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Additive manufacturing of plastics—Environment, health, and safety — Test method for determination of particle and chemical emission rates from desktop material extrusion 3D printer

Fabrication additive de plastiques — Environnement, santé et sécurité — Méthode d'essai pour la détermination des taux d'émission de particules et de produits chimiques des imprimantes 3D de bureau par extrusion de matériau

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 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).

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This document was prepared by Technical Committee ISO/TC 261. Additive manufacturing. in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 438. Additive manufacturing, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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.

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Introduction

Academic communities have been releasing several papers warning that a significant number of particles and chemical substances emitted from material extrusion (MEX) AM processes commonly used in schools, private homes and similar non-industrial environments would be hazardous to humans when inhaled and absorbed into the human body.

However, currently, there is no well-known test method to measure particle and chemical substances emitted from desktop MEX-TRB/P machines, commonly called "3D printers" installed in the office environment, classroom, and residential space.

Therefore, the goal of this document is to provide test procedures in line with specific operating conditions for measuring particle and chemical emission rates emitted from desktop MEXTRB/P machine, also known as a 3D printer which is widely used in the national marketplace.

Manufacturers of desktop MEX-TRB/P machines, also known as 3D printers, will be able to take advantage of this document to develop and improve their products by minimizing particle and chemical emission rates, and the end-users also would purchase more safe and improved machines from the market.

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Additive manufacturing of plastics — Environment, health, and safety—— Test method for determination of particle and chemical emission rates from desktop material extrusion 3D printer

1 Scope

This document specifies test methods to determine particle emissions (including ultrafine particles) and specified volatile organic compounds (including aldehydes) from desktop MEX-TRB/P processes often used in non-industrial environments such as school, homes and office spaces in an emission test chamber under specified test conditions. However, these tests do not necessarily accurately predict real-world results.

This document specifies a conditioning method using an emission test chamber with controlled temperature, humidity, air exchange rate, air velocity, and procedures for monitoring, storage, analysis, calculation, and reporting of emission rates.

This document is intended to cover desktop MEX-TRB/P machine which is typically sized for placement on a desktop, used in non-industrial places like school, home and office space. The primary purpose of this document is to quantify particle and chemical emission rates from desktop MEX-TRB/P machine.

However, not all possible emissions are covered by this method. Many feedstocks can release hazardous emissions that are not measured by the chemical detectors prescribed in this document. It is the responsibility of the user to understand the material being extruded and the potential chemical emissions. An example is Poly Vinyl Chloride feedstocks that can potentially emit chlorinated compounds, which cannot be measured by the method described in this document.

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.

<std>ISO 554, Standard atmospheres for conditioning and/or testing — Specifications</std>

<std>ISO 14644 12015, Cleanrooms and associated controlled environments — Part 1: Classification of a cleanliness by particle concentration </std>

<std>ISO 15900:2020, Determination of particle size distribution — Differential electrical mobility analysis for aerosol particles</std>

<std>ISO 16000-ISO 554. Standard atmospheres for conditioning and/or testing — Specifications

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

SVOC) in indoor and test chamber air by active sampling on sorbent tubes, thermal desorption and gas chromatography using MS or MS FID

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std>ISO 27891, Aerosol particle number concentration—Calibration of condensation particle counters</std>

<std>ISO/IEC 28360-ISO 27891, Aerosol particle number concentration — Calibration of condensation particle counters

ISO/IEC 28360-1;2021, Information technology — Determination of chemical emission rates from electronic equipment — Part 1: Using consumables </std>

<std>ISO/ASTM 52900, Additive manufacturing General principles Fundamentals and vocabulary</std>

ISO/ASTM 52900, Additive manufacturing — General principles — Fundamentals and vocabulary

3 Terms and definitions

For the purposes of this document, the terms and definitions given in <u>ISO/ASTM 52900</u>, <u>ISO/IEC 28360-1</u> and the following are applied.

