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Standard Guide for Size and Shape of Solid Particles, Liquid Droplets, and Gas Bubbles, Dynamically Conveyed, Using a Dynamic Imaging Analyzer[1]

This standard is issued under the fixed designation E3338; 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 This guide provides information for determining particle size and shape using Dynamic Imaging Analyzers (DIA) in multiple application points including in-line, at-line and stand alone, lab based or portable, configurations. This guide focuses on concepts and strategies for applying imaging techniques to process applications in a way that improves the knowledge of the particles contained in dynamic flows, dry and wet, which can lead to more improved control of manufacturing processes.

1.2 Analyzers may be configured for open, dry or wet analysis, or enclosed, dry or wet analysis, as appropriate for analysis of the process or test specimen. Particles in liquid borne flows can be analyzed at least up to 1000 µm and dry particle flows can be analyzed up to several cm if equipment is appropriate for the size. Limitations will be discussed in Section 6.

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

1.4 *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.*

1.5 *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 Standards:*[2]

B215 Practices for Sampling Metal Powders

B821 Guide for Liquid Dispersion of Metal Powders and Related Compounds for Particle Size Analysis

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D6323 Guide for Laboratory Subsampling of Media Related to Waste Management Activities

D7596 Test Method for Automatic Particle Counting and Particle Shape Classification of Oils Using a Direct Imaging Integrated Tester

E2589 Terminology Relating to Nonsieving Methods of Powder Characterization

E2651 Guide for Powder Particle Size Analysis

2.2 *API Standard:*[3]

API STD 19C Measurement of and Specifications for Proppants Used in Hydraulic Fracturing and Gravel-packing Operations

2.3 *DIN Standard:*[4]

DIN 66141 Representation of Particle Size Distributions – Basic Standard

2.4 *ISO Standards:*[5]

ISO 13322-1 Particle sizing analysis – Image analysis methods – Part 1: Static image analysis methods

ISO 13322-2 Particle size analysis – Image analysis methods – Part 2: Dynamic image analysis methods

[1] This guide is under the jurisdiction of ASTM Committee E29 on Particle and Spray Characterization and is the direct responsibility of Subcommittee E29.02 on Non-Sieving Methods.

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[2] 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.

[3] Available from American Petroleum Institute (API), 200 Massachusetts Ave. NW, Suite 1100, Washington, DC 20001, http://www.api.org.

[4] Available from Deutsches Institut für Normung e.V.(DIN), Am DIN-Platz, Burggrafenstrasse 6, 10787 Berlin, Germany, http://www.din.de.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

ISO 14488 Particulate materials – Sampling and sample splitting for the determination of particulate properties
ISO 14887 Sample preparation – Dispersing procedures for powders in liquids

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, refer to Terminology E2589 and ISO 13322-2.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bounding box, n—in image analysis*, the narrowest fit of a rectangular box enclosing a particle defined by the minimum Feret diameter, $X_{FE\ Min}$.

3.2.2 *dynamic imaging analyzer (DIA), n—in image analysis*, a type of instrument where a test specimen is conducted through an illuminated measurement volume where images of the particles (solid particles, liquid droplets or gaseous bubbles) of the specimen are captured and their size and shape characteristics are determined as appropriate to the application.

3.2.3 *pixel, n—in image analysis*, the smallest addressable element of an image display.

3.2.4 *smoothness, n—in image analysis*, with reference to the perimeter of the particle projection, the measure of the roundness of a particle's contours and is defined by the ratio of the area of the particle projection (Ap) to the area of the smallest ellipse which encloses the particle projection (Ae); Smoothness = Ap / Ae.

3.2.5 *transparent circularity, n—in image analysis*, refers to a modification of the traditional circularity calculation by replacing the outer perimeter with the sum of the outer and inner perimeters of particles with transparent centers.

3.3 *Symbols:*

3.3.1 A—area of the two-dimensional particle projection

3.3.2 $X_{FE\ Max}$—maximum Feret diameter

3.3.3 $X_{FE\ Min}$—minimum Feret diameter

3.3.4 X_{Length}—calculated particle length

3.3.5 $X_{Ma\ Min}$—minimum Martin diameter

4. Significance and Use

4.1 This guide is intended to inform those who have need for particle analysis data of their product or process, how imaging technology, in the form of a DIA, can be employed to provide the required information for a wide range of processes and material types. It expands on dynamic imaging information provided in Guide E2651 which is a broad view of particle analysis methods.

4.2 This guide can be used to assess the suitability of the technology to particular applications as well as any limitations that may be encountered. It is also intended to help the user make an informed decision on how to best use the technology to make the measurement(s) most important in providing data that best describes the process or product.

4.3 Determining particle shape of materials such as proppants, catalysts, additive manufacturing powders, and many more materials, is critical to their performance. Imaging technology can provide a consistent assessment of shape factors based on objective criteria and a statistically significant number of particles analyzed. Human visual methods generally compare a small number of particles to a standard leaving room for subjective interpretation.

4.4 Determining particle count, size and shape are important in assessing contamination of fluids such as fuels, lubricating oils, water, injectables, and other liquids where particle contamination can affect their performance. Particle shape can point to the type and source of these particles which can help analysts improve process control.

4.5 Shape information is also advantageous in categorizing particles detected so as to not skew particle analysis results. For instance, if a flowing mixture of solid particles in liquid also contains gas bubbles or water droplets, it is important to be able to identify the bubbles and droplets and not count them as solid particles.

5. Sampling and Sample Preparation

5.1 Analyzers may be installed directly into a pipe with flowing liquid, at-line by sampling liquid or off-line by sampling liquids for test. Analyzers, differently configured, can also be used to measure size and shape of dry particles conveyed through the measurement volume.

5.1.1 Obtaining a representative sample for analysis is a critical first step in achieving good results. Guide E2651 discusses standards available for sampling and sample handling (reduction, dilution, etc.) that are used in industries where particle analysis is performed. One should refer to ASTM standards for sampling practices and methods whenever possible. A good reference for sampling of liquids, stationary and flowing, is Practice D4057. Good references for sampling dry powders are Practice B215 and ISO 14488.

5.1.2 Preparation of the test specimen may be required in order to ensure the analyzer sees a true representation of the sample. For instance, inspection of fluids which contain solid particles require the test specimen to be agitated to disperse the particulate in the fluid and to avoid settling out of particles prior to analysis. The particle concentration of a mixture may also cause particles to be overlapping in the image capture which can lead to error in assessing size and shape.

5.1.3 Dry solid analyzers generally have a hopper and vibratory feed mechanism. There is a tendency for solids of different sizes to segregate with the smallest particles collecting at the bottom of the hopper and being analyzed first. It is important that the entire test specimen be analyzed in order to avoid errors that could arise from partial analysis of the test specimen.

5.1.4 Dry solids in powder form may more easily be analyzed in slurry form (see 6.2). Guide B821 and ISO 14887 describe methods that may be used to slurry metal powders for analysis. This practice is included as a general reference as these methods may be applicable to other materials.

5.1.5 Samples obtained may require further reduction in volume in order to create a test specimen that is suitable for the analyzer. Guide D6323 provides an overview of standards available to accomplish this function. In addition to creating a sample size appropriate for the physical restrictions of the