entry level solution, for low concentrations or intermittent contamination episodes (one possible example can be temporary forest fire/haze). LD dose values for the four selected pollutants are given in Table 4.

— Medium duty corresponds to a removal efficiency versus dose performance for a GPACD that is used for medium contamination concentrations, e.g. in an urban environment. MD dose values for the four reference pollutants are given in Table 4.

— Heavy duty corresponds to a removal efficiency versus dose performance for a GPACD that is used in challenging environments, e.g. heavily polluted or high purity critical environments. HD dose values for the four reference pollutants are given in Table 4.

This document aims to include, compare, classify and group any possible GPACD that is intended for the application as defined in the scope. Other standards may look into product recommendations for each specific environment and contamination levels. The requirement for being awarded very light duty is therefore open so even products with an initial efficiency below 50 % can be classified and these are further not required to pass the dose level LD. The requirement for the dose level heavy duty is also open; but the test shall be terminated as soon as the dose level HD is reached. The duty levels selected for the different pollutants are given in Table 4.

5.6 Pollutants and concentrations

Ozone, sulphur dioxide, nitrogen dioxide and toluene are the specific pollutants selected and shall be used. These are typical pollutants in an urban area entering with the outdoor air to general ventilation for buildings, are considered dangerous to health and are therefore regulated. Concentrations for the initial efficiency determination and the duty level determination shall be as given in Table 2 and Table 3.

Table 2 — Challenge gas, concentration and test demands for the initial efficiency determination

Selected gas	Formula	Challenge level	Unit	Reference analysis technique	Max permissible efficiency decay during test %
Ozone	O_3	150	ppb(v)	UV photometric[a]	5
Sulphur dioxide	SO_2	450	ppb(v)	UV fluorescence[a]	5
Nitrogen dioxide	NO_2	450	ppb(v)	Chemiluminescence[a]	5
Toluene	C_7H_8	900	ppb(v)	PID[a] or FID[a]	5

[a] The reference techniques are the preferred ones in this document. However, other techniques may be used provided that the test supplier can show documented correlation versus the reference technique. In the case of nitrogen dioxides, there is a demand that the method used can measure both NO and NO_2 upstream and downstream.

Table 3 — Challenge gas, concentration and test demands for the efficiency versus dose determination

Selected gas	Formula	Challenge level	Unit	Reference analysis technique	Min efficiency to continue to next duty level %
Ozone	O_3	3	ppm(v)	UV photometric[a]	50[c]
Sulphur dioxide[b]	SO_2	9	ppm(v)	UV fluorescence[a]	50[c]
Nitrogen dioxide[b]	NO_2	9	ppm(v)	Chemiluminescence[a]	50[c]
Toluene[b]	C_7H_8	9	ppm(v)	PID[a] or FID[a]	50[c]

[a] The reference techniques are the preferred ones in this document. However, other techniques may be used provided that the test supplier can show documented correlation versus the reference technique. In the case of nitrogen dioxides, there is a demand that the method used can measure both NO and NO_2 upstream and downstream.

[b] A retentivity determination is compulsory.

