



## Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels<sup>1</sup>

This standard is issued under the fixed designation D1405/D1405M; 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 ( $\epsilon$ ) 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 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:<br>Grades 80, 82, 100/130, and 115/145 | Specification <a href="#">D910</a><br>Specification <a href="#">D6227</a><br>DEF STAN 91–90<br>NATO Code F-18 |
| Aviation turbine fuels:<br>JP-4, Avtag/FSII                     | MIL-DTL-5624<br>DEF STAN 91–88<br>NATO Code F-40                                                              |
| JP-5, Avcat/FSII                                                | MIL-DTL-5624<br>DEF STAN 91–86<br>NATO Code F-44                                                              |
| Jet A, Jet A-1, Avtur                                           | Specification <a href="#">D1655</a><br>DEF STAN 91–91<br>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 [D4529](#). Test Method [D4529](#) requires calculation of a single equation for all aviation fuels with a precision equivalent to that of this test method.

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.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>2</sup>

- [D129 Test Method for Sulfur in Petroleum Products \(General High Pressure Decomposition Device Method\)](#)
- [D240 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter](#)
- [D287 Test Method for API Gravity of Crude Petroleum and Petroleum Products \(Hydrometer Method\)](#)
- [D611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents](#)
- [D910 Specification for Aviation Gasolines](#)
- [D941 Test Method for Density and Relative Density \(Specific Gravity\) of Liquids by Lipkin Bicapillary Pycnometer \(Withdrawn 1993\)<sup>3</sup>](#)
- [D1217 Test Method for Density and Relative Density \(Specific Gravity\) of Liquids by Bingham Pycnometer](#)
- [D1250 Guide for Use of the Petroleum Measurement Tables](#)
- [D1266 Test Method for Sulfur in Petroleum Products \(Lamp Method\)](#)

<sup>1</sup> 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.

Current edition approved May 1, 2013. Published August 2013. Originally approved in 1956. Last previous edition approved in 2008 as D1405/D1405M – 08. DOI: 10.1520/D1405\_D1405M-08R13.

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

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

**D1298** Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

**D1655** Specification for Aviation Turbine Fuels

**D2622** Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry

**D3120** Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry

**D4052** Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter

**D4294** Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry

**D4529** Test Method for Estimation of Net Heat of Combustion of Aviation Fuels

**D4809** Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)

**D5453** Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence

**D6227** Specification for Unleaded Aviation Gasoline Containing a Non-hydrocarbon Component

2.2 *U.S. Military Standards:*<sup>4</sup>

**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:*<sup>5</sup>

**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:*<sup>5</sup>

**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<sup>6,7</sup> 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 | $Q_p(\text{net}) = 41.9557 + 0.00020543 (A \times G)$ | (1) |
| JP-4                                          | $Q_p(\text{net}) = 41.8145 + 0.00024563 (A \times G)$ | (2) |
| JP-5                                          | $Q_p(\text{net}) = 41.6680 + 0.00024563 (A \times G)$ | (3) |
| Kerosine Jet A or A-1                         | $Q_p(\text{net}) = 41.6796 + 0.00025407 (A \times G)$ | (4) |

where:

$Q_p(\text{net})$  = 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 per pound].

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

where:

$Q_p(\text{net})$  = 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):

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

where:

$Q'$  = net heat of combustion, MJ/kg, of the sample containing  $S$  % sulfur,

<sup>4</sup> Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://www.dodssp.daps.mil>.

<sup>5</sup> Available from Directorate of Standardization, Stan Ops I, Room 1138, Kentigern House, 65 Brown Street, Glasgow, G2 8EX, U.K.

<sup>6</sup> Coglian, 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.

<sup>7</sup> 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.

$S$  = 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 per 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 D1655, 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 D240 and D4809.

## 5. Procedure

5.1 Determine the aniline points of the sample to the nearest 0.05°C [0.1°F] as described in Test Method D611.

5.2 Determine the API gravity of the sample to the nearest 0.1° API as described in Test Method D287. Alternatively, determine the relative density by Test Methods D941, D1217, and D4052 and correct the result to API gravity by Guide D1250.

