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An American National Standard

Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels[1]

This standard is issued under the fixed designation D 3338; 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 estimation of the net heat of combustion (megajoules per kilogram or Btu per pound) of aviation gasolines and aircraft turbine and jet engine fuels.

1.2 This test method is purely empirical and is applicable to liquid hydrocarbon fuels that conform to the specifications for aviation gasolines or aircraft turbine and jet engine fuels of grades Jet A, Jet A-1, Jet B, JP-4, JP-5, JP-7, and JP-8.

NOTE 1—The experimental data on heat of combustion from which the Test Method D 3338 correlation was devised was obtained by a precision method similar to Test Method D 4809.

NOTE 2—The estimation of the net heat of combustion of a hydrocarbon fuel is justifiable only when the fuel belongs to a well-defined class for which a relation between heat of combustion and aromatic and sulfur contents, density, and distillation range of the fuel has been derived from accurate experimental measurements on representative samples of that class. Even in this case, the possibility that the estimates may be in error by large amounts for individual fuels should be recognized. The fuels used to establish the correlation presented in this method are defined as follows:

~~*Fuels:*~~ ~~Aviation~~
Fuels:
~~Aviation gasoline—Grades 100/130 and 115/145~~ **~~(1, 2)~~**
~~—Kerosines,[2]~~
Aviation gasoline—Grades 100/130 and 115/145 **(1, 2)**[2]
~~Kerosines, alkylates, and special WADC fuels~~ **~~(3)~~** ~~Pure~~
Kerosines, alkylates, and special WADC fuels **(3)**
~~Pure hydrocarbons—paraffins, naphthenes, and aromatics~~ **~~(4)~~** ~~Fuels~~
Pure hydrocarbons—paraffins, naphthenes, and aromatics **(4)**
~~Fuels for which data were reported by the Coordinating Research Council~~ **~~(5).~~**
Fuels for which data were reported by the Coordinating Research Council **(5).**

~~1.3 Although the test method permits the calculation of net heat of combustion in either SI or inch-pound units, SI units are the preferred units.~~

~~1.4 The net heat of combustion can also be estimated in inch-pound units by Test Method D 1405~~

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

1.3.1 Although the test method permits the calculation of net heat of combustion in either SI or inch-pound units, SI units are the preferred units.

1.3.2 The net heat of combustion can also be estimated in inch-pound units by Test Method D 1405 or in SI units by Test Method D 4529. Test Method D 1405 requires calculation of one of four equations dependent on the fuel type with a precision equivalent to that of this test method. Test Method D 4529 requires calculation of a single equation for all aviation fuels with a precision equivalent to that of this test method. Unlike Test Method D 1405 and D 4529, Test Method D 3338 does not require the use of aniline point.

~~1.5~~

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.*

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.05 on Properties of Fuels, Petroleum Coke and Carbon Material.

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[2] The boldface numbers in parentheses ~~refers~~refer to ~~the~~a list of references at the end of this ~~test method.~~standard.

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

2. Referenced Documents

2.1 *ASTM Standards:* [3]

D 86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure
D 240 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter
D 1266 Test Method for Sulfur in Petroleum Products (Lamp Method)
D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
D 1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
D 1405 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
D 1552 Test Method for Sulfur in Petroleum Products (High-Temperature Method)
D 2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
D 2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
D 3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry
D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter
D 4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive ~~X-Ray~~X-ray Fluorescence Spectrometry
D 4529 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
D 4809 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)
D 5453 ~~Test Method for Determination of Total Sulfur in Light Hydrocarbons, Motor Fuels and Oils by Ultraviolet Fluorescence~~ Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
D 6379 Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection

2.2 ~~*IP Standard:*~~ *Energy Institute Standard:*[4]

IP 436 Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection

3. Terminology

3.1 *Definitions:*

3.1.1 *gross heat of combustion, Qg (MJ/kg)*—~~the quantity~~—quantity of energy released when a unit mass of fuel is burned in a constant volume enclosure, with the products being gaseous, other than water, which is condensed to the liquid state.

3.1.2 *net heat of combustion, Qn (MJ/kg)*—~~the quantity~~—quantity of energy released when a unit mass of fuel is burned at constant pressure, with all of the products, including water, being gaseous.

4. Summary of Test Method

4.1 A correlation **(6)** in inch-pound units has been established between the net heat of combustion and gravity, aromatic content, and average volatility of the fuel. This correlation was converted to SI units; the relationships are given by the following equations:

Type Fuel

All aviation gasolines, aircraft turbine, and jet engine fuels

Equation

$$Q_{p1} = 16.24(G) - 3.007(A) + 0.01714(G \times V) - 0.2983(A \times G) + 0.00053(A \times G \times V) + 17685 \quad (1)$$

or in SI units

$$Q_{p\,2} = [5528.73 - 92.6499A + 10.1601T + 0.314169AT]/D + 0.0791707A - 0.00944893T - 0.000292178AT + 35.9936 \quad (2)$$

where:

$Q_{p\,1}$ = net heat of combustion, Btu/lb, sulfur-free basis,
Q_{p2} = net heat of combustion, MJ/kg, sulfur-free basis,

[3] 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.