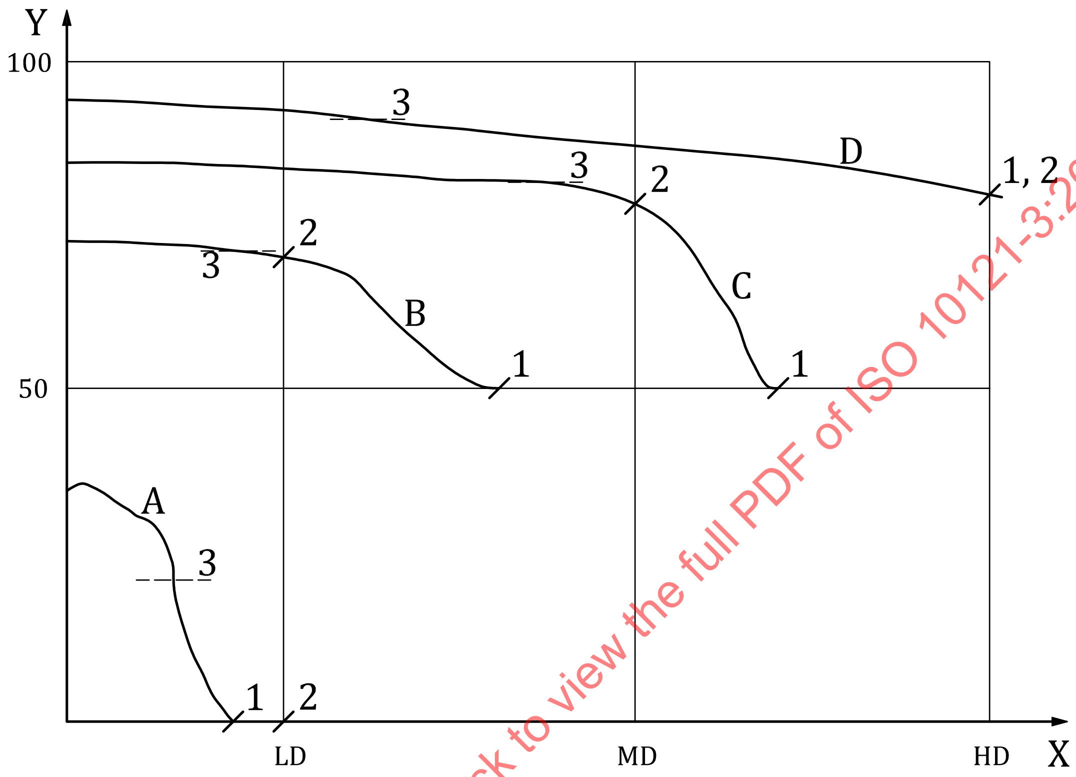
[c] Min efficiency is defined as when the instantaneous value of E_c becomes less than 50 % for LD, MD and HD. Min efficiency are not applicable to vLD.

5.7 Integrated removal efficiency

The integrated removal efficiency reflects the average performance for the GPACD from the start up to the highest duty level it can pass with a minimum removal efficiency still above 50 % or reaching HD (see Figure 1).

5.8 Classification example graph

Figure 1 describes how the classification works for any of the reference pollutants and how the different terms are related. Clause 6 describes the test sequence for the classification arriving at one determination for the initial removal efficiency and one performance test where the test object is subjected to the dose D (g) and the resulting E_c (%) versus D_N (g/m^2) graphs are made. The specific duty levels for the four reference pollutants and a classification example are given in Clause 7.



Key

X normalised dose D_N (g/m^2)

Y removal efficiency E_c (%)

1 stop of test

2 end point for calculation of the integrated removal efficiency E_Σ (%)

3 value of E_Σ (%) for curve A, B, C or D

A GPACD with a ~35 % initial efficiency of E_c

B GPACD with a ~70 % initial efficiency of E_c

C GPACD with a ~80 % initial efficiency of E_c

D GPACD with a ~90 % initial efficiency of E_c

NOTE This graph applies to a single reference pollutant.

Figure 1 — E_c versus D_N for four different examples of GPACDs denoted A, B, C and D

Curve A in Figure 1 describes a GPACD with a ~35 % initial efficiency of E_c that drops toward zero before reaching LD (point 1). Since the GPACD does not pass LD at a removal efficiency above 50 % the GPACD is denoted vLD. Regardless of this, the integrated removal efficiency E_Σ is calculated from the start to the removal efficiency value noted when LD is reached, see point 2 at LD. If the GPACD becomes completely exhausted before reaching LD, the test may be aborted for environmental and cost reasons and calculated data used for the remaining time (see 6.4.1 and 6.4.2). The value of E_Σ is shown as dashed line 3 for curve A in Figure 1.

Curve B in Figure 1 describes a GPACD with a ~70 % initial efficiency of E_c that passes LD and drops below 50 % between LD and MD and wherein the test is stopped when E_c reaches 50 % (point 1). This GPACD is awarded an LD classification with the integrated removal efficiency E_Σ calculated from the start to the removal efficiency value noted when LD was passed (point 2 on the curve where it intersects the LD line). The value of E_Σ is shown as dashed line 3 for curve B in Figure 1.

Curve C in Figure 1 describes a GPACD with a ~80 % initial efficiency of E_c that passes LD and MD and drops below 50 % between MD and HD and wherein the test is stopped when E_c reaches 50 % (point 1). This GPACD is awarded a MD classification with the integrated removal efficiency E_Σ calculated from the start to the removal efficiency value noted when MD was passed (point 2 on the curve where it intersects the MD line). The value of E_Σ is shown as dashed line 3 for curve C in Figure 1.

