Designation: D2157 – 94 (Reapproved 2013)

Standard Test Method for Effect of Air Supply on Smoke Density in Flue Gases from Burning Distillate Fuels[1]

This standard is issued under the fixed designation D2157; 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 test method covers the evaluation of the performance of distillate fuels from the standpoint of clean, efficient burning. It is intended primarily for use with home heating equipment burning No. 1 or No. 2 fuel oils. It can be used either in the laboratory or in the field to compare fuels using a given heating unit or to compare the performance of heating units using a given fuel.

NOTE 1—This test method applies only to pressure atomizing and rotary-type burners.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered 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]

D2156 Test Method for Smoke Density in Flue Gases from Burning Distillate Fuels

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *efficiency*—defined as the percentage of gross heat of combustion of the fuel which is retained by the equipment and which does not pass out in the flue gases.

3.1.2 *excess combustion air*—the percentage of air entering the equipment over and above that needed for stoichiometric conversion of the fuel to the ultimate combustion products, essentially CO_2 and water, for a normal fuel. This may be calculated from the percentage CO_2 in the flue gas and the carbon-hydrogen ratio of the fuel.

3.1.3 *flue-gas carbon dioxide (CO_2)*—the percentage concentration of carbon dioxide in the flue gas, measured by conventional Orsat analysis, or the equivalent.

3.1.4 *net stack temperature*—the difference between the stack temperature and the ambient temperature of the air near the inlet to the burner.

3.1.5 *smoke density*—the concentration of smoke in the flue gas, measured as a Smoke Spot Number as described in Test Method D2156.

4. Summary of Test Method

4.1 The flue-gas smoke density is measured for various amounts of combustion air while the burner is operating at equilibrium conditions. Results are expressed as a plot of smoke density as a function of flue-gas carbon dioxide (CO_2) content, or alternatively, as a function of percentage excess combustion air.

5. Significance and Use

5.1 This test method relates efficiency of operation of domestic heating equipment to clean burning. Reducing combustion air in a burner gives more efficient operation. The extent to which combustion air can be reduced is limited by the onset of unacceptable smoke production. By delineating the relation between smoke density and air supply, this test method (together with net stack temperature data) defines the maximum efficiency for a given installation at any acceptable smoke level.

5.2 For certain types of equipment, such as the rotary wall-flame burner, too much excess air will cause smoke as well as too little. For these cases, the point of minimum excess air at the acceptable smoke level indicates the optimum efficiency.

5.3 The operating temperatures of the equipment will affect these test results. The relation of excess air to smoke density is

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.E0 on Burner, Diesel, Non-Aviation Gas Turbine, and Marine Fuels.

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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.

thus susceptible to some change at different points in an operating cycle. In practice, an adequate compromise is possible by operating the burner for 15 min before any readings are recorded and then obtaining the test data within a succeeding 25-min period.

5.4 Under laboratory conditions, CO_2 readings are reproducible to ±0.3 % and smoke readings are reproducible to ±½ smoke spot number.

6. Apparatus

6.1 *Sampling Device* for determining smoke density, as described in the Apparatus section of Test Method D2156.

6.2 *Conventional Orsat Apparatus,* or the equivalent, for determining the volume percentage of CO_2 in the dry flue gases.

6.3 *Suitable Flue Gas Probes* for smoke density and CO_2 measurements. These are to be located not more than 12 in. (300 mm) from the outlet of the boiler or furnace and at least two flue-pipe diameters before any barometric draft control (Note 2). The probe ends shall be located so that the samples are withdrawn from the centerline of the flue pipe.

NOTE 2—In some field installations, a compromise can be made, in which case the probes may be inserted as close to the outlet as possible, but not closer to a barometric draft control than one flue pipe diameter. In the event this compromise cannot be met, the manufacturer may be requested to furnish instructions stating the location of sampling points and the procedure for taking measurements.

7. Procedure

7.1 Start the burner and operate for 15 min according to manufacturer's specifications (particular attention should be paid to draft and oil pressure). Then take flue-gas samples for smoke and CO_2 and record.

7.2 Change the air shutter settings, operate for 4 min, sample, and record smoke and CO_2. Repeat until a minimum of four data points is obtained, spaced over the range of interest. The entire data-taking period must be accomplished within about 25 min for a field installation.

8. Report

8.1 Report the smoke density-CO_2 relation or the smoke density-excess air relation, or both, in graphical form. Fig. 1 shows typical pressure-atomizing burner and typical rotary wallflame burner data.

8.2 For fuels of varying composition, excess air is of more fundamental significance than CO_2. It is calculated from fuel composition data and flue gas CO_2 by conventional methods. For many purposes, however, available No. 1 and No. 2 fuel oils are similar enough in composition so that results reported only in terms of percent CO_2 are useful. When this is done, report the fuel as either No. 1 or No. 2 fuel oils.

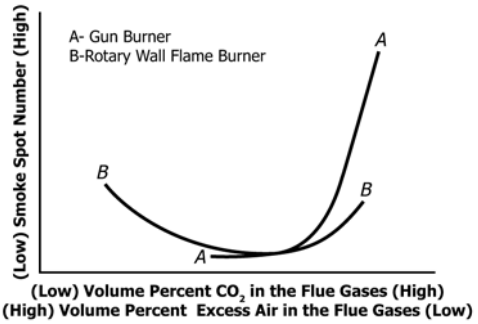

FIG. 1 Typical Smoke-CO_2 and Excess Air-CO_2 Curves

9. Precision and Bias

9.1 *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 air levels is as follows:

9.1.1 *Repeatability*—The difference between the two smoke spot 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 3).

9.1.2 *Reproducibility*—Under laboratory conditions, CO_2 measurements are reproducible to ±0.3 volume percent CO_2. 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 3).

NOTE 3—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. No CO_2 measurements were performed during this program. The cited reproducibility for CO_2 is taken from the 1980 version of this test method, which did not reference the source of the reproducibility.[3]

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

10. Keywords

10.1 heating oil; kerosine; smoke density

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