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Standard Test Method for Determining Liquid Drop Size Characteristics in a Spray Using Optical Nonimaging Light-Scattering Instruments[1]

This standard is issued under the fixed designation E1260; 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.

INTRODUCTION

This standard is one of several describing a different class of test methods for determining liquid drop size characteristics in a spray. These test methods can be broadly distinguished as "optical" or "non-optical." In the optical category there are test methods that essentially make images (such as photographs) of drops that can be measured either manually or automatically, and test methods that do not make images but use optical phenomena exhibited by single drops or ensembles of drops which can be recorded and used to calculate either individual drop sizes or the distribution of drop sizes in an ensemble. This test method deals with the latter class, and hence, is described as "nonimaging." The various optical phenomena involved are commonly described as "light-scattering." Using any of these test methods, the spray is observed for a period of time during which a large number of drops is examined, and the data are treated so as to derive drop-size statistics for the sample investigated.

1. Scope

1.1 The purpose of this test method is to obtain data which characterize the sizes of liquid particles or drops such as are produced by a spray nozzle or similar device under specified conditions using a specified liquid. The drops will generally be in the size range from 5-μm to the order of 1 000-μm diameter; they will occur in sprays which may be as small as a few cubic centimetres or as large as several cubic metres. Typically the number density of the particles can vary significantly from one point to another.

1.2 This test method is intended primarily for use in standardizing measurements of the performance of sprayproducing devices. It is limited to those techniques and instruments that operate by passing a beam of light through the spray and analyzing the light scattered by the droplets to derive size information. Such techniques do not produce images of individual drops, and therefore, are known as "optical (nonimaging) instruments."

1.3 The measurements made, when referred to the entire spray being sampled, may be flux sensitive or spatial, as defined in Practice E799, depending on the techniques used with a particular instrument.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E456 Terminology Relating to Quality and Statistics

E799 Practice for Determining Data Criteria and Processing for Liquid Drop Size Analysis

E1088 Definitions of Terms Relating to Atomizing Devices (Withdrawn 1997)[3]

E1296 Terminology for Liquid Particle Statistics (Withdrawn 1997)[3]

E1620 Terminology Relating to Liquid Particles and Atomization

2.2 *NFPA Standards:*

NFPA 30 Flammable and Combustible Liquids Code[4]

[1] This test method 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] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

NFPA 33 Spray Application Using Flammable and Combustible Materials[4]

3. Terminology

3.1 *Definitions*—For terminology pertaining to this test method, refer to Terminology E456, Practice E799, Definitions E1088, and Terminology E1296.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *spray*—the term "spray" in this test method includes all ensembles, arrays, or clouds composed of liquid particles or drops whether produced artificially or naturally. Although it is usual to consider a spray as implying significant motion of the drops relative to the atmosphere there are situations in which the relative velocity is or becomes sufficiently low to be negligible. In this case, a "spray" is indistinguishable from a "cloud" which implies a static ensemble of drops.

4. Summary of Test Method

4.1 The spray is examined by a means whereby a beam of light passes through local regions, which make a representative sample, and one of the forms of light-scattering phenomena that occur is detected by the instrument. The data are recorded, usually by data-processing equipment, and are transformed mathematically into statistics characterizing the size distribution These operations may be performed manually or automatically and the instrument may provide a visual display or a printed report.

5. Significance and Use

5.1 The purpose of this test method is to provide data on liquid drop-size characteristics for sprays, as indicated by optical nonimaging light-scattering instruments. The results obtained generally will be statistical in nature. The number of variables concerned in the production of liquid spray, together with the variety of optical, electronic, and sampling systems used in different instruments, may contribute to variations in the test results. Care must be exercised, therefore, when attempting to compare data from samples obtained by different means.

6. Interferences

6.1 *Spray Nozzle*—Many spray nozzles are designed with internal liquid passages of small dimensions and it is important to ensure that these passages do not become blocked with foreign matter. Some nozzles have built-in filters or screens but in all cases it is advisable to fit a filter in the liquid supply line immediately upstream of the nozzle inlet to remove any solid particles that are considered likely to cause problems.

6.1.1 The use of one liquid to simulate another fuel may affect the performance of certain types of nozzle due to differences in density, viscosity, and surface tension. In addition, however, occasionally a problem may occur due to differences in wetting the surfaces, for example, a nozzle tested previously in fuel (or other hydrocarbon) may exhibit a poor quality spray when first tested with water and may require the use of a degreasing agent to remove traces of hydrocarbon from the surfaces containing the liquid.

6.1.2 It is very important to protect the edges of the discharge orifice of a spray nozzle from accidental damage prior to testing. This protection is best accomplished by the use of a cover over the discharge orifice of the nozzle during storage and installation on the test stand.

6.2 Care must be exercised to prevent the ingress of liquid drops into the instrument. The surfaces of lenses, mirrors, and windows should be inspected at frequent intervals for cleanliness or damage and the manufacturer's recommendations followed.