Curve D in Figure 1 describes a GPACD with a ~90 % initial efficiency of E_c that passes LD, MD and reached HD still over 50 % efficiency wherein the test is stopped (point 1). This GPACD is awarded a HD classification with the integrated removal efficiency E_Σ calculated from the start to the removal efficiency value noted when HD was reached (point 2 on the curve where it intersects the HD line). The value of E_Σ is shown as dashed line 3 for curve D in Figure 1.

5.9 Desorption and retentivity

The majority of GPACDs on the market uses two different mechanisms to retain a challenge compound. These mechanisms are generally referred to as chemisorption and physisorption.

Chemisorption refers to a case where the pollutant is irreversibly transformed into a new compound. In this case, the amount of pollutant removed from the air stream, i.e. the capacity, is the correct value giving the performance of the GPACD.

Physisorption on the other hand relies on weak physical forces like Van der Waals forces or pore condensation that are reversible and dependent on concentration, temperature and atmospheric pressure. When a test is stopped by removing the challenge compound while retaining the air flow, the GPACD starts to desorb resulting in a downstream concentration which is first high but eventually reaches a low steady value. The amount of pollutant still retained by the GPACD at a certain stop criterion is referred to as the retentivity. According to ISO 10121-2:2013, 6.5, the criterion is that “the test should continue until the downstream concentration is ≤ 5 % of the original challenge concentration or for maximum 6 h, whichever occurs first”. However, in this document, the progress of the test is expressed as normalised dose D_N on the x axis. This document shall use normalised retentivity R calculated as m_r per GPACD face area.

To be able to reach consistent results at different laboratories, it shall also be important to consider the atmospheric pressure and to compensate for any larger differences due to different altitude for example, since this results in lower physisorption at lower atmospheric pressure. Variations in air pressure with changing weather may often be neglected but the atmospheric pressure should be noted in the test report.

6 Classification test sequence

6.1 General

The test sequence given in ISO 10121-2:2013, Clause 6 shall be used but with the addition of calculating and comparing the normalised dose D_N according to Clause 5. Four tests are made, one for each pollutant, i.e. ozone, sulphur dioxide, nitrogen dioxide and toluene, on separate GPACDs. The test sequence described in 6.2 to 6.6 is approved for all four pollutants, but the time needed for the ozone test may exceed the time goal < 8 h. The GPACD’s removal efficiency for NO_2 is determined as per Formula (1) in order not to count reduction of NO_2 (inlet) to –NO (outlet) as removal of NO_2.

$$E = \frac{NO_{2\ (inlet)} - \left(NO_{2\ outlet} + \left(NO_{outlet} - NO_{inlet}\right)\right)}{NO_{2\ inlet}} \times 100 \qquad (1)$$

6.2 Conditioning

Start the conditioning of the GPACD according to the procedure defined in ISO 10121-2:2013, 6.2.1. Steps 9 to 11 can be omitted if the pressure drop is not needed for other purposes.

6.3 Initial removal efficiency

The initial removal efficiency is determined according to ISO 10121-2:2013, 6.3.1 to 6.3.2 with challenge concentrations as specified in Table 2 and reported as $E_i = E$ in Table 5. In the case of nitrogen oxides, both NO and NO_2 shall be measured upstream and downstream and the efficiency calculated as shown in Formula (1). The adsorbate capacity m_s is not used in this document and can be skipped. Instead, the initial dose D_i shall be noted in the test report together with information if both initial efficiency and capacity determinations are made on the same product. If two separate but identical products are used, the initial dose D_i can be skipped.

6.4 Capacity determination expressed as E_c (%) versus D_N (g/m^2)

6.4.1 Zero to LD

Start a removal efficiency versus capacity curve according to ISO 10121-2:2013, 6.4 and 6.4.1 with challenge concentrations as specified in Table 3. In addition and during the uptake of the curve, calculate and record the pollutant dose imposed on the GPACD i.e. the upstream dose level D_N (g/m^2). For removal efficiency of nitrogen dioxides, refer to 6.1. The results shall be shown in the test report as an E_c versus D_N graph.

