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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 1405/D 1405M; 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

~~1.1This test method covers the estimation of the net heat of combustion at constant pressure in SI units (megajoules per kilogram) or inch-pound units (Btu per pound).~~ *

1.1 This test method covers the estimation of the net heat of combustion at constant pressure in SI units (megajoules per kilogram) or inch-pound units [Btu per pound].

1.2 This test method is purely empirical and 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 aniline-gravity product is justifiable only when the fuel belongs to a well-defined class for which a relation between heat of combustion and aniline-gravity product 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 classes of fuels used to establish the correlation presented in this test method are represented by the following specifications:

Fuel	Specification
Aviation gasoline fuels:	
Grades 80, 82, 100/130, and 115/145	Specification D 910 Specification D 6227 DEF STAN 91–90 NATO Code F-18
Aviation turbine fuels:	
JP-4,Avtag/FSII	MIL-DTL-5624 DEF STAN 91–88 NATO Code F-40
JP-5,Avcat/FSII	MIL-DTL-5624 DEF STAN 91–86 NATO Code F-44
Jet A, Jet A-1, Avtur	Specification D 1655 DEF STAN 91–91 NATO Code F-35

1.3 This test method is not applicable to pure hydrocarbons. It is not intended as a substitute for experimental measurements of heat of combustion.

1.4 The heat of combustion may also be determined in SI units by Test Method D 4529. Test Method D 4529 requires calculation of a single equation for all aviation fuels with a precision equivalent to that of this test method.

~~1.5The values stated in SI units are to be regarded as the standard, unless otherwise stated (see 1.1).~~

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with 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.*

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[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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This test method has been approved by the sponsoring committee and accepted by the Cooperating Societies in accordance with established procedures.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D 129 Test Method for Sulfur in Petroleum Products (General Bomb Method)
D 240 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter
D 287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)
D 611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents
D 910 Specification for Aviation Gasolines
D 941 Test Method for Density and Relative Density (Specific Gravity) of Liquids by Lipkin Bicapillary Pycnometer[3]
D 1217 Test Method for Density and Relative Density (Specific Gravity) of Liquids by Bingham Pycnometer
D 1250 Guide for Use of the Petroleum Measurement Tables
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 1655 Specification for Aviation Turbine Fuels
D 2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
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 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, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
D 6227 Specification for Grade 82 Unleaded Aviation Gasoline

2.2 *U.S. Military Standards:*[4]

MIL-DTL-5624 Aviation Turbine Fuels, Grades JP-4, JP-5, and JP-5/JP-8 ST
MIL-T-83133 Aviation Turbine Fuel, Grade JP-8

2.3 *Directorate of Standardization, Ministry of Defence:*[5]

DEF STAN 91–86 Aviation Turbine Fuel, High Flash Kerosene Type with Fuel System Icing Inhibitor
DEF STAN 91–88 Aviation Turbine Fuel, Wide Cut Type with Fuel System Icing Inhibitor
DEF STAN 91–90 Aviation Gasoline 80 and 100LL
DEF STAN 91–91 Aviation Turbine Fuel, Kerosene Type, Jet A-1

2.4 *NATO Codes:*[5]

F-18 Aviation Gasoline
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 Correlations[6,7] have been established between the net heat of combustion and the product of the aniline point and API gravity. These relations, assuming the sample to be sulfur free, are given by the following equations:

3.1.1 Where the net heat of combustion is required in SI units (Note 2) (megajoules per kilogram):

Type Fuel	Equation	
Aviation gasoline, Grades 100–130 and 115–145	$Qp\,(\text{net}) = 41.9557 + 0.00020543\,(A \times G)$	(1)
JP-4	$Qp\,(\text{net}) = 41.8145 + 0.00024563\,(A \times G)$	(2)

[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.
[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.
[4] Available from Department of Defense Single Stock Point, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111–5098.
[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.
[5] Available from Directorate of Standardization, Stan Ops I, Room 1138, Kentigern House, 65 Brown Street, Glasgow, G2 8EX, U.K.
[6] Cogliano, 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 of 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 Correlations with Other Properties," *Journal of Chemical and Engineering Data*, Vol 3, 1958, pp. 20–28.
[7] Armstrong, G. T., Fano, L., Jessup, R. S., Marantz, S., Mears, T. W., and Walker, J. A., "Net Heat of Combustion and Other Properties of Kerosene and Related Fuels," *Journal of Chemical and Engineering Data*, National Institute of Standards and Technology, Gaithersburg, MD. Vol 7, No. 1, January 1962, pp. 107–117.

Type Fuel	Equation	
JP-5	$Qp\ (\text{net}) = 41.6680 + 0.00024563\ (A \times G)$	(3)
Kerosine Jet A or A-1	$Qp\ (\text{net}) = 41.6796 + 0.00025407\ (A \times G)$	(4)

where:
Q_p (net) = net heat of combustion, MJ/kg, on a sulfur-free basis,
A = aniline point, °F, and
G = gravity, °API.

NOTE 2—In SI, the unit of heat of combustion has the dimensions J/kg, but for practical use a multiple is more convenient. The megajoule per kilogram (MJ/kg) is 10^6 J/kg 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.

3.1.2 Where the net heat of combustion is required in inch-pound units or British Thermal Units ~~(Btu~~[Btu per ~~pound).~~ pound].

Type Fuel	Equation	
Aviation gasoline, Grades 100–130 and 115–145	$Qp\ (\text{net}) = 18\,037.7 + 0.0883\ (A \times G)$	(5)
JP-4	$Qp\ (\text{net}) = 17\,977 + 0.1056\ (A \times G)$	(6)
JP-5	$Qp\ (\text{net}) = 17\,914 + 0.1056\ \ (A \times G)$	(7)
Kerosine Jet A or A-1	$Qp\ (\text{net}) = 17\,919 + 0.10923\ \ (A \times G)$	(8)

where:
Q_p (net) = net heat of combustion, Btu/lb, on a sulfur-free basis,
A = aniline point, °F, and
G = gravity, °API.