5.3 Determine the sulfur content of the sample to the nearest 0.02 % sulfur as described in Test Methods D129, D1266, D2622, D3120, D4294, or D5453 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.

**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      |

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 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 D1655, Jet A or A-1).

**TABLE 2 Values of Q' for JP-4 Fuels Calculated from Eq 2 and Eq 9 in MJ/kg**

| Aniline-Gravity Product | Net Heat of Combustion, MJ/kg |             |             |             |             |             |
|-------------------------|-------------------------------|-------------|-------------|-------------|-------------|-------------|
|                         | 0% Sulfur                     | 0.2% Sulfur | 0.4% Sulfur | 0.6% Sulfur | 0.8% Sulfur | 1.0% Sulfur |
| 5 200                   | 43.092                        | 43.026      | 42.960      | 42.894      | 42.828      | 42.762      |
| 5 400                   | 43.141                        | 43.075      | 43.009      | 42.943      | 42.877      | 42.811      |
| 5 600                   | 43.190                        | 43.124      | 43.058      | 42.992      | 42.926      | 42.860      |
| 5 800                   | 43.239                        | 43.173      | 43.107      | 43.041      | 42.975      | 42.908      |
| 6 000                   | 43.288                        | 43.222      | 43.156      | 43.090      | 43.023      | 42.957      |
| 6 200                   | 43.337                        | 43.271      | 43.205      | 43.138      | 43.072      | 43.006      |
| 6 400                   | 43.387                        | 43.320      | 43.254      | 43.187      | 43.121      | 43.054      |
| 6 600                   | 43.436                        | 43.369      | 43.303      | 43.236      | 43.169      | 43.103      |
| 6 800                   | 43.485                        | 43.418      | 43.351      | 43.285      | 43.218      | 43.152      |
| 7 000                   | 43.534                        | 43.467      | 43.400      | 43.334      | 43.267      | 43.200      |
| 7 200                   | 43.583                        | 43.516      | 43.449      | 43.383      | 43.316      | 43.249      |
| 7 400                   | 43.632                        | 43.565      | 43.498      | 43.431      | 43.364      | 43.297      |
| 7 600                   | 43.681                        | 43.614      | 43.547      | 43.480      | 43.413      | 43.346      |
| 7 800                   | 43.730                        | 43.663      | 43.596      | 43.529      | 43.462      | 43.395      |
| 8 000                   | 43.780                        | 43.712      | 43.645      | 43.578      | 43.511      | 43.443      |

**TABLE 3 Values of Q' for JP-5 Fuels Calculated from Eq 3 and Eq 9 in MJ/kg**

| Aniline-Gravity Product | Net Heat of Combustion, MJ/kg |             |             |             |             |             |
|-------------------------|-------------------------------|-------------|-------------|-------------|-------------|-------------|
|                         | 0% Sulfur                     | 0.2% Sulfur | 0.4% Sulfur | 0.6% Sulfur | 0.8% Sulfur | 1.0% Sulfur |
| 4 200                   | 42.700                        | 42.635      | 42.569      | 42.504      | 42.439      | 42.374      |
| 4 400                   | 42.749                        | 42.684      | 42.618      | 42.553      | 42.488      | 42.423      |
| 4 600                   | 42.798                        | 42.733      | 42.667      | 42.602      | 42.537      | 42.472      |
| 4 800                   | 42.847                        | 42.782      | 42.716      | 42.651      | 42.586      | 42.520      |
| 5 000                   | 42.896                        | 42.831      | 42.765      | 42.700      | 42.634      | 42.569      |
| 5 200                   | 42.945                        | 42.880      | 42.814      | 42.749      | 42.683      | 42.617      |
| 5 400                   | 42.994                        | 42.929      | 42.863      | 42.797      | 42.732      | 42.666      |
| 5 600                   | 43.044                        | 42.978      | 42.912      | 42.846      | 42.780      | 42.715      |
| 5 800                   | 43.093                        | 43.027      | 42.961      | 42.895      | 42.829      | 42.763      |
| 6 000                   | 43.142                        | 43.076      | 43.010      | 42.944      | 42.878      | 42.812      |
| 6 200                   | 43.191                        | 43.125      | 43.059      | 42.993      | 42.927      | 42.861      |
| 6 400                   | 43.240                        | 43.174      | 43.108      | 43.042      | 42.975      | 42.909      |
| 6 600                   | 43.289                        | 43.223      | 43.157      | 43.090      | 43.024      | 42.958      |
| 6 800                   | 43.338                        | 43.272      | 43.206      | 43.139      | 43.073      | 43.007      |
| 7 000                   | 43.387                        | 43.321      | 43.255      | 43.188      | 43.122      | 43.055      |

6.3 From the values obtained in 6.2, make a linear interpolation for the sulfur content within the row for the calculated aniline gravity constant.