Run steps 25 to 29 according to ISO 10121-2:2013, 6.4.1 and continue to measure downstream until the D_N value corresponding to LD is reached; check the removal efficiency E_c at this point. However, if the removal efficiency drops below 5 % and remains at or below this level for a time long enough to determine that the GPACD is completely exhausted (< 5 % efficiency), then the test may be aborted for environmental and cost reasons.

6.4.2 Check E_c at LD

If E_c is lower than 50 %, stop the test and calculate the integrated removal efficiency E_Σ from D_N =0 to D_N =LD and report E_Σ and class vLD (E_Σ) as shown in Table 5. If the test is aborted (due to < 5 % efficiency), then the integrated removal efficiency E_Σ is calculated using fictive E_c values at half of the last recorded value for the remaining time to reach LD.

If E_c still exceeds 50 %, continue the test started in ISO 10121-2:2013, 6.4.1 with steps 30 to 34 according to ISO 10121-2:2013, 6.4.1 and stay on step 34 towards the D_N value corresponding to MD.

6.4.3 LD to MD

If E_c goes below 50 % before reaching the D_N value corresponding to MD, stop ISO 10121-2:2013, 6.4.1 step 34 and start the retentivity uptake in 6.5 immediately.

From the collected E_c versus D_N data, calculate the integrated removal efficiency E_Σ from D_N =0 to D_N =LD and report E_Σ and class LD (E_Σ) as shown in Table 5.

If E_c still exceeds 50 %, continue the test towards the D_N value corresponding to HD.

6.4.4 MD to HD and HD

If E_c goes below 50 % before reaching the D_N value corresponding to HD, stop ISO 10121-2:2013, 6.4.1. step 34 and start the retentivity uptake in 6.5 immediately.

From the collected E_c versus D_N data, calculate the integrated removal efficiency E_Σ from D_N =0 to D_N =MD and report E_Σ and class MD (E_Σ) as shown in Table 5.

If E_c has not dropped to 50 % when the D_N value corresponding to HD is reached, stop the test and start the retentivity uptake in 6.5 immediately and calculate the integrated removal efficiency E_Σ from D_N =0 to D_N =HD and report E_Σ and class HD (E_Σ) as shown in Table 5.

6.5 Retentivity

Retentivity is compulsory for toluene, SO_2 and NO_2 for GPACDs passing LD at an E_c value exceeding 50 %. The retentivity test is performed according to ISO 10121-2:2013, 6.5 but the value is normalised by dividing with the GPACD face area and expressed as the normalised retentivity R.

6.6 Premature stop

If E_c is close to but exceeding 50 % at D_N corresponding to LD or MD, the test may be stopped as agreed between the user and the supplier. The reason for this would be that the user is satisfied with the duty level reached and wants to end the test for cost reasons.

7 Classification system

7.1 General

As described in Clause 5, the GPACD is evaluated based on its performance as long as the removal efficiency exceeds 50 %, which follows the procedure for particle filters in ISO 16890-1.

The normalised dose D_N of the GPACD before reaching the end point, which is E_c = 50 %, is used to classify the GPACD into the duty level LD, MD or HD. Each duty level is targeted to a specified loading capacity for each pollutant. The integrated removal efficiency is calculated and reported in the test report. For the classification duty level, the integrated removal efficiency is also added to the level but shall be rounded downwards to the nearest multiple of 5 % points. The classification shall be reported by the format shown in Table 5. The general explanation of the system is given in Figure 1.

7.2 LD, MD and HD dose values

The LD, MD and HD level correspond to the specified doses as listed in Table 4.

From the capacity of GPACD when it reaches E_c = 50 %, a GPACD loaded to LD level but not MD level shall be denoted LD; a GPACD loaded with MD but not HD level shall be denoted MD; and a GPACD that can load up to HD level and above shall be denoted HD.

