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Standard Test Method for Estimation of Net Heat of Combustion (Specific Energy) of Aviation Fuels[1]

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1. Scope

1.1 This test method covers the estimation of the net heat of combustion (specific energy) at constant pressure in SI units, megajoules per kilogram, from the fuel density, sulfur, and hydrogen content.

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 that conform to the requirements of specifications for aviation turbine fuels of limited boiling ranges and compositions, as described in Note 1 and permitted by each specification.

NOTE 1—The estimation of the heat of combustion of a hydrocarbon fuel from its hydrogen content, density, and sulfur 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 classes of fuels used to establish the correclation presented in this test method are represented by the following specifications:

Fuel	Specification
JP-5, Avcat/FSII	MIL-DTL-5624 DEF STAN 91-86 NATO Code F-44
JP-8, Avtur/FSII	MIL-DTL-83133 DEF STAN 91–87 NATO Code F-34
Jet A, Jet A-1, Avtur	Specification D 1655 DEF STAN 91-91 NATO Code F-35 CAN/CGSB-3.23

1.3 The heat of combustion can also be estimated by Test Methods D 1405, D 3338, and D 4529.

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 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 1552 Test Method for Sulfur in Petroleum Products (High-Temperature Method)[2]

D 1655 Specification for Aviation Turbine Fuels[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]

D 3338 Test Method for Estimation of Heat of Combustion of Aviation Fuels[3]

D 3701 Test Method for Hydrogen Content of Aviation Turbine Fuels by Low Resolution Nuclear Magnetic Resonance Spectrometry[3]

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

D 4294 Test Method for Sulfur in Petroleum Products by Energy-Dispersive X-Ray Fluoroscence Spectroscopy[3]

D 4529 Test Method for Estimation of Net Heat of Combustion of Aviation Fuels[3]

D 4808 Test Method for Hydrogen Content of Light Distillates, Middle Distillates, Gas Oils, and Residua by Low-Resolution Nuclear Magnetic Resonance Spectrometry[4]

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.05.0B on Calorimetry of Liquid Hydrocarbon Fuels.

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[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.

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

D 5291 Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants[4]

D 5453 Test Method for the Determination of Total Sulfur in Light Hydrocarbons, Motor Fuel, and Oils by Ultraviolet Fluorescence[4]

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

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

MIL-DTL-83133 Aviation Turbine Fuel, Kerosene Types, NATO F-34 (JP-8), NATO F-35 , and JP-8+100

2.3 *Directorate of Standardization, Ministry of Defence:*[6]

DEF STAN 91-86 Aviation Turbine Fuel, High Flash Kerosene Type with Fuel System Icing Inhibitor

DEF STAN 91-87, Aviation Turbine Fuel, Kerosene Type with Fuel System Icing Inhibitor

DEF STAN 91-91, Aviation Turbine Fuel, Kerosene Type, Jet A-1

2.4 *NATO Code:*[6]

F-34 Aviation Turbine Fuel, Grade JP-8

F-35 Aviation Turbine Fuel, Jet A Type

F-44 Aviation Turbine Fuel, JP-5

3. Summary of Test Method

3.1 The hydrogen content, 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.

4. Significance and Use

4.1 This test method is intended for use as a guide in cases in which an experimental determination of heat of combustion is not available and cannot be made conveniently, and in which an estimate is considered satisfactory. It is not intended as a substitute for experimental measurements of heat of combustion (see Note 2).

NOTE 2—The procedures for the experimental determination of the net heat of combustion are described in Test Methods D 240 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. 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.

5. Procedure

5.1 Determine the hydrogen content of the sample to the nearest 0.01 mass %, as described in Test Method D 3701, D 4808, or D 5291.

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 1217, D 1298, or D 4052 or Guide D 1250.

5.3 Determine the sulfur content of the sample to the nearest 0.02 mass %, as described in Test Method D 129, D 1266, D 1552, D 2622, D 3120, D 4294, or D 5453.

6. Calculation

6.1 Calculate the net heat of combustion of the fuel at constant pressure by inserting the measured values of hydrogen content, density, and sulfur content in Eq 1.

$$Q_p = 37.2889 + 0.566173\,H - 0.3266\,S - 0.0023003\,D \quad (1)$$

where:

Q_p = net heat of combustion, MJ/kg,
H = hydrogen content, mass %,
S = sulfur content, mass %, and
D = density at 15 C, kg/m^3.

6.2 Calculate the net heat of combustion on a volumetric basis by Eq 2.

$$Q_v = Q_p\,D \quad (2)$$

where:

Q_v = net heat of combustion, MJ/m^3.

7. Report

7.1 Report the result for the net heat of combustion Q_p in MJ/kg to the nearest 0.01 MJ/kg.

7.2 Report the result for the volumetric net heat of combustion Q_v in MJ/m^3 to the nearest 10 MJ/m^3.

8. Precision and Bias [7]

8.1 *Precision*—The following criteria shall be used for judging the acceptability of estimated heat of combustion results when using data on the hydrogen content, the density, and the sulfur content of a fuel determined by Test Methods D 3701, D 1298, and D 129, respectively (see Note 3).

NOTE 3—The correlation between net heat of combustion and the hydrogen content, the density and the sulfur content defined in Eq 1 was developed based on measured data by Test Methods D 3701, D 1298, and D 129, respectively. Use of alternative test methods having a greater or lesser precision will have a like trend on the precision of the estimated net heart of combustion.

8.1.1 *Repeatability*—The difference between two 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 the following values in only 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

[5] Available from Department of Defense Single Stock Point, 700 Robbins Ave., Building 4D, Philadelphia, PA 19111-5098.

[6] Available from Directorate of Standardization, Stan Ops 1, Room 1138, Kentigern House, 65 Brown Street, Glasgow G2 8EX, U.K.

[7] The precision statement was determined in a cooperative laboratory program. Supporting data have been filed at ASTM Headquarters. Request RR:D02-1461.

the long run, in the normal and correct operation of the test method, exceed the following values in only one case in twenty:

Reproducibility 0.06 MJ/kg

NOTE 4—As a guide, an estimate on a volume basis for a fuel with a density of 810 kg/m^3, rounded to the nearest 10 MJ/kg is:

Repeatability 40 MJ/m^3
Reproducibility 50 MJ/m^3

8.2 *Bias*—No general statement is made on bias for the test method since the data used to determine the correlation cannot be compared with accepted reference materials.

9. Keywords

9.1 aviation fuels; energy content; heat of combustion; heating tests; net heat of combustion; specific energy