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Standard Test Method for Estimation of Net and Gross Heat of Combustion of Burner and Diesel Fuels¹

This standard is issued under the fixed designation D 4868; 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 This test method is under the jurisdiction of ASTM Committee D-2 D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.05 on Properties of Fuels, Petroleum Coke and Oil Shale.

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1. Scope

1.1 This test method covers the estimation of the gross and net heat of combustion in SI units, megajoules per kilogram, of petroleum fuels from the fuel density, sulfur, water, and ash content.

NOTE 1—The equation for estimation of net and gross heat of combustion used in this method were originally published by the NIST Publication No. 97.

1.2 This test method is especially useful for estimating, using a minimum number of tests, the heat of combustion of burner and diesel fuels for which it is not usually critical to obtain very precise heat determinations.

NOTE 2—More accurate estimation methods are available for aviation fuels (Test Methods D 1405 and D 3338, and D 4529). However, those estimation methods require additional tests to those required in this test method.

1.3 This test method is purely empirical (Note 1). It is applicable only to liquid hydrocarbon fuels derived by normal refining processes from conventional crude oil that conform to the requirements of specifications for petroleum fuels as described in Note 3. This test method is valid for those fuels in the density range from 750 to 1,000 kg/m³ and those that do not contain an unusually high aromatic content. High aromatic content fuels will not normally meet fuel specification criteria.

NOTE 3—The estimation of the heat of combustion of a hydrocarbon fuel from its density and sulfur, water, and ash content is justifiable only when the fuel belongs to well-defined classes for which a relationship between these quantities have been derived from accurate experimental measurements on representative samples of these classes. Even in these classes, the possibility that the estimate may be in error by large amounts for individual fuels should be recognized. This test method has been tested for a limited number of fuels from oil sand bitumen and shale oil origin and has been found to be valid. The classes of fuels used to establish the correlation presented in this test method are represented by the following applications:

Fuel	Specification
Fuel Oils	
Grades 1, 2, 4 (light), 4, 5 (light), 5 (heavy), and 6	D 396
Diesel	
Grades 1-D, 2-D, and 4-d	D 975
Aviation Turbine	
Jet A, Jet A-1, and Jet B	D 1655
Gas Turbine	
Grades 0-GT, 1-GT, 2-GT, 3-GT and 4-GT	D 2880
Kerosine	
Grades 1-K and 2-K	D 3699

1.4 This test method is not applicable to pure hydrocarbons. It is not intended as a substitute for experimental measurements of heat of combustion (Note 4).

NOTE 4—The procedures for the experimental determination of the gross and net heats of combustion are described in Test Methods D 240, D 2382 D 240 and D 4809.

1.5 The values stated in acceptable SI units are to be regarded as the standard.

1.6 *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:*

- D 95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation²
 D 129 Test Method for Sulfur in Petroleum Products (General Bomb Method)²
 D 240 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter²
 D 396 Specification for Fuel Oils²
 D 482 Test Method for Ash from Petroleum Products²
 D 975 Specification for Diesel Fuel Oils²
 D 1266 Test Method for Sulfur in Petroleum Products (Lamp Method)²
 D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method²
 D 1405 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels²
 D 1480 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Bingham Pycnometer²
 D 1481 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Lipkin Bicapillary Pycnometer²
 D 1552 Test Method for Sulfur in Petroleum Products (High-Temperature Method)²
 D 1655 Specification for Aviation Turbine Fuels²
 D 1744 Test Method for Water in Liquid Petroleum Products by Karl Fischer Reagent²
 D 1796 Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)²
 D 238622 Test Method for ~~Heat of Combustion of Hydrocarbon Fuels~~ Sulfur in Petroleum Products by Bomb Calorimeter (High-Precision Method) Wavelength Dispersive X-Ray Fluorescence Spectrometry²
~~D-2622 Test 2880 Specification for Gas Turbine Fuel Oils²~~
D 3338 Test Method for Sulfur in Petroleum Products by X-Ray Spectrometry Estimation of Heat of Combustion of Aviation Fuels³
~~D-2880 Specification for Gas Turbine Fuel Oils³~~
~~D-3338 Test Method for Estimation of Heat of Combustion of Aviation Fuels³~~
~~D-3699 Specification 3699 Specification for Kerosine³~~
 D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter³
 D 4294 Test Method for Sulfur in Petroleum Products by Energy-Dispersive X-Ray Fluorescence Spectroscopy³
 D 4529 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels³
 D 4809 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Intermediate Precision Method)³
D 5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Motor Fuels and Oils by Ultraviolet Fluorescence⁴
 2.2 *NIST Standard*:⁵
 NIST Publication No. 97 Thermal Properties of Petroleum Products

3. Summary of Test Method

3.1 The density and sulfur, water, and ash content of the sample are determined by experimental test methods. The heat of combustion is calculated using the values obtained by these test methods based on reported correlations.