#### 6.3.1 Example:

Sample: JP-4 Fuel

##### 6.3.1.1 Determined Values:

Aniline point,  $A = 137^{\circ}\text{F}$

Gravity,  $G = 54.8^{\circ}\text{ API}$

Sulfur content = 0.10 mass %

##### 6.3.1.2 Calculated Value:

$A \times G$  product = 7508

|              |                                |                     |                     |
|--------------|--------------------------------|---------------------|---------------------|
| $A \times G$ | By interpolation from Table 2: |                     |                     |
|              | 0 % Sulfur                     | 0.1 % Sulfur        | 0.2 % Sulfur        |
|              | 7400                           | 43.632              | 43.565              |
|              | 7508 <sup>A</sup>              | 43.659 <sup>B</sup> | 43.592 <sup>B</sup> |
| $A \times G$ | By interpolation from Table 6: |                     |                     |
|              | 0.0 % Sulfur                   | 0.1 % Sulfur        | 0.2 % Sulfur        |
|              | 7400                           | 18 758              | 18 729              |
|              | 7508 <sup>A</sup>              | 18 769 <sup>B</sup> | 18 740 <sup>B</sup> |
| 7600         | 18 779                         |                     | 18 750              |

<sup>A</sup> Value calculated from determined values.

<sup>B</sup> First step interpolation between rows in columns bracketing the sulfur content.

<sup>C</sup> Second step interpolation within a row between columns.

#### 6.3.1.3 Estimated Net Heat of Combustion:

43.625 MJ/kg  
[18 755 Btu/lb]

## 7. Report

7.1 Report the result in megajoule per kilogram to the nearest 0.001 or [British thermal units per pound] to the nearest integer as estimated Net Heat of Combustion, D1405 or [D1405M].

## 8. Precision and Bias

8.1 *Repeatability*—The difference between successive test results obtained by the same operator with the apparatus under constant operating conditions on identical test material (using a second set of measured values for the aniline point temperature, the relative density, and the sulfur content determined by Test Methods D611, D1298, and D129, respectively) 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:

$$\text{Repeatability} = 0.012 \text{ MJ/kg or } [5 \text{ Btu/lb}] \quad (11)$$

8.2 *Reproducibility*—The difference between two single and independent results obtained by different operators working in different laboratories on identical test material (using the aniline point temperature, the relative density, and the sulfur content determined by Test Methods D611, D1298, and D129, respectively) would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in twenty:

$$\text{Reproducibility} = 0.035 \text{ MJ/kg or } [15 \text{ Btu/lb}] \quad (12)$$

NOTE 4—Use of fuel property data obtained with greater or lesser precision than that of the methods indicated will have a like trend on the precision of the predicted heat of combustion.

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

## 9. Keywords

9.1 aviation fuel; gross heat of combustion; heat energy; heat of combustion; heating tests; net heat of combustion

