Designation: D2156 – 09

Standard Test Method for Smoke Density in Flue Gases from Burning Distillate Fuels[1]

This standard is issued under the fixed designation D2156; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the evaluation of smoke density in the flue gases from burning distillate fuels. It is intended primarily for use with home heating equipment burning kerosine or heating oils. It can be used in the laboratory or in the field to compare fuels for clean burning or to compare heating equipment.

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

1.2.1 Arbitrary and relative units are also used.

1.3 *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]

E97 Test Method for Directional Reflectance Factor, 45-deg 0-deg, of Opaque Specimens by Broad-Band Filter Reflectometry[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *smoke spot number*—the number of the spot on the standard scale most closely matching the color (or shade) of the test spot.

4. Summary of Test Method

4.1 A test smoke spot is obtained by pulling a fixed volume of flue gas through a fixed area of standard filter paper. The color (or shade) of the spot thus produced is visually matched with a standard scale, and the smoke density is expressed as a "smoke spot number."

5. Significance and Use

5.1 This test method provides a means of controlling smoke production in home heating equipment to an acceptable level. Excessive smoke density adversely affects efficiency by heat-exchanger fouling.

5.2 The range of smoke densities covered by this test method is that which has been found particularly pertinent to home-heating application. It is more sensitive to small amounts of smoke than several other smoke tests as indicated in the following comparison:

Smoke Spot Number	Icham, percent Transmission	Ringelman Smoke Number
0	100	0
2	95	0
4	80	0
6	54	0
8	18	0
9	0	0
9	0	0 to 5

6. Apparatus

6.1 *Sampling Device*—A suitable device providing a total flue gas sample volume of 36.9 ± 1.65 L at 16°C, 101 kPa for each 645 mm^2 effective surface area of filter paper shall be employed. The sampling device and connections shall be of such construction that the total travel of flue gas sample from flue to filter paper shall not exceed 410 mm. The device shall provide for cooling the sample below the charring temperature for the filter paper but not below the dew point of the sample. Suitable laboratory and portable field service equipment is illustrated in Fig. 1 and Fig. 2.

6.2 *Smoke Scale*—The smoke scale required consists of ten spots numbered consecutively from 0 to 9, ranging in equal photometric steps from white through neutral shades of gray to black, imprinted or otherwise processed on white paper or plastic stock having a surface reflectance of between 82.5 and 87.5 % 45°, 0° daylight luminous directional reflectance in accordance with Test Method E97. The smoke scale spot number is defined as the reduction (due to smoke) in reflected incident light divided by 10. Thus, the first spot, which is the color of the unimprinted scale, will be No. 0, since in the case

[1] This method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.E0.01 on Burner Fuels.

Current edition approved Dec. 1, 2009. Published December 2009. Originally approved in 1963. Last previous edition approved in 2008 as D2156–08. DOI: 10.1520/D2156-09.

[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] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org

