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

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1. Scope

1.1 This test method covers the estimation of the net heat of combustion at constant pressure in metric (SI) units, megajoules per kilogram.

1.2 This test method is purely empirical, and it is applicable only to liquid hydrocarbon fuels derived by normal refining processes from conventional crude oil which conform to the requirements of specifications for aviation gasolines or aircraft turbine and jet engine fuels of limited boiling ranges and compositions as described in Note 1.

NOTE 1—The estimation of the net heat of combustion of a hydrocarbon fuel from its aniline point temperature and density is justifiable only when the fuel belongs to a well-defined class for which a relationship between these quantities has been derived from accurate experimental measurements on representative samples of that class. Even in this class, the possibility that the estimates can be in error by large amounts for individual fuels should be recognized. The JP-8 fuel, although not experimentally tested, has properties similar to JP-5 and Jet A fuels and can be considered in the same class. The classes of fuels used to establish the correlation presented in this test method are represented by the following applications:

Fuel	Specification
Aviation gasoline	MIL-G-5572
Grades 100/130, 100LL	ASTM D910
and 115/145	DERD 2485
	NATO Code F-18
JP-4, Jet B, Avtag/FSII	MIL-T-5624
	DERD 2454
	DERD 2486
	NATO Code F-40
JP-5, Avcat/FSII	MIL-T-5624
	NATO Code F-44
JP-8, Avtur/FSII	MIL-T-83133
	DERD 2453
	NATO Code F-34
Jet A, Jet A-1, Avtur	ASTM D1655
	DERD 2494
	NATO Code F-35

1.3 The net heat of combustion can also be estimated by Test Method D 1405. Test Method D 1405 requires calculation of one of four equations dependent on the fuel type with the precision equivalent to that of this test method.

1.4 The values stated in acceptable metric units are to be regarded as the standard.

1.5 *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 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 Calorimeter[2]

D 611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents[2]

D 910 Specification for Aviation Gasolines[2]

D 941 Test Method for Density and Relative Density (Specific Gravity) of Liquids by Lipkin Bicapillary Pycnometer[2]

D 1217 Test Method for Density and Relative Density (Specific Gravity) of Liquids by Bingham Pycnometer[2]

D 1250 Guide for Petroleum Measurement Tables[2]

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 Method[2]

D 1405 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels[2]

D 1655 Specification for Aviation Turbine Fuels[2]

D 2382 Test Method for Heat of Combustion of Hydrocarbon Fuels by Bomb Calorimeter (High-Precision Method)[2]

D 2622 Test Method for Sulfur in Petroleum Products by X-Ray Spectrometry[3]

D 3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry[3]

[1] This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.05 on Petroleum, Coke, and Carbon Materials.

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

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

D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter[3]

D 4809 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Intermediate Precision Method)[4]

2.2 *U.S. Military Standards:*[5]

MIL-G-5572 Aviation Gasoline

MIL-T-5624 Aviation Turbine Fuel, Grades JP-4 and PP-5

MIL-T-83133 Aviation Turbine Fuel, Grade JP-8

2.3 *Department of Energy Research and Development*:[6]

DERD 2453 Aviation Turbine Fuel, Kerosine

DERD 2454 Aviation Turbine Fuel, Wide-Cut with AIA

DERD 2494 Aviation Turbine Fuel, Kerosine

DERD 2485 Aviation Gasoline

DERD 2486 Aviation Turbine Fuel, Wide Cut

NOTE 2—The following are typical fuel designations: *NATO Codes*[6]

F-18 Aviation Gasoline

F-34 Aviation Turbine Fuel, Grade JP-8

F-35 Aviation Turbine Fuel, Jet A Type

F-40 Aviation Turbine Fuel, Grade JP-4

F-44 Aviation Turbine Fuel, Grade JP-5

3. Summary of Test Method

3.1 The aniline point, density, and sulfur content of the sample are determined by experimental test methods and the net heat of combustion is calculated using the values obtained by these test methods based on reported correlations.[7,8,9]

4. Significance and Use

4.1 This test method is intended for use as a guide 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 measurements of heat of combustion (Note 3).

NOTE 3—The procedures for the experimental determination of the gross and net heats of combustion are described in Test Methods D 240, D 2382, and D 4809.

