



ANSI/CAN/UL 2904

JOINT CANADA-UNITED STATES
NATIONAL STANDARD

STANDARD FOR SAFETY

Standard Method for Testing and Assessing Particle and Chemical Emissions from 3D Printers



ANSI/UL 2904-2019



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UL Standard for Safety for Standard Method for Testing and Assessing Particle and Chemical Emissions from 3D Printers, ANSI/CAN/UL 2904

First Edition, Dated January 31, 2019

Summary of Topics

The First Edition of ANSI/CAN/UL 2904 has been issued to reflect the latest ANSI and SCC approval dates, and to incorporate the proposals dated August 31, 2018 and December 7, 2018.

The new requirements are substantially in accordance with Proposal(s) on this subject dated August 31, 2018 and December 7, 2018.

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ANSI/CAN/UL 2904

**Standard Method for Testing and Assessing Particle and Chemical
Emissions from 3D Printers**

First Edition

January 31, 2019

This ANSI/CAN/UL Safety Standard consists of the First Edition.

The most recent designation of ANSI/UL 2904 as an American National Standard (ANSI) occurred on January 31, 2019. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface or SCC Foreword.

This standard has been designated as a National Standard of Canada (NSC) on January 31, 2019.

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Preface

This is the First Edition of the ANSI/CAN/UL 2904, Standard Method for Testing and Assessing Particle and Chemical Emissions from 3D Printers.

UL is accredited by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC) as a Standards Development Organization (SDO).

This Standard has been developed in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization.

This ANSI/CAN/UL 2904 Standard is under continuous maintenance, whereby each revision is approved in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization. In the event that no revisions are issued for a period of four years from the date of publication, action to revise, reaffirm, or withdraw the standard shall be initiated.

In Canada, there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the possibility that some Canadian authorities may require additional markings and/or installation instructions to be in both official languages.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at <http://csds.ul.com>.

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This Edition of the Standard has been formally approved by the UL Standards Technical Panel (STP) on Chemical and Particle Emissions from 3D Printers, STP 2904.

This list represents the STP 2904 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

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This Standard is intended to be used for conformity assessment.

The intended primary application of this standard is stated in its scope. It is important to note that it remains the responsibility of the user of the standard to judge its suitability for this particular application.

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INTRODUCTION

1 Scope

1.1 This standard presents methodologies for characterizing and quantifying coarse, fine, and ultrafine particles and volatile organic compound (VOC) emissions from operating three-dimensional (3D) printers under normal conditions of use in defined indoor environments including classroom, office, and residential scenarios.

1.2 This method primarily applies to the emissions of particles and volatile organic chemicals from 3D printers and feedstock which are widely used in classrooms, offices, libraries, residential settings, small and medium size enterprises, and other non-industrial indoor spaces. The 3D printers are operated with a variety of commercially available feedstock.

For environmental chamber tests under controlled conditions, a 3D printer's maximum size and format is limited.

For measurements, it is required that environmental chamber conditions are known and can be kept stable at least during the measurement.

1.3 The measurement protocols may be used to

- a) compare emissions from different feedstock or adhesion materials operated by a specific 3D printer, (material impact)
- b) compare emissions from printing objects of different shape, design, and size on a specific 3D printer (printed object impact)
- c) compare emissions from different 3D printers operated under identical conditions i. e. same object, same feedstock (print media), same environmental conditions (3D printer hardware impact)
- d) quantify emissions in a given specific exposure scenario – e.g. workshop, small production line, etc. (environmental impact)
- e) obtain data for use in risk assessments or product claims

1.4 This method includes requirements on laboratory quality management systems and measurement uncertainty estimation.

1.5 This standard establishes emissions criteria for particles and certain chemicals based on existing standards, guidelines, and research data for the management of airborne gaseous and aerosol pollutants in indoor environments.

1.6 This standard may be utilized as the basis for product testing and for certification/verification programs.

1.7 This standard specifies the maximum allowable concentrations of target chemicals and particles. However, this standard does not purport to address all of the safety, health, comfort (e.g., odor) and performance concerns, if any associated with its use. Users of this standard may establish additional safety, health, comfort and other performance conditions, and determine the applicability of regulatory requirements prior to use.

1.8 This standard provides guidance for use of the measurement protocols as a basis for product claims or verifications.

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2 Undated References

Any undated reference to a code or standard appearing in the requirements of this Standard shall be interpreted as referring to the latest edition of that code or standard.

3 Definitions

3.1 Accumulated Particle Number Concentration, $C_p(t)$ [cm^{-3}]

Time-dependent particle number concentration in a specified particle size range (at a minimum between 10 nm and 5 μm).

3.2 Aerosol

System of particles (solid and/or liquid) suspended in gas.

3.3 Aerosol Measurement Device

For the purposes of this test method, a device for determining the time-dependent particle number concentration of an aerosol within a defined particle size and concentration ranges and with a certain time resolution.

3.4 Air Exchange Rate (ACH), n [h^{-1}]

Ratio of the volume of clean air at room temperature (see [3.22](#)) and pressure brought into the chamber per hour [$\text{m}^3 \text{h}^{-1}$] to the unloaded chamber volume [m^3].

3.5 Air Flow Rate [$\text{m}^3 \text{h}^{-1}$]

Air volume at room temperature and pressure entering the environmental chamber per unit time.

3.6 Air Velocity [m s^{-1}]

The air speed measured in the unloaded environmental testing chamber.

3.7 Aldehydes (ALD)

Aldehydes are low molecular weight organic compounds containing a functional group with the structure –CHO. The measured aldehydes are 2-butenal, acetaldehyde, benzaldehyde, 2,5-dimethylbenzaldehyde, 2-methylbenzaldehyde, 3 (and/or) 4-methylbenzaldehyde, butanal, 3-methylbutanal, formaldehyde, hexanal, pentanal, and propanal, individually calibrated to a compound specific standard via High-Performance Liquid Chromatography (HPLC) analysis.