7. Apparatus

7.1 *Light Source,* (including lasers),

7.1.1 *Optical Means,* for producing a suitable beam that passes through a region of the spray,

7.1.2 *Detecting Means,* for recording light-scattering phenomena resulting from the liquid drops and means for transforming the observations into statistical estimates of drop size and dispersion characteristics, as shown in Fig. 1.

7.2 *Spray Chamber,* preferably without components that could affect the optical behavior of the incident/scattered light (or have known effect thereon). It is convenient to employ this when the spray or spray-producing device to be tested is small in size relative to the apparatus. Use of this chamber may be desirable to protect the optical and electronic components of the apparatus from damage by the liquid spray (see also Section 8). In this case the apparatus is preferably securely installed in a suitable location. The chamber should not affect the normal formation of the spray.

7.2.1 In cases where there are known or suspected steep drop concentration gradients or variations in the spray, for example, in hollow-cone spray patterns, means shall be provided for accurately locating the spraying device relative to the light beam source and sensor. Provision should also be made for selectively examining a number of different locations or regions in the spray.

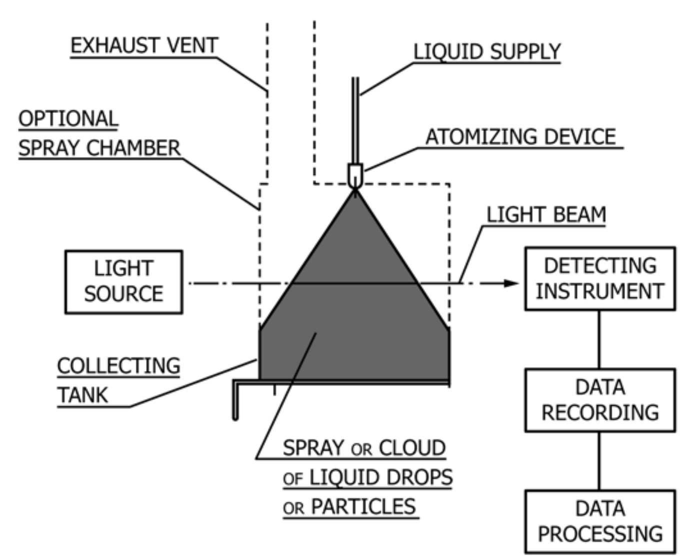

FIG. 1 Diagram of Test Arrangement

7.3 Operating instructions shall be supplied by the manufacturer or contractor of the apparatus or instrument. The instructions shall contain:

7.3.1 Description of the operational principles of the instrument, oriented towards a trained technical operator. Reference to relevant published literature shall be included;

7.3.2 Recommendations for installation and use of the apparatus;

7.3.3 Range of ambient temperature, humidity, and line voltage variation, and any known limitations on the operating environment;

7.3.4 Ranges of liquid particle size, velocity, and number density or some equivalent parameter for which the instrument is designed;

7.3.5 Maintenance procedures recommended and required;

7.3.6 Calibration verification procedures; and

7.3.7 Statement of accuracy, repeatability, and reproducibility of the resultant drop-size data.

8. Hazards

8.1 *Safety Precautions:*

8.1.1 **Warning—***A spray of flammable liquid dispersed in air presents the risk of explosion and fire.* Refer to NFPA 30 or NFPA 33 for information about safe practices for storage and handling of flammable liquids and for spray processes involving sprays of flammable liquids.

8.1.2 **Warning—***Exposure to drops of various liquids by inhalation, ingestion, and skin contact, may constitute health hazards.*

8.1.3 **Warning—***Emission of some sprayed liquids into the atmosphere may be harmful to the environment or may pose a health risk.*

8.1.4 **Warning—***Laser-based instruments contain lasers or other strong light sources which may pose a hazard to persons in their vicinity.*

8.1.5 Always read and follow the label, federal, state, and local guidelines for the handling, application, and disposal of chemicals, and manufacturer instructions for instrument use.

8.2 Containment is normally required.

8.3 Additional hazards may need to mitigated or avoided.

9. Sampling

9.1 For purposes of this test method each discrete test is considered a sample. If the duration of the test observation period is sufficiently long the sample may be regarded as time-averaged data for a large number of liquid particles for the particular location in the spray. In this case there may be no need for repetitive (replicated) tests.

9.2 If the test objective is to obtain measurements as representative as possible of the entire spray, then the sampling locations shall be chosen to accomplish this purpose. If large drop concentration gradients are apparent or detected in preliminary tests, a sufficient number of sampling locations shall be selected to allow an averaging procedure to be employed.

9.3 Where previously observed data exist relative to the device under test or where operating circumstances dictate it shall be permissible to take observations at a single location in the spray and to report the result as a "standardized representative determination."