Table 4 — Dose corresponding to LD, MD and HD

Pollutant	D_N (moles per unit GPACD face area) mol/m^2			D_N (grams per unit GPACD face area) g/m^2		
	LD	MD	HD	LD	MD	HD
Ozone	1,5	6,0	24,0	72	288	1 152
SO_2	1,5	6,0	24,0	96	384	1 538
NO_2	1,5	6,0	24,0	69	276	1 104
Toluene	1,5	6,0	24,0	138	553	2 211

A GPACD shall be reported in terms of the integrated removal efficiency which is illustrated in Formula (2). According to this formula, the integrated removal efficiency is calculated as the weighted average of removal efficiency for N dose increments up to the highest duty level achieved with a removal efficiency over 50 %.

$$\overline{E_{LD\ or\ MD\ or\ HD}} = \frac{\sum_{k=1}^{N_{LD\ or\ MD\ or\ HD}} \frac{(E_{ck-1} + E_{ck})}{2} * \Delta D_{Nk}}{\sum_{k=1}^{N_{LD\ or\ MD\ or\ HD}} \Delta D_{Nk}} \quad (2)$$

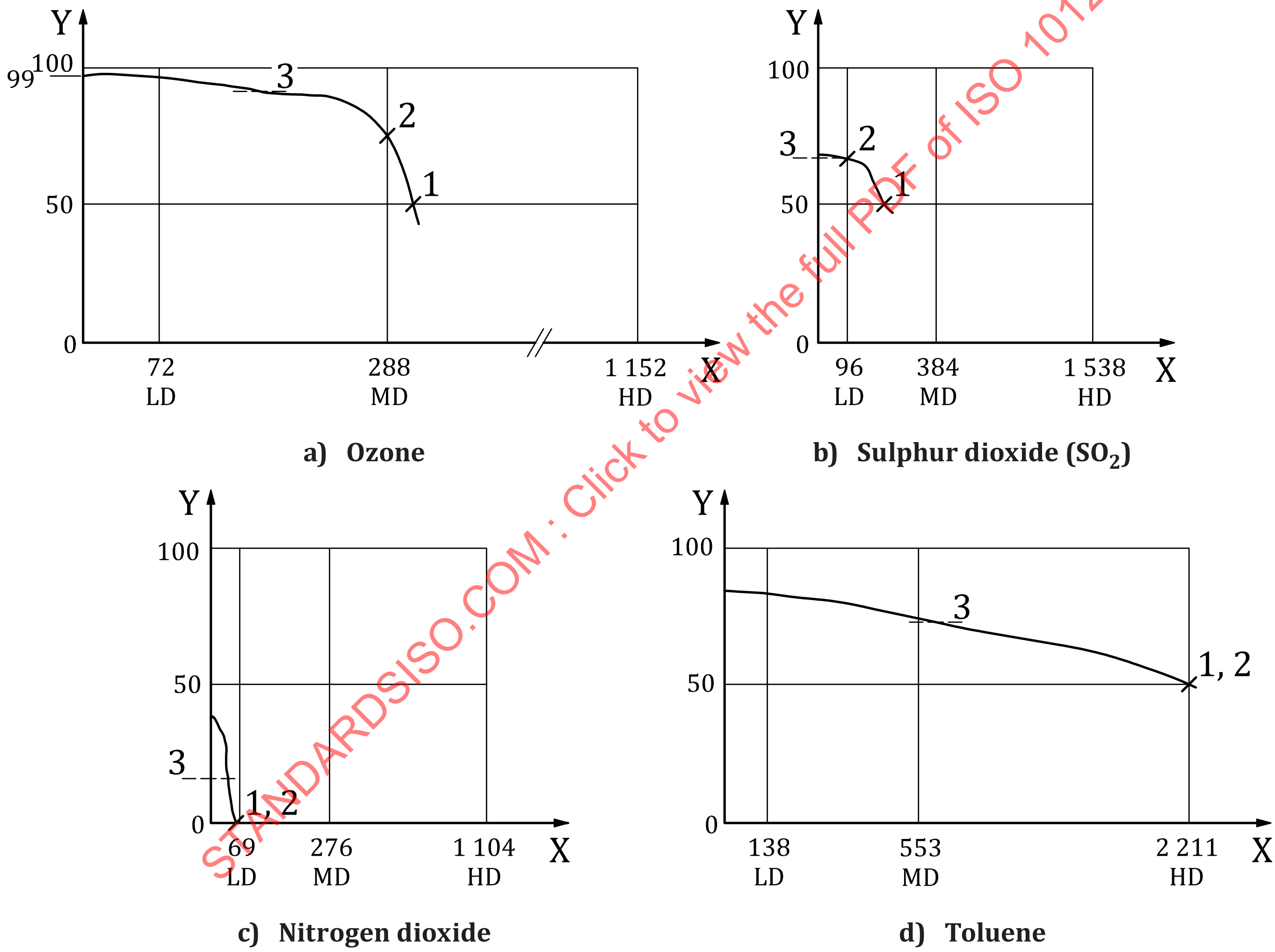
7.3 Classification example

The performance of a GPACD shall be reported for all four reference pollutants. The level of the GPACD for different pollutants shall often be different. Four specific levels are reported with the integrated removal efficiency stated beside the level of the GPACD to the reference pollutant.