ISO and IEC maintain terminological 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

loading factor

ratio of the device volume to the volume of the unloaded Emission Test Chamber

Note-1-to-entry:-For the purpose of this standard, the device subjected to the testing is typically a desktop MEX-TRB/P-machine, also popularly called a 3D printer

[SOURCE: ISO/IEC, 28360-1; 2021(E), 4.18, modified — "EUT" replaced by "device" and Note 1 to entry added.]

3.2

emission test chamber

ETC

enclosure with controlled operational parameters for the determination of chemical compounds and amount of particles emitted during the process

Note-1-to-entry:-For determining the emissions from AM process, typical controlled parameters include, but are not*limited to, temperature, humidity, air exchange rate, and others

 $[SOURCE: \underline{ISO, 16000-9:2006, 3.6, modified--Terminological\ entry\ is\ changed\ considering\ AM\ process]$

3.3

differential electrical mobility classifier DEMC

classifier able to select aerosol (3.1) particles according to their electrical mobility and pass them to its exit

Note—1—to entry:—A DEMC classifies aerosol particles by balancing the electrical force on each particle with its aerodynamic drag force in an electrical field. Classified particles are in a narrow range of electrical mobility determined by the operating conditions and physical dimensions of the DEMC, while they can have different sizes due to difference in the number of charges that they have.

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2.4	L	Formatted: Default Paragraph Font	
3.4 differential mobility analysing system		Formatted: Default Paragraph Font	
DMAS	/ //	Formatted: Default Paragraph Font	
system to measure the size distribution of submicrometre <u>aerosol-(3.1)</u> particles consisting of a charge		Formatted	
conditioner, a DEMC, flow meters, a particle detector, interconnecting plumbing, a computer and suitable software	, //	Commented [A8]: The term "differential mobility analys	ind
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Note_1toentry:Another common acronym for the DMAS is MPSS (mobility particle size spectrometer).	*	Formatted	
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instrument capable of counting and sizing single airborne particles and reporting size data in terms of	f\\	Formatted	
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time-dependent number for the concentration of particles in a specified size range	- 	Formatted	
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3.13		/ //	F	ormatted	<u></u>
total volatile	organic compounds	[/]	F	ormatted	
sum of the co	ncentrations of identified and unidentified volatile organic compounds eluting between and		F	ormatted	()
including n-he	xane and n-hexadecane.		<u> </u> [F	ormatted	(
	y:_For a MEX-TRB/P-process, the total volatile organic compounds are typically measured using a non-	/ /	<u> </u> [F	ormatted	
polar capillary (factor	C column and the concentrations of the converted areas of unidentified peaks using the toluene response		<u> </u> [F	Formatted Table	
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[SOURCE: ISO	16000-9: 2006, :,3.14, modified} Note 1 to entry rewritten and Note 2 to entry deleted.]	1	<u>//</u> _F	ormatted	
4 Abbrevi	ated terms and symbols		<u> </u> _F	Formatted	
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4.1 Abbrev	lated terms	111111	<u>//</u> _	ormatted	
ABS	Acrylonitrile Butadience Styrenebutadience styrene]]]]]]]	'/⊱	Formatted	
CPC	Condensation Particle Counterparticle counter	//////	'/ <u> </u>	Formatted	
DNPH	Dinitrophenylhydrazine]]]]]]	'/⊱	Formatted	
FP	Fine Particles SUAMOLANCES SUA]]]]]]]	'/⊱	Formatted	
GC/MS	Gas Chromatography/Mass SpectrometryGas chromatography/mass spectrometry]]]]]]]	'/⊱	Formatted	
HPLC	High Performance Liquid Chromatography performance liquid chromatography]]]]]]]	'/⊱	Formatted	
PLA	Poly Lactic Acid acid	//////	'/⊱	Formatted	
	· ———	//////	>	Formatted	<u> </u>
RH	Relative Humidity ISO/FDIS 27548]]]]]]]	//⊱	Formatted Table	
RPD https:/	Relative Percentage Difference percentage difference /e2ec411e-b646-4cf1-be70-		"/>	Formatted	()
RSD	Relative Standard Deviationstandard deviation		'/⊱	Formatted	
TP	Total Particles particles	'// <i> //</i>	'/⊱	Formatted	
UFP	Ultrafine Particles particles	' /	/ F	Formatted	
4.2 Symbol	s	 //	/ F	Formatted	
, and the second		////	/ F	Formatted	
<u>-β</u> -β	particle loss-rate coefficient (h-1)	1///	/ F	ormatted	
$C_{\rm av}$	arithmetic average of $C_p(t)$, $C_p(t)$ between t_{start} , t_{start} and t_{stap} , t_{stap} , t_{stap} (cm ⁻³)	1///	/ F	ormatted	
C	VOC concentration during the extrusion phase (μg·cm ⁻³)	1///	<u>/</u> F	ormatted	
$C_{\mathbf{b}}$	VOC concentration during the pre-extruding phase (μg·cm ⁻³)	1//	<u> </u>	Formatted	
L	loading factor (m³·m⁻³)	1//	/ F	Formatted	
PER(t)	time-dependent particle emission rate (s-1)	#	\succeq	ormatted	
$[r_{\rm pe}(t)]$			\succ	Formatted	
$\frac{PER_{hour}}{PER_h}$	particle emission rate for an average hour (h-1)		\succ	Formatted	
$(r_{\text{pe,h}})$			\vdash	Formatted	
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	ISO/FDIS 27548:2024(en)	
Δt	time difference between two successive data points (s)	*
t _{start}	time when print command sent (s)	4
$t_{\rm stop}$	time when extrusion ends (s)	4
n <u>r</u>	air exchange rate (h-1)	4
$P_{m_{\underline{\bullet}}}$	final test specimen mass after extrusion completes (g)	
Vc	emission test chamber volume (m³)	4
Vs	sample volume during the extruding phase (m³)	4