***A Summary of Changes section appears at the end of this standard.**

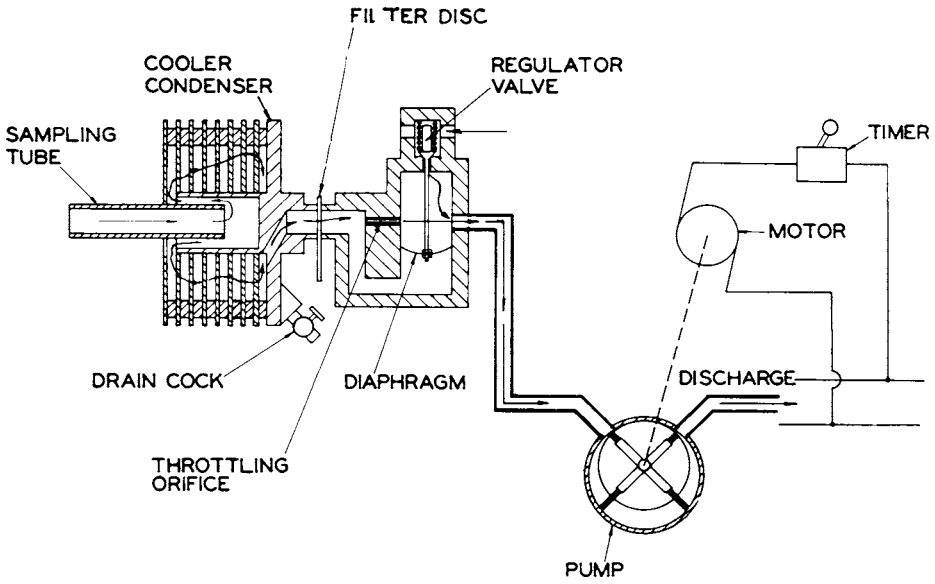

FIG. 1 Laboratory Type Smoke Meter

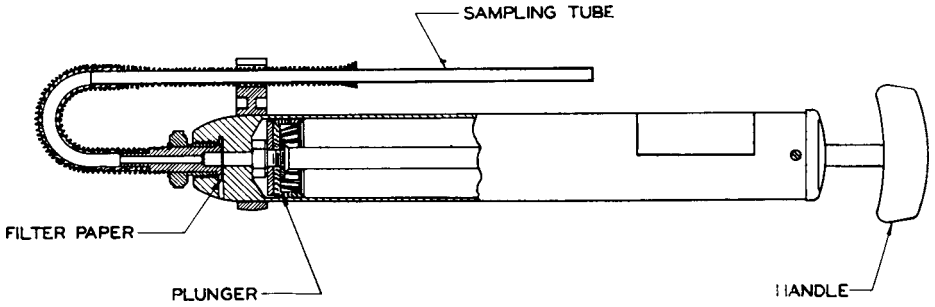

FIG. 2 Field Service Type Smoke Tester

of this spot there will be no reduction in reflected incident light directed thereon. The last spot, however, is very dark, reflecting only 10% of the incident light directed thereon; thus in this case the reduction in reflected incident light is 90 %, which gives to this darkest spot the No. 9. Intermediate spot numbers are similarly established. Limits of permissible reflectance variation of any smoke scale spot shall not exceed ±3 % relative reflectance (Note 1 and Note 2).

NOTE 1—Such smoke scales are sufficiently accurate for field use and for many laboratory smoke testing applications. However, specially calibrated scales (known as certified smoke scales) will sometimes be required. A certified smoke scale is obtained by individually calibrating each smoke spot of a normal smoke scale.

NOTE 2—Where the smoke scale is protected with a plastic or transparent cover the construction employed shall be such that when the smoke spot on the filter paper is viewed for matching with the number spots on the smoke scale, both shall be visible through the same thickness and number of sheets of transparent protective cover.

7. Materials

7.1 *Test Filter Paper*, made from white filter paper stock having a surface reflectance of 82.5 to 87.5 % 45°, 0° daylight luminous directional reflectance, in accordance with the Test Method E97. When clean air at standard conditions is drawn through clean filter paper at a rate of 476 L/s·m^2 effective surface area of filter paper, the pressure drop across the filter paper falls between limits of 1.7 and 8.4 kPa.

8. Procedure

8.1 The sampling procedure used is critical. Therefore, the procedure recommended by the equipment manufacturer shall be rigidly followed.

8.2 Use a clean, dry, sampling device. If a hand sampler is used, warm it above room temperature to prevent condensation on the filter paper. (This can usually be done conveniently by placing the sampler on the boiler or furnace to be tested.)

8.3 Insert filter paper in the sampler and tighten the filter paper holder. Connect the sampling device to the flue gas probe. When taking smoke measurements in the flue pipe, position the end of the sampling probe at the center line of the flue pipe.

8.4 Draw the required sample. When a hand sampler is used, permit the pressures in the flue gas stream and the sampler to equalize after each stroke.

8.5 Remove the filter paper. Compare the test spot backed with a piece of white paper or plastic having 45°, 0° daylight luminous directional reflectance of not less than 75 %, with the standard scale.

9. Report

9.1 Report the smoke density as *smoke spot number* on the standard scale most closely corresponding to the test spot. Interpolate differences between two standard *smoke spot numbers* to the nearest half number. Report *smoke spot numbers* higher than 9 as "Greater than No. 9."

NOTE 3—Where more accurate results are desired, the human factor involved in visually comparing filter paper test spots with smoke scale spots can be eliminated by resort to direct use of a suitable photometer for evaluating test spots. This procedure is described in the Annex.

10. Precision and Bias

10.1 *Precision*—Numerical rating of the smoke spot number as determined by the statistical examination of the test results obtained by seven operators and smoke guns on identical smoke samples at six different excess air levels is as follows:

10.1.1 *Repeatability*—The difference between the two test results obtained by the same operator with the same apparatus under constant operating conditions on identical test material would, in the long run, in the normal and correct operation of the test method, exceed one-half of a smoke spot number for only one case in twenty (Note 4).

10.1.2 *Reproducibility*—The difference between two single and independent measurements of smoke spot number by different operator/instrument pairs at the same location on identical test material would, in the long run and in the normal and correct operation of the test method, exceed one smoke spot number for only one case in twenty (Note 4).

NOTE 4—On July 10, 1989, seven test participants performed the measurement of Smoke Density in Flue Gases from Burning Distillate Fuels at six different excess air settings. All smoke spot determinations were made, in duplicate, by each operator using a separate smoke gun, at one test site.[4]

10.2 *Bias*—The bias of this test method cannot be determined because there is no accepted standard distillate fuel with a known smoke spot number.