[4] ~~Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02-1183.~~

[4] Available from Energy Institute, 61 New Cavendish St., London, WIG 7AR, U.K., http://www.energyinst.org.uk.

A = aromatics, volume %
G = gravity, API,
V = volatility: boiling point or average of Test Method D 86 or D 2887 10 %, 50 %, and 90 % points, °F,
D = density, kg/m^3 at 15°C
T = volatility: boiling point or average of Test Method D 86 or D 2887 10 %, 50 %, and 90 % points, °C.

4.2 To correct for the effect of the sulfur content of the fuel on the net heat of combustion, apply the following equation:

$$Q = Q_p \times [1 - 0.01(S_1)] + C(S_1) \quad (3)$$

where:

Q = net heat of combustion, MJ/kg or ~~BTU/lb,~~Btu/lb, of the fuel containing S_1 weight percent sulfur,
Q_p = Q_{p1} (inch-pound units) or Q_{p2} (SI units),
S_1 = sulfur content of the fuel, mass %, and
C = 0.10166 (SI units) or 43.7 (inch-pound units) = a constant based on the thermochemical data on sulfur compounds.

4.3 The empirical equations for the estimated net heat of combustion, sulfur-free basis, were derived by stepwise linear regression methods using data from 241 fuels, most of which conform to specifications for aviation gasolines and aircraft turbine or jet engine fuels.

5. Significance and Use

5.1 This test method is intended for use as a guide in cases where 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 measurements of heat of combustion. Table 1 shows a summary for the range of each variable used in developing the correlation. The mean value and an estimate of its distribution about the mean, namely the standard deviation, is shown. This indicates, for example, that the mean density for all fuels used in developing the correlation was 779.3 kg/m^3 and that two thirds of the samples had a density between 721.4 and 837.1 kg/m^3, that is, plus or minus one standard deviation. The correlation is most accurate when the values of the variables used are within one standard deviation of the mean, but is useful up to two standard deviations of the mean. The use of this correlation may be applicable to other hydrocarbon distillates and pure hydrocarbons; however, only limited data on non-aviation fuels over the entire range of the variables were included in the correlation.

NOTE 3—The procedures for the experimental determination of the gross and net heats of combustion are described in Test Methods D 240 and D 4809.

5.2 The calorimetric methods cited in Note 3 measure gross heat of combustion. However, net heat is used in aircraft calculations because all combustion products are in the gaseous state. This calculation method is based on net heat, but a correction is required for condensed sulfur compounds.

6. Procedure

6.1 Determine the aromatic content of the fuel to the nearest 0.1 % vol as described in Test Method D 1319.

~~6.1.1Test Method D6379 or IP436~~

6.1.1 Test Method D 6379 or IP 436 may be used as an alternative to Test Method D 1319 for determining fuel aromatics content for use in this test method.

~~6.1.2If Test Method D6379 or IP436~~

6.1.2 If Test Method D 6379 or IP 436 is used, multiply the total aromatics content in vol% by 25/26.5 (=0.9434), and use this corrected value in place of aromatics determined by Test Method D 1319 in Eq 2.

6.2 Determine the density at 15°C or the API gravity of the fuel to the nearest 0.1 kg/m^3 or 0.1° API as described in Test Method D 1298 or in Test Method D 4052.

6.3 Determine the 10 %, 50 %, and 90 % boiling points of the fuel to the nearest 1°C or 1°F as described in Test Method D 86. Average these three temperatures to obtain the T value (°C) or the V value (°F) used in the equations of 4.1. For a pure hydrocarbon, T or V is the normal boiling point.

6.3.1 Test Method D 2887 may be used as an alternative to Test Method D 86 for determining fuel volatility for use in this test method. The average of the 10 %, 50 %, and 90 % boiling points determined by Test Method D 2887 may be used directly in place of the corresponding average determined by Test Method D 86.

6.4 Determine the sulfur content of the fuel to the nearest 0.02 % sulfur as described in Test Methods D 1266, D 1552, D 2622, D 3120, D 4294, or D 5453, depending upon the volatility of the sample.

TABLE 1 Mean and Standard Deviation of the Variables

Variable	Mean	Standard Deviation
Aromatics, volume %	13.5	23.9
Density, kg/m^3(°API)	779.3 (50.0)	58.0 (13.5)
Volatility, °C (°F)	171.11 (340)	57.2 (103)
Heat of combustion, MJ/kg (Btu/lb)	43.421 (18 668)	0.862 (371)