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

3.2.1 Where the net heat of combustion is required in SI units (megajoules per kilogram):

$$Q' = Qp\ (\text{net}) \times [1 - 0.01(S)] + 0.1016(S) \quad (9)$$

where:
Q' = net heat of combustion, MJ/kg, of the sample containing S % sulfur,
S = sulfur content of the sample, mass, %, and
0.1016 = a constant based on the thermo-chemical data on sulfur compounds.

3.2.2 Where the net heat of combustion is required in inch-pound units or British Thermal Units ~~(Btu~~[Btu per ~~pound):~~ pound]:

$$Q' = Qp\ (\text{net}) \times [1 - 0.01(S)] + 43.7(S) \quad (10)$$

where:
Q' = net heat of combustion, Btu/lb, of the sample containing S % sulfur,
S = sulfur content of the sample, mass %, and
43.7 = a constant based on the thermochemical data on sulfur compounds.

3.3 The empirical linear Eq 1-4 and Eq 5-9 for the estimated net heat of combustion were derived by the method of least squares from accurate data on fuels, most of which conformed at least approximately to specifications for aviation gasolines, or aircraft turbine and jet engine fuels of Types JP-4 and JP-5 and to Specification D 1655, Jet A and A-1.

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—The procedure for the experimental determination of the net heat of combustion is described in Test Methods D 240 and D 4809.

5. Procedure

5.1 Determine the aniline points of the sample to the nearest 0.05°C ~~(0.1°F)~~[0.1°F] as described in Test Method D 611.

5.2 Determine the API gravity of the sample to the nearest 0.1° API as described in Test Method D 287. Alternatively, determine the relative density by Test Methods D 941, D 1217, and D 4052 and correct the result to API gravity by Guide 1250.

5.3 Determine the sulfur content of the sample to the nearest 0.02 % sulfur as described in Test Methods D 129, D 1266, D 2622, D 3120, D 4294, or D 5453 depending upon the volatility of the sample.

6. Calculation

6.1 Calculate the product of the aniline point in degrees Fahrenheit and the gravity in degrees API; round off the value obtained to the nearest integer.

6.2 From Tables 1-8, make a linear interpolation between rows bracketing the aniline-gravity products and within columns bracketing the sulfur content of the sample. Use the table applicable to the type of product being tested. Thus, use Table 1 or Table

TABLE 1 Values of Q′ for Aviation Gasolines Calculated from Eq 1 and Eq 9 in MJ/kg

Aniline-Gravity Product	Net Heat of Combustion, MJ/kg				
	0% Sulfur	0.1% Sulfur	0.2% Sulfur	0.3% Sulfur	0.4% Sulfur
4 000	42.777	42.745	42.712	42.680	42.647
4 200	42.819	42.786	42.753	42.721	42.688
4 400	42.860	42.827	42.794	42.761	42.729
4 600	42.901	42.868	42.835	42.802	42.770
4 800	42.942	42.909	42.876	42.843	42.811
5 000	42.983	42.950	42.917	42.884	42.852
5 200	43.024	42.991	42.958	42.925	42.892
5 400	43.065	43.032	42.999	42.966	42.933
5 600	43.106	43.073	43.040	43.007	42.974
5 800	43.147	43.114	43.081	43.048	43.015
6 000	43.188	43.155	43.122	43.089	43.056
6 200	43.229	43.196	43.163	43.130	43.097
6 400	43.270	43.237	43.204	43.171	43.138
6 600	43.312	43.278	43.245	43.212	43.179
6 800	43.353	43.319	43.286	43.253	43.220
7 000	43.394	43.360	43.327	43.294	43.261
7 200	43.435	43.402	43.368	43.335	43.302
7 400	43.476	43.443	43.409	43.376	43.343
7 600	43.517	43.484	43.450	43.417	43.384
7 800	43.558	43.525	43.491	43.458	43.424
8 000	43.599	43.566	43.532	43.499	43.465
8 200	43.640	43.607	43.573	43.540	43.506
8 400	43.681	43.648	43.614	43.581	43.547
8 600	43.722	43.689	43.655	43.622	43.588
8 800	43.763	43.730	43.696	43.663	43.629
9 000	43.805	43.771	43.737	43.704	43.670
9 200	43.846	43.812	43.778	43.745	43.711
9 400	43.887	43.853	43.819	43.786	43.752
9 600	43.928	43.894	43.860	43.827	43.793
9 800	43.969	43.935	43.901	43.867	43.834
10 000	44.010	43.976	43.942	43.908	43.875
10 200	44.051	44.017	43.983	43.949	43.916
10 400	44.092	44.058	44.024	43.990	43.956
10 600	44.133	44.099	44.065	44.031	43.997
10 800	44.174	44.140	44.106	44.072	44.038
11 000	44.215	44.181	44.147	44.113	44.079
11 200	44.257	44.222	44.188	44.154	44.120
11 400	44.298	44.263	44.229	44.195	44.161
11 600	44.339	44.305	44.270	44.236	44.202
11 800	44.380	44.346	44.311	44.277	44.243
12 000	44.421	44.387	44.352	44.318	44.284

5 for Aviation Gasolines, Table 2 or Table 6 for JP-4 jet-type fuels; Table 3 or Table 7 for JP-5 jet type fuels, and Table 4 or Table 8 for kerosene-type aviation turbine fuels (Specification D 1655, Jet A or A-1).