11. Keywords

11.1 heating oil; kerosine; smoke density; smoke spot number

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report D02-1325.

ANNEX

(Mandatory Information)

A1. ALTERNATIVE PHOTOMETRIC METHOD

A1.1 Direct Photometric Evaluation

A1.1.1 The human factor involved in visually comparing filter paper test spots with smoke scale spots can be eliminated by resorting to direct use of a suitable photometer for evaluating test spots. To make this direct photometric test spot evaluation, the following procedure shall be employed:

A1.1.1.1 Mount a clean, unused filter paper, backed by a plaque painted with MgO or material having a 45°, 0° daylight luminous directional reflectance of not less than 75 %, in the light beam of a suitable type reflectance photometer. Adjust the photometer to read 100 % reflectance in terms of the light reflected from this clean surface. Expose test smoke spot on filter paper to the photometer light beam and measure the percentage reduction in reflected light due to the presence of smoke particles on the filter paper. Gross smoke spot number shall be defined as equal to the percentage reduction in reflected light divided by ten.

A1.2 Photometer Specifications

A1.2.1 The photometer to be employed for direct test spot number evaluation shall be of the electrically operated reflectance type employing a photoelectric cell, fitted with a special holder(s) to accommodate filter paper test specimens. It is to be capable of measuring the 45°, 0° daylight luminous directional reflectance. It is to be furnished complete with a green tristimulus filter and with reflectance standards of approximately 20, 40, 60, and 80 % 45°, 0° daylight luminous directional reflectance, to permit photometer readings between 10 and 90 % (relative to clean filter paper) to be made within ±2 % accuracy.

APPENDIX

X1. CONVERSION OF MEASUREMENT UNITS

X1.1 Measurement units in ASTM standards are to be SI (International System of Units). Test Method D2156 has traditionally used I-P units, so the introduction of SI units may lead to some confusion for those familiar with the previous versions of the test method. This appendix provides conversions between the two systems.

X1.1.1 This table show the units used in this test method in both systems.

SI Units		Other Systems of Units	
Name	Abbreviation	Name	Abbreviation
Litre	L	cubic inch	$in.^3$
cubic centimetre	cm^3	cubic inch	$in.^3$
square centimetre	cm^2	square inch	$in.^2$
square millimetre	mm^2	square inch	$in.^2$
millimetre	mm	inch	in.
kiloPascal	kPa	atmosphere	atm
kiloPascal	kPa	inches of mercury (Hg)	in. Hg
kiloPascal	kPa	millimetres of Hg	mm Hg

X1.1.2 The following table shows conversion factors for the units previously found in this test method to SI units or related units.

To convert from	To	Multiply by
$in.^3$	L	0.01639
cm^3	L	0.001
atm	kPa	101.325
$in.^2$	mm^2	645.16
$in.^2$	cm^2	6.4516
in.	mm	25.40
$in.^3/min \cdot in.^2$	$L/s \cdot m^2$	1.762×10^{-7}
$in.^3/min \cdot in.^2$	$cm^3/s \cdot cm^2$	1.762
in. Hg	kPa	3.3864
in. Hg	mm Hg	25.4
°F	°C	Formula for conversion: (°F – 32)/1.8

X1.1.3 The following table shows some measurements used in previous versions of Test Method D2156 with the current units and earlier units.

Current Test Method Units	Units from Earlier Versions	Section
36.9 ± 1.65 L	36 900 ± 1650 cm^3	6.1
36.9 ± 1.65 L	2250 ± 100 $in.^3$	6.1
101 kPa	1 atm	6.1
16°C	60°F	6.1
645 mm^2	6.45 cm^2	6.1
645 mm^2	1 $in.^2$	6.1
410 mm	16 in.	6.1
476 $L/s \cdot m^2$	2.70×10^9 $in.^3/min \cdot in.^2$	7.1
1.7 kPa	13 mm Hg	7.1
1.7 kPa	0.5 in. Hg	7.1
8.4 kPa	64 mm Hg	7.1
8.4 kPa	2.5 in. Hg	7.1

SUMMARY OF CHANGES

Subcommittee D02.E0.01 has identified the location of selected changes to this standard since the last issue (D2156–08) that may impact the use of this standard. (Approved Dec. 1, 2009.)

(*1*) Added Appendix X1 on SI conversion.

Subcommittee D02.E0.01 has identified the location of selected changes to this standard since the last issue (D2156–94(2003)) that may impact the use of this standard. (Approved Dec. 1, 2008.)

(*1*) Modified Section 1.1, Scope, to eliminate reference to parenthetical inch-pound units.
(*2*) Modified Section 6, Apparatus, to express units as preferred SI.
(*3*) Modified Section 7, Materials, to express units as preferred SI.