Figure 2 is an example of the test result of four different pollutants tested on a GPACD. Four performance curves are generated when the four GPACD are challenged with the pollutants, i.e. ozone, toluene, SO_2 and NO_2 respectively. The performance data are recorded as per the requirements in ISO 10121-2 and the data used to calculate the integrated removal efficiency based on Formula (2).

Figure 2 shows examples of E_c versus D_N data for a) ozone, b) sulphur dioxide, c) nitrogen dioxide and d) toluene for a GPACD.

The GPACD tests yield the initial removal efficiency, E_i, and the class with the integrated removal efficiency, E_Σ, as shown in Table 5 and calculated by Formula (2).



Key

X normalised dose D_N (g/m^2)

Y removal efficiency E_c (%)

1 stop of test

2 end point for calculation of the integrated removal efficiency E_Σ (%)

3 value of E_Σ (%) for the different pollutants tested

Figure 2 — Example of the test result of four different pollutants tested on a GPACD

Table 5 — Example of reporting values for a GPACD

Pollutant	E_i (at low concentration) %	E_Σ %	Class E_Σ
Ozone	99	92	MD 90
SO_2	73	58	LD 55
NO_2	50	28	vLD 25
Toluene	95	72	HD 70

8 Report

8.1 General

Information in the report is a combination of test data from ISO 10121-2 and the classification result. Any deviation of this test from the standard test method shall be stated in the report. The basic list of data of the report shall include:

— GPACD type;

— tested pollutant;

— inlet pollutant concentration;

— inlet air stream relative humidity and temperature;

— the volume of air flow rate;

— data and result of air flow rate and GPACD pressure drop measurement;

— measured initial removal efficiency;

— measured instantaneous removal efficiency curve as a function of total pollutant loaded in mass.

The test report shall follow the layout of the report format defined in 8.2.

8.2 Test report layout

A summary page of the results and classification is given as example in Table 6 and Table 7. The information listed in the report shall be included, except those with an optional choice.

The pressure drop curve is shown in Table 7. There are then four separate curves in the report that shows the GPACD performance when loaded with the pollutants, i.e. ozone [see Figure 3 a)], sulphur dioxide [see Figure 3 b)], nitrogen dioxide [see Figure 3 c)] and toluene [see Figure 3 d)] respectively. To aid in comparison between reports, the four curves shall show E_c on the Y axis with a scale from zero to 100 % and D_N on the X axis with a scale from zero to 1 200, 1 600, 1 200 and 3 000 for O_3, SO_2, NO_2 and toluene respectively. The integrated removal efficiency calculated from these curves shall be reported as in Table 7. The class of the GPACD (LD, MD or HD) is determined from each curve and given in the report with the format as follows:

[Type of pollutant] [initial removal efficiency, E_i] – Class LD/MD/HD (integrated removal efficiency, E_Σ rounded downwards to the nearest multiple of 5 % points.)

Values larger than 95 % are reported as "> 95 %". Reporting examples are shown in Table 6 and Table 7.