5 Method overview

This document specifies test methods to determine particle and chemical emission rates during the operation of the desktop MEX-TRB/P machine. Particle and chemical emissions are determined by the chamber concentration emitted from the operation of the desktop MEX-TRB/P machine inside an ETC where temperature, humidity, air exchange rate, and air velocity are controlled. Test procedures are divided into three phases: pre-extruding, extruding and post-extruding.

The observed chamber concentration during the extruding phase is converted to the particle emission rate per hour or used material mass by mathematical calculations. The procedures for the build conditions should be under the standard operating conditions (see Clause A.2)A.2) of the desktop MEX-TRB/P machine. Chemical emissions (TVOC and aldehydes) are directly calculated from the chamber concentration as mass per hour.

There are various reasons for performing these measurements. For example, determining the maximum emissions for using machines or comparing emissions from different AM machines. The procedures used for the test can be tailored for the specific purpose of the test. In the case of determining maximum emission rates, the AM machine should be set at the conditions that result in maximum emissions, which are typically the fastest extruding speed, the thickest layer, and the highest nozzle temperature recommended by the manufacturer. For comparing emission rates from different AM machines, the process settings can shall be referred to values that are outlined in Annex A. Annex A.

6 Requirements of the instrument for measurement /e2ec411e-b646-4cf1-be70-

6.1 General

6.1.1 Emission test chamber (ETC)

The ETC shall be designed with stainless steel electropolished materials so that it does not emit or absorbs substances that can affect measurements during background and AM process tests. During operation, the ETC shall be controlled for constant temperature, humidity, and air exchange rate (see 7.1), 7.1), and they shall be continuously monitored by using data logging instruments that are calibrated and traceable to primary standards.

General requirements for other materials comprising of an air supply system, mixing equipment and air tightness which are used to construct ETC shall be tested in the ETC to confirm that they do not contribute to the emission test chamber background concentration through emission or adsorption. The test setup of ETC shall not recirculate chamber air so as not to have the contaminated air put into the ETC again.

When flow changes are made to chamber air, a tracer gas test shall be performed to confirm the accuracy df the air exchange rate. The verification process for the test conditions of the ETC such as a tracer gas test procedure and a recovery test shall be performed in accordance with ISO 16000-9 or ASTM D6670.

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