4.2 The net heat of combustion is a factor in the performance of all aviation fuels. Because the exhaust of aircraft engines contains uncondensed water vapors, the energy released by fuel in vaporizing water cannot be recovered and must be subtracted from gross heat of combustion determinations to calculate net heat of combustion. For high performance weight-limited aircraft, the net heat of combustion per unit mass and the mass of fuel loaded determine the total safe range. The proper operation of the aircraft engine also requires a certain minimum net energy of combustion per unit volume of fuel delivered.

4.3 Because the heat of combustion of hydrocarbon fuel-mixtures are slowly varying functions of the physical properties of the mixtures, the heat of combustion of the mixtures can often be estimated with adequate accuracy from simple field tests of density and aniline point temperature, without the elaborate apparatus needed for calorimetry.

4.4 The empirical quadratic equation for the net heat of combustion of a sulfur-free fuel was derived by the method of least squares from accurate measurements on fuels, most of which conformed to specifications for fuels found in Note 1 and were chosen to cover a range of values of properties. Those fuels not meeting specifications were chosen to extend the range of densities and aniline-point temperatures above and below the specification limits to avoid end effects. The sulfur correction was found by a simultaneous least-squares regression analysis of sulfur-containing fuels among those tested.

5. Procedure

5.1 Determine the aniline point temperature of the sample to the nearest 0.05°C as described in Test Methods D 611.

5.2 Determine the density at 15°C of the sample to the nearest 0.5 kg/m^3 as described in Test Method D 941, Test Method D 1217, Test Method D 1298, or Test Method D 4052 or Guide D 1250.

5.3 Determine the sulfur content of the sample to the nearest 0.02 mass % sulfur as described in Test Method D 129, Test Method D 1266, Test Method D 2622, or Test Method D 3120.

6. Calculation

6.1 Calculate the net heat of combustion using either Procedure A or B.

6.1.1 *Procedure A* (*By Equation*)—Insert the measured values in (Eq 1) and calculate *Qp*, the net heat of combustion at constant pressure on a sulfur-free basis (Note 4).

$$Qp = 22.9596 - 0.0126587\,A + 26\,640.9\,(1/\rho) + 32.622\,(A/\rho) - 6.69030 \times 10^{-5}(A)^2 - 9\,217\,760\,(1/\rho)^2 \quad (1)$$

where:

ρ = density at 15°C, kg/m^3,

A = aniline point temperature, °C, and

Qp = net heat of combustion on sulfur-free basis, MJ kg^{-1}.

NOTE 4—In SI units the heat of combustion has the unit J kg^{-1}, but for practical purposes a multiple is more convenient. The megajoule per kilogram (MJ kg^{-1}) is 10^6 J kg^{-1} and is customarily used for the representation of heats of combustion of petroleum fuels, particularly for mixtures such as those covered in this international standard.

6.1.2 *Procedure B* (*See Table 1*)—Make a linear interpolation between rows bracketing the density and within columns bracketing the aniline point of the sample. Then make a linear interpolation for the aniline point within the row for the calculated density to obtain *Qp*.

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

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[6] Available from Ministry of Defense, 154 St. Giles Court, London WC2H 8LD, England.

[7] Armstrong, G. T., Fano, L., Jessup, R. S. Maraatz, S., Mears, T. W., and Walker, J. A., "Net Heat of Combustion and Other Properties of Kerosine and Related Fuels," *Journal of Chemical and Engineering Data*, National Institute for Standards and Technology, Washington, DC, Vol 7, No. 1, January 1962, pp. 107–117.

[8] Cogliance, J. A., and Jessup, R. S., "Relation Between Net Heat of Combustion and Aniline-Gravity Product of Aircraft Fuels," *ASTM Bulletin*, ASTBA. No. 201. October 1954, p. 55 (TP 217); also the National Institute for Standards and Technology findings as reported by Armstrong, G. T., Jessup, R. S., and Mears, T. W., "Net Heat of Combustion of Aviation Gasoline and its Correlation with Other Properties," *Journal of Chemical and Engineering Data*, Vol 3, 1958, pp. 20–28.

[9] Nuttall, R. L., and Armstrong, G. T., "Estimation of Net Enthalpies of Some Aviation Fuels Expressed in the International System of Units (SI)," NIST Technical Note 937, April 1977.