3.8 Average Gas Emission Rate, $ER_{g,i}$ [$\mu\text{g h}^{-1}$]

Average mass of the analyte i (VOC or aldehyde) emitted from a tested 3D printer per unit time.

3.9 Average Particle Emission Rate, ER_p [h^{-1}]

Average number of particles emitted from a tested 3D printer per unit print time, calculated from total number of emitted particles (TP) divided by the total print time in hours.

3.10 Blank Value/ Empty Chamber background

Background concentration of the measuring system (environmental chamber, sampling media, and analyzer) for individual substances, total volatile organic compounds (TVOC) and particles including coarse, fine, and ultrafine particles.

3.11 Chamber Loading

Placing a tested 3D printer into the environmental chamber.

3.12 Clean Air

Air supplied to the chamber that meets requirements in [8.2](#) Chamber Parameters.

3.13 Coarse Particles

Particles having an aerodynamic diameter greater than 2.5 μm and less than or equal to 10 μm .

3.14 Condensation Particle Counter, CPC

Instrument that measures the particle number concentration of an aerosol by condensational growth to optical detection sizes using a working fluid such as water or butanol. For the measurement of total particle number concentration, a CPC with butanol as a working fluid is suggested.

3.15 Environmental Chamber

An enclosed test environment consisting of a known volume with controlled environmental parameters used for the purpose of providing accurate and reproducible particle and chemical emission measurements from defined product sources.

3.16 Emission Time [h]

Time between when 3D printer starts extruding (t_{start}) and 3D printer is no longer emitting new particles or 3D printer stops extruding, whichever comes after (t_{stop}).

3.17 Emission Yield, EY_i [$\mu\text{g g}^{-1}$]

This quantity gives the mass of the analyte i (VOC or aldehyde) or the number of particles, which is emitted from a tested 3D printer per unit of mass of feedstock used.

3.18 Feedstock

3D printer media consumed to create a printed object, for example, filament and liquid resin.

3.19 Fine Particles, FP

Particles having an aerodynamic diameter smaller than 2.5 μm and greater than 0.1 μm .

3.20 Load Factor

Quotient of the volume of the tested 3D printer (see [8.2](#)) and the volume of the empty environmental chamber.

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3.21 Mass/Number Concentration

Mass/number of particles or mass of VOC per unit air volume at room temperature and pressure.

3.22 Normal Environment

Environmental conditions: $23 \pm 1^\circ\text{C}$, $50 \pm 5\%$ relative humidity as per ISO 554. Conditioning environment is the same as normal environment.

3.23 Particles

Small discrete solid or liquid objects that can be chemically homogeneous or heterogeneous, and are suspended in air or gas with specified physical parameters.

3.24 Particle Emission Rate, $PER(t)$ [s^{-1}]

Time-dependent system-specific rate during the printing phase and post-operating phase.

3.25 Particle Loss Coefficient, β [s^{-1}]

Coefficient for describing particle loss in the environmental chamber.

3.26 Particle Size/Particle Diameter

The physical dimension of a particle. The term particle size is often used as a synonym for particle diameter. The term particle diameter is also used to classify particles in particle size classes.

3.27 Particle Size Spectrometer based on Electrical Mobility

Instrument that measures the particle number concentration of an aerosol in various particle size ranges, where particle size is determined by particle electrical mobility.

3.28 Printing Phase

Examination of the 3D printer during printing phase following pre-operating phase. The printing phase begins when the feedstock starts extruding and ends when the object is printed and the nozzle stops extruding and will not resume extruding.

3.29 Print Time [h]

The length of the printing phase.

3.30 Pre-operating Phase

Phase following the preparation phase. Experimental arrangement under normal environmental conditions where the 3D printer in the chamber is turned on (receiving electrical supply) and is waiting to start. Warming-up and energy saving modes are included. At the beginning of the pre-operating phase the 3D printer is switched on. Thereafter the 3D printer is operated with the default settings for the feedstock used.

3.31 Preparation Phase

First phase where the environmental chamber is prepared for testing. The phase includes chamber cleaning, unpacking test supplies, and confirming operability of 3D printer system.

3.32 Post-operating Phase

Phase following the printing phase. Experimental arrangement in which the 3D printer is still in the chamber with the same air exchange rate as in the printing phase, but printing has already been completed.

3.33 Relative Humidity, RH [%]

The amount of water vapor present in air expressed as a percentage of the amount needed for saturation at the same temperature.

3.34 Sampling Interval

Time over which a single air sample is collected.

3.35 Sampling Period

Established time for collection of an air sample from the environmental chamber.

3.36 Temperature, T [°C]

Degree of hotness or coldness expressed in degrees Celsius.

3.37 Test Protocol

A defined process with specified materials, chemicals, application instructions and equipment for implementation in an environmental chamber.

3.38 Total Volatile Organic Compounds, TVOC

The sum value of all compounds within the C₆ to C₁₆ range (those that elute between hexane and hexadecane) as measured by gas chromatography/mass spectrometry (GC/MS) techniques such as U.S. EPA Method TO-17 or ASTM D6196, and the concentrations of the converted areas of unidentified peaks using the toluene response factor.

3.39 Toluene Equivalent

Concentration of an unidentified compound determined from Toluene calibration. For GC/MS analysis, the TIC (total ion chromatogram) shall be used.

3.40 Total Particles, TP [-]

TP is calculated from the measured particle number concentration for a specified duration of particle emission sampling and quantifies the total number of emitted particles during a print job.