9.4 In most instances, measurements at a single location are not sufficient, so the spray should usually be traversed laterally, longitudinally, or axially, depending upon individual requirements. The number of points to be tested should ensure that a statistically representative sample of the spray is made.

10. Preparation of Apparatus

10.1 Use of this test method requires that the presence of the instrument, or any portions thereof, in proximity to the spray shall not interfere with the process of producing the spray (by atomization of the liquid) or the air patterns in the region being examined. This technique is described as "nonintrusive."

10.2 The instruments are invariably designed and calibrated to provide equivalent spherical diameters for particles. The instruments may be fully automatic in the sense that they produce a printed report of the results of each test, or they may require manual processing of the data observed. In any case the individuals performing the test methods are required to use judgment in aligning the light beam in relation to the spray in accordance with established procedures for each subject. These procedures may include multiple positions in the spray, replication of tests, and other averaging techniques.

10.3 Liquid particles may change size, for example, due to evaporation. Furthermore, breakup of liquids from jets or sheets into particles changes as the particles travel from their source. The test procedure must take these factors into account by recognizing the need for sufficient distance from the origin of the spray for atomization to be essentially complete. For this reason an instrument that requires dilution of a sample of the spray (by adding air, for example) in order to reduce the effective drop concentration may not be suitable for use with volatile liquids.

10.4 The physical size or shape of the spray nozzle presents no special problem provided the spray is visible and accessible to the light beam. The shape and size of the spray, however, must be considered in relation to the view volume of the optical system employed.

11. Calibration Verification

11.1 Optical nonimaging instruments and systems in general have optical or electronic components, or both, which necessitate validation of the overall instrument. A periodic check or verification of the performance of the instrument using particles or particle images shall be performed.

11.2 Unlike the solid particle situation there is no way of preserving a sample of liquid drops in spray form, so at this time there is no primary standard available.

11.3 In the absence of primary reference sprays, the following secondary reference methods are available:

11.3.1 A monodisperse droplet generator,

11.3.2 Solid beads or particles, and

11.3.3 Reticles or graticules.

11.4 A preserved spray nozzle also may be used periodically as an approximate check on the operation of the system when providing a carefully defined reference spray.

12. Conditioning

12.1 In many cases the spray-producing devices to be tested will have been designed to operate with specific liquids. These may be of any kind including flammable, toxic, or otherwise hazardous substances, or multiple phase systems such as emulsions or drops containing air bubbles. It is important to determine whether or not such liquids are compatible with or suitable for the particular optical instrument to be employed. If not compatible, then different measurement systems or substitute liquids could be considered. It is desirable to simulate as closely as possible the physical and optical properties of the specified liquid such as viscosity, surface tension, density, and refractive index.

12.2 Whatever liquid is used for testing purposes its physical and optical properties must be carefully noted as part of the test record. It is advisable in any event to maintain the test liquid at a controlled temperature since this frequently has a large effect on the spray.

12.3 Since the ambient atmosphere into which the liquid is sprayed can have a significant effect on the drop characteristics, it is advisable to record the barometric pressure, temperature, and humidity of the air. The use of other atmospheres, for example, nitrogen, may be necessary in special cases.

13. Test Procedure

13.1 For testing spray nozzles install the nozzle in the apparatus in accordance with operating instructions, paying particular attention to the position of the spray relative to the light source and lenses, and taking all necessary safety precautions.

13.1.1 Adjust and record the test conditions pertinent to the atomizer and to the instrument as required to ensure that the instrument can take satisfactory readings. A practice run is advisable in most cases.

13.1.2 With the test conditions fully set, operate the instrument in accordance with the manufacturer's instructions.

13.2 If the instrument is capable of indicating or recording raw (unprocessed) data, then these data should be examined to ensure that the results are consistent with available information.

13.3 A verification of the performance of the instrument should be done after each series of tests.

14. Calculation of Results

14.1 The procedures given in Practice E799 shall be used as applicable.

15. Report

15.1 Data obtained by this test method shall be reported in such a manner as to clearly distinguish between observed data, including the use of conversion factors customarily employed, and interpretative results such as are obtained by curve-fitting procedures requiring judgment.

15.2 The report shall describe as fully as possible the recorded conditions under which the test was conducted so that the test can subsequently be repeated under identical conditions. This description shall include information on sampling and replication procedures. Instrument hardware and software parameters shall also be reported.

15.3 Data presentation shall conform to Practice E799.

15.4 The standard unit of length measurement for liquid drop size shall be the micrometre (μm).

16. Precision and Bias

16.1 A statement shall be included in the report, by reference if more convenient, relative to the reputed precision and bias of measurements as defined by Practice E177. The source of this information, for example, instrument manufacturer, independent laboratory or organization performing the reported tests, shall be clearly indicated.

16.2 The standard reference materials or test methods used in calibration and the date of the most recent calibration shall be reported.

17. Keywords

17.1 drop; droplet; light-scattering; liquid; optical; particle; sizing; spray