4. Significance and Use

4.1 This test method is intended for use in cases where an experimental determination of heat of combustion is not available and cannot be made conveniently, and where an estimate is considered satisfactory. It is not intended as a substitute for experimental measurement of heat of combustion.

5. Procedure

5.1 Determine the density to the nearest 0.1 kg/m³ as described in Practice D 1298, and Test Methods D 1480, D 1481 or D 4052.

5.2 Determine the sulfur content of the sample to the nearest 0.01 mass % sulfur as described in Test Methods D 129, D 1266, D 1552, D 2622, D 4294, or ~~D 4294~~-D 5453.

5.3 Determine the water content of the sample to the nearest 0.05 mass% water as described in Test Methods D 95, D 1744, or D 1796.

5.4 Determine the ash content of the sample to two significant figures as described in Test Method D 482.

6. Calculation

6.1 Calculate the gross heat of combustion of the fuel corrected for the sulfur, water and ash content in accordance with the following equation:

² *Annual Book of ASTM Standards*, Vol 05.01.

³ *Annual Book of ASTM Standards*, Vol 05.02.

⁴ *Annual Book of ASTM Standards*, Vol 05.03.

⁵ Available from National Institute of Standards and Technology, Gaithersburg, MD 20899.

$$Q_v(\text{gross}) = \frac{(51.916 - 8.792 d^2 \times 10^{-6})}{[1 - (x + y + s)] + 9.420s} \quad (1)$$

where:

- Q_v = gross heat of combustion at constant volume, MJ/kg,
- d = density at 15°C, kg/m³,
- x = mass fraction of water (% divided by 100),
- y = mass fraction of ash (% divided by 100), and
- s = mass fraction of sulfur (% divided by 100).

6.2 Calculate the net heat of combustion of the fuel corrected for the sulfur, water and ash content in accordance with the following equation:

$$Q_p(\text{net}) = \frac{(46.423 - 8.792 d^2 \times 10^{-6} + 3.170d \times 10^{-3})}{[1 - (x + y + s)] + 9.420s - 2.449x} \quad (2)$$

where:

- Q_p = net heat of combustion at constant pressure, MJ/kg, d = density at 15°C, kg/m³,
- x = mass fraction of water,
- y = mass fraction of ash, and
- s = mass fraction of sulfur.

=density at 15°C

7. Report

7.1 Report the result as the estimated gross or net heat of combustion in MJ/kg to the nearest 0.01.

8. Precision and Bias

8.1 *Precision*—The precision⁶ of the estimated values will be dependent upon the accuracy of the determined density and sulfur, water and ash contents. The following precision is the aggregate precision of the measurements used to calculate the heat content by (Eq 1) and (Eq 2) and does not indicate the precision of the heat content of an individual sample. That precision is estimated in Note 4. When using data on the density, sulfur, water and ash content of a fuel determined by Test Methods D 4052, D 4294, D 1796, and D 482, respectively, the following criteria shall be used for judging the acceptability of estimated heat of combustion results.

8.1.1 *Repeatability*—The difference between successive 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 the following value only in one case in twenty:

Repeatability 0.05 MJ/kg

8.1.2 *Reproducibility*—The difference between two single and independent results, obtained by different operators working in different laboratories on identical test material would, in the long run, and in the normal and correct operation of the test method, exceed the following value only in one case in twenty:

Reproducibility 0.15 MJ/kg

8.2 *Bias*—Bias cannot be determined for the procedure in Test Method D 4868 since the data used to determine the correlation cannot be compared with accepted reference materials.

NOTE 5—The correlation equations were tested using 199 present day fuels. The data is included in ASTM Research Report RR:D02-1233. About 95 % of the calculated data were within 0.35 MJ/kg of measured heats of combustion.

9. Keywords

9.1 burner fuels; diesel fuels; gross heat of combustion; heat energy; heat of combustion; heating tests; net heat of combustion

⁶ Data supporting this test method is available at ASTM Headquarters. Request RR:D02-1233.

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