Designation: E3325 – 21

Standard Practice for Sampling of Solar Photovoltaic Modules for Toxicity Testing[1]

This standard is issued under the fixed designation E3325; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The purpose of this practice is to describe a representative and repeatable sample preparation methodology to conduct toxicity testing on solar photovoltaic (PV) modules for use with EPA Test Method 1311: Toxicity Characteristic Leaching Procedure (TCLP).

1.2 This practice refers to the extraction and preparation of PV module samples by EPA Method 1311, the testing for eight (8) distinct metals – mercury (by Method 7470A), arsenic, barium, cadmium, chromium, lead, selenium and silver (by Method 6010C) as well as the analysis and interpretation of the test results on a module level.

1.3 This practice applies to only *(1)* standard crystalline silicon (c-Si) modules, multi and mono-crystalline silicon with aluminum back surface field (Al-BSF) cell technology and *(2)* cadmium telluride (CdTe) PV modules.

1.4 Other and newer PV technologies and module architectures, for example, passivated emitter and rear cell (PERC), interdigitated back contact (IBC), hetero-junction technology (HJT), multiwire, half cut, shingled etc., have not been evaluated with this practice, although the concept and practice can be easily extended and applied to other technologies following the conceptual approach presented in this document.

1.5 The sample extraction/removal methodology applied in this practice is the waterjet cutting sampling method. Sample extraction with mechanical cutting has been extensively evaluated but the variability of TCLP test results based on the mechanical cut samples tend to be much higher (30 %) than that of the waterjet cut samples (8 %).[2] Therefore, the mechanical cut method is not presented in this practice.

1.6 Only the laminate area of the PV module is considered for TCLP testing, as other possible module parts, such as aluminum frame, junction box and cables contain recyclable materials that are already well-documented and are not specific to the PV modules.

1.7 The material gravimetric density (g/cm^3) throughout the laminate area is considered constant.

1.8 This practice was developed to be consistent with three fundamental requirements:

1.8.1 Sample pieces with particle size not to exceed the allowed size limit of EPA 1311 standard which is 9.5 mm,

1.8.2 The particle size used in this practice as sample piece is consistent with the median particle size expected in landfill disposal[2], and

1.8.3 An assumption that each laminate sample piece will result in 100 % glass coverage area, due to the presence of bonding encapsulant layers once it is broken in the landfill.

1.9 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.11 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standard:*[3]

D4538 Terminology Relating to Protective Coating and Lining Work for Power Generation Facilities

E772 Terminology of Solar Energy Conversion

[1] This practice is under the jurisdiction of ASTM Committee E44 on Solar, Geothermal and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.09 on Photovoltaic Electric Power Conversion.

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[2] TamizhMani, G., Libby, C., Shaw, S., Krishnamurthy, R., Leslie, J., Yadav, R., Tatapudi S., and Bicer, B. "Evaluating PV Module Sample Removal Methods for TCLP Testing," IEEE Photovoltaic Specialists Conference, June 2018.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

2.2 *EPA Methods:*[4]

Test Method 1311 Toxicity Characteristic Leaching Procedure

Method 6010C (SW-846) Inductively Coupled Plasma - Atomic Emission Spectrometry

Method 7470A (SW-846) Mercury in Liquid Wastes (Manual Cold-Vapor Technique)

3. Terminology

3.1 Definitions of Terms used in this practice may be located in Terminology E772

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cell area, n*—the area of all the cells in the laminate excluding the cell ribbon/interconnect area, string-ribbon area and non-cell/non-ribbon area.

3.2.2 *cell-ribbon area, n*—the area of all the cell interconnect ribbons in the laminate excluding cell area, string-ribbon area and non-cell/non-ribbon area.

3.2.3 *laminate, n—of a PV module*, a stack of layers that are laminated together with superstrate (typically, glass), encapsulant (typically, polymeric material), solar cell and substrate (typically, polymeric sheet). A laminate does not include the frame and junction box of the module.