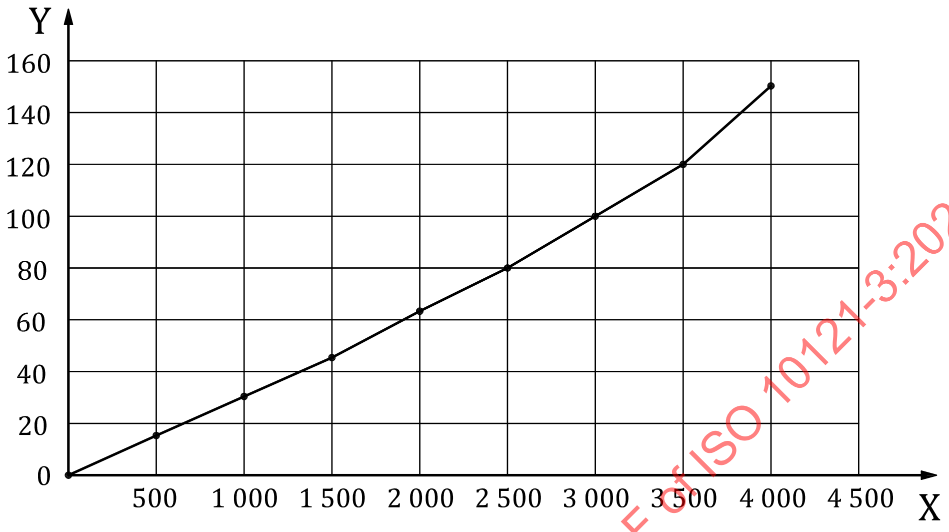
Table 6 — Example of classification report (1 of 2)

ISO 10121-3 CLASSIFICATION REPORT				
Report no	*insert applicable info*	**Date received**	*insert applicable info*	
Date tested	*insert applicable info*	**Date report**	*insert applicable info*	
TEST SUPPLIER				
Test organization	Testlabs inc	**Address**	no1 Test Blwd, NZ	
Phone	800-123-123	**Web**	www.test.com	
Operator		**Supervisor**		
TEST CUSTOMER				
Mr Customer		**Address**	no1 Cust Blwd, NZ	
Phone	800-100-100	**Email**	customer@email.com	
TESTED DEVICE				
Manufacturer	GPACD Supply	**Address**	no1 Supply Blwd, NZ	
Phone	800-110-120	**Web**	www.supply.com	
Model	GPACD deluxe			
Pollutant type	Ozone/SO_2/NO_2/VOC	**Type**	4vee cell type	
Rated flow (m^3/h)	3 400	**Dimensions (mm)**	610 x 610 x 292	
Pressure drop (Pa)	100	**GPACD mass (g)**	5 200	
Serial no of GPACD used for E_i determination		**Serial no of GPACD used for E_c versus D_N curve**		
Adsorbent	carbon	**Other identifications**	black	
TESTING CONDITIONS				
Air Flow (m^3/h)	3 400	**Initial efficiency concentration (ppb)**	Table 2	
Face velocity (m/s)	2,5	**Challenge concentration (ppb)**	Table 3	
Test pollutant	Ozone	SO_2	NO_2	Toluene
Temperature (°C)	23,1	23,2	22,9	23,0
Relative humidity (%)	51	49	50	51
Atmospheric pressure	At test start (kPa)		At test stop (kPa)	
Initial efficiency concentration (ppbv)	150	450	450	900
Initial Dose (g)	1	2	2	3
Challenge concentration (ppmv)	9	27	27	90
Analyser type	UV Photometric	UV fluorescence	Chemiluminescence	FID/PID
Analyser model	X3	X5	X7	X9
Analyser calibration date	01 Jan 2020	02 Jan 2020	03 Jan 2020	04 Jan 2020

Table 7 — Example of classification report (2 of 2)

RESULT: pressure drop			
Initial pressure drop (Pa)	100	**Final pressure drop (Pa)**	110

Pressure drop curve



Key

X airflow (m^3h^{-1})