3.2.4 *non-cell/non-ribbon area (electrically inactive area), n*—the sum of all the areas (including the area embedded inside the groove of the frame) which are not covered by the cells, cell ribbons/interconnects and string ribbons.

3.2.5 *string-ribbon area, n*—the area of all the string ribbons in the laminate excluding cell area, cell-ribbon area and non-cell/non-ribbon area.

3.2.6 *total laminated area, n*—a sum of three or four areas – cell area, cell-ribbon area (c-Si modules only), string-ribbon area and non-cell/non-ribbon area.

4. Apparatus

4.1 *Waterjet Cutting Facility*—Waterjet cutting is an erosive process that uses high-pressure water to cut through the laminate for obtaining sample pieces required for the TCLP testing, typically provided by third-party waterjet cutting companies. An important benefit of the waterjet is the smooth cut with 100 % glass coverage in the cut pieces and ability to cut material without separating layers of the laminate into glass, encapsulant, cell and backsheet/backglass, as there is no heat-affected zone and glass vibration is minimized. Square pieces with each side not more than 9.5 mm in length are cut with the waterjet. These square pieces can be cut individually, or in the following two-step process. Initially, linear strips are cut with a width of 9.5 mm from each of the different laminate areas. In a second step, these strips will be placed on the waterjet machine and individual sample pieces will be cut as square pieces with each side not more than 9.5 mm in length.

4.2 *Convection Oven*—An oven used to dry the sample pieces at 50 °C by evenly distributing the heat around the sample pieces.

4.3 *Deionized Water*—Deionized water is the water that contains no mineral ions. “Deionized water, —water that has been purified of salts by passing through a cation-exchange resin to replace metal ions, such as calcium and iron, with the hydrogen ion and through an anion-exchange resin to remove both the hydrogen ions and the corresponding negative ions.” [D4538]

5. Summary of Practice

5.1 This practice presents a representative and repeatable methodology to remove sample pieces from PV modules for later use in the TCLP testing. This practice refers to the extraction and preparation of PV module sample pieces complying to the EPA Method 1311 for later testing to eight (8) distinct metals – mercury (by Method 7470A), arsenic, barium, cadmium, chromium, lead, selenium and silver (by Method 6010C) as well as the analysis and interpretation of the TCLP test results on a module level.

5.2 Sample pieces must be 9.3 by 9.3 – 9.5 by 9.5 mm square.

5.3 The total weight of all sample pieces must be a minimum of 100 g for TCLP testing, plus 5–10 g for pH testing.

5.4 For both module types (crystalline silicon and cadmium telluride), the following step-wise procedure is used:

5.4.1 Measure the required areas of the module; these differ for crystalline-Si (four areas) and CdTe (three areas) modules.

5.4.2 Calculate the percentage of the total laminate area for each required area.

5.4.3 Estimate the number of samples needed from the total weight of samples needed divided by the average weight of a sample piece.

5.4.4 Remove samples using the waterjet cutting approach.

5.4.5 Rinse and dry samples.

5.4.6 Group samples according to the areas from which they were removed.

5.4.7 Weigh all samples in each area group.

5.4.8 Calculate the number of samples needed for each area group.

5.4.9 Verify that the samples meet the total weight in 5.3.

5.4.10 Submit the samples for TCLP testing.

6. Significance and Use

6.1 The primary goal of this practice is to extract representative samples from PV modules for TCLP toxicity testing purposes in order to receive unbiased, comparable and repeatable toxicity test results from independent TCLP testing laboratories.

6.2 Solar photovoltaic (PV) modules in the United States and the world reaching end-of-life due to failure, underperformance or breakage due to extreme weather have to be recycled or otherwise safely disposed of following the Resource Conservation and Recovery Act (RCRA) regulation [United States, Resource Conservation and Recovery Act. Pub.L. 94–580,

[4] Available from United States Environmental Protection Agency (EPA), William Jefferson Clinton Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20460, http://www.epa.gov.