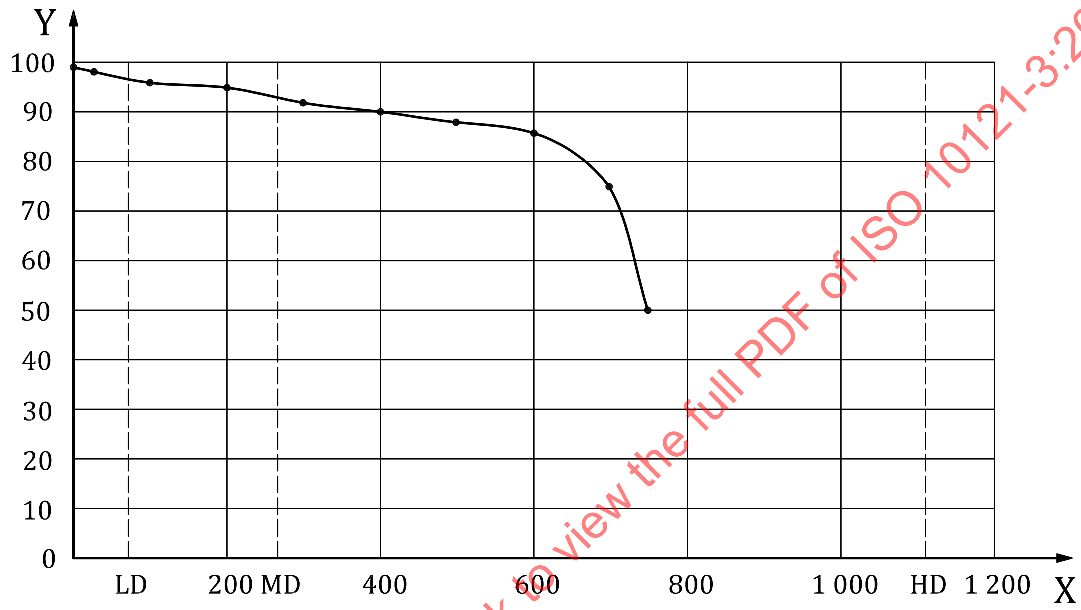
Y pressure drop (Pa)

Adsorption and desorption results		
Challenge gas/vapor	Adsorption to E_{50} (g)	Desorption (g)
Ozone	279	N.A.
SO_2	44	3
NO_2	0	N.A. (due to vLD)
Toluene	1 050	363

ISO 10121-3 CLASSIFICATION RESULT				
Pollutant	E_i (%)	E_Σ (%)	**GPACD Class**	R (g/m^2)
Ozone	99	96	MD 95	N.A.
SO_2	68	66	LD65	35
NO_2	40	38	vLD 35	N.A. (due to vLD)
Toluene	85	72	HD 70	975

Efficiency Curves

Ozone



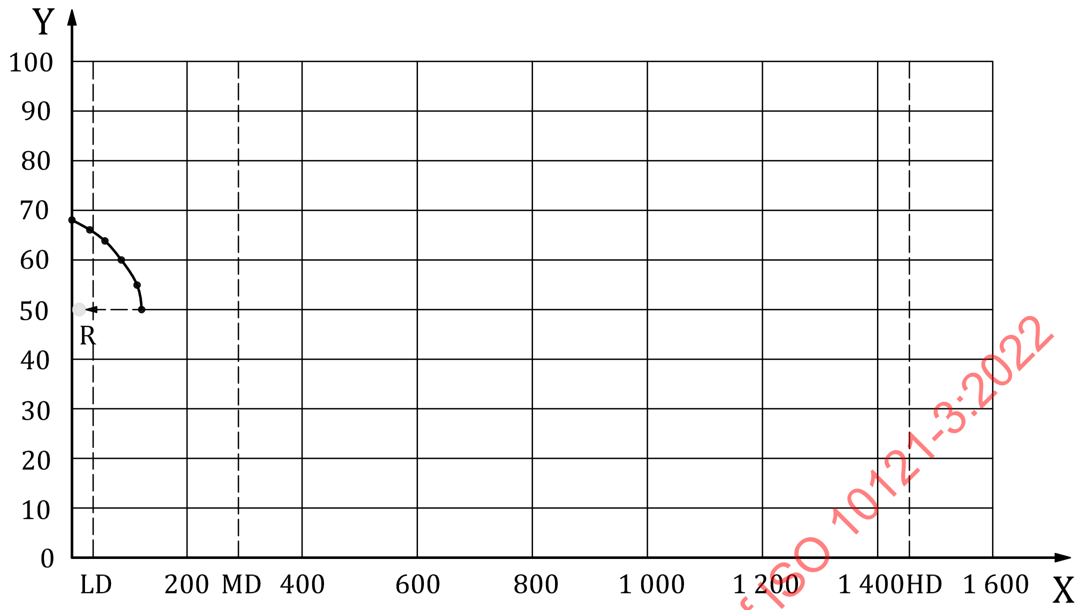
Key

X *E*, %

Y D_N, g/m^2

a) Efficiency *E* versus normalised dose D_N for Ozone

SO_2



Key

X *E*, %

Y D_N, g/m^2

b) Efficiency *E* versus normalised dose D_N for SO_2