**TABLE 4 Values of Q' for Aviation Turbine Fuels Jet A and A-1  
Calculated from Eq 4 and Eq 9 in MJ/kg**

| Aniline-<br>Gravity<br>Product | Net Heat of Combustion, MJ/kg |             |             |             |             |
|--------------------------------|-------------------------------|-------------|-------------|-------------|-------------|
|                                | 0% Sulfur                     | 0.1% Sulfur | 0.2% Sulfur | 0.3% Sulfur | 0.4% Sulfur |
| 4 200                          | 42.747                        | 42.714      | 42.682      | 42.649      | 42.616      |
| 4 400                          | 42.798                        | 42.765      | 42.732      | 42.700      | 42.667      |
| 4 600                          | 42.848                        | 42.816      | 42.783      | 42.750      | 42.718      |
| 4 800                          | 42.899                        | 42.866      | 42.834      | 42.801      | 42.768      |
| 5 000                          | 42.950                        | 42.917      | 42.884      | 42.852      | 42.819      |
| 5 200                          | 43.001                        | 42.968      | 42.935      | 42.902      | 42.869      |
| 5 400                          | 43.052                        | 43.019      | 42.986      | 42.953      | 42.920      |
| 5 600                          | 43.102                        | 43.069      | 43.037      | 43.004      | 42.971      |
| 5 800                          | 43.153                        | 43.120      | 43.087      | 43.054      | 43.021      |
| 6 000                          | 43.204                        | 43.171      | 43.138      | 43.105      | 43.072      |
| 6 200                          | 43.255                        | 43.222      | 43.189      | 43.156      | 43.122      |
| 6 400                          | 43.306                        | 43.273      | 43.239      | 43.206      | 43.173      |
| 6 600                          | 43.356                        | 43.323      | 43.290      | 43.257      | 43.224      |
| 6 800                          | 43.407                        | 43.374      | 43.341      | 43.308      | 43.274      |
| 7 000                          | 43.458                        | 43.425      | 43.391      | 43.358      | 43.325      |
| 7 200                          | 43.509                        | 43.476      | 43.442      | 43.409      | 43.376      |
| 7 400                          | 43.560                        | 43.526      | 43.493      | 43.460      | 43.426      |
| 7 600                          | 43.611                        | 43.577      | 43.544      | 43.510      | 43.477      |
| 7 800                          | 43.661                        | 43.628      | 43.594      | 43.561      | 43.527      |
| 8 000                          | 43.712                        | 43.679      | 43.645      | 43.612      | 43.578      |
| 8 200                          | 43.763                        | 43.729      | 43.696      | 43.662      | 43.629      |
| 8 400                          | 43.814                        | 43.780      | 43.746      | 43.713      | 43.679      |
| 8 600                          | 43.865                        | 43.831      | 43.797      | 43.763      | 43.730      |
| 8 800                          | 43.915                        | 43.882      | 43.848      | 43.814      | 43.780      |
| 9 000                          | 43.966                        | 43.932      | 43.899      | 43.865      | 43.831      |
| 9 200                          | 44.017                        | 43.983      | 43.949      | 43.915      | 43.882      |
| 9 400                          | 44.068                        | 44.034      | 44.000      | 43.966      | 43.932      |
| 9 600                          | 44.119                        | 44.085      | 44.051      | 44.017      | 43.983      |
| 9 800                          | 44.169                        | 44.135      | 44.101      | 44.067      | 44.033      |
| 10 000                         | 44.220                        | 44.186      | 44.152      | 44.118      | 44.084      |

**TABLE 5 Values of Q' for Aviation Gasolines Calculated from Eq 5 and Eq 10 in [Btu/lb]**

| Aniline-Gravity Product | Net Heat of Combustion, Btu/lb |             |             |             |             |
|-------------------------|--------------------------------|-------------|-------------|-------------|-------------|
|                         | 0% Sulfur                      | 0.1% Sulfur | 0.2% Sulfur | 0.3% Sulfur | 0.4% Sulfur |
| 4 000                   | 18 391                         | 18 377      | 18 363      | 18 349      | 18 335      |
| 4 200                   | 18 409                         | 18 395      | 18 381      | 18 367      | 18 352      |
| 4 400                   | 18 426                         | 18 412      | 18 398      | 18 384      | 18 370      |
| 4 600                   | 18 444                         | 18 430      | 18 416      | 18 402      | 18 388      |
| 4 800                   | 18 462                         | 18 448      | 18 433      | 18 419      | 18 405      |
| 5 000                   | 18 479                         | 18 465      | 18 451      | 18 437      | 18 423      |
| 5 200                   | 18 497                         | 18 483      | 18 469      | 18 455      | 18 440      |
| 5 400                   | 18 515                         | 18 500      | 18 486      | 18 472      | 18 458      |
| 5 600                   | 18 532                         | 18 518      | 18 504      | 18 490      | 18 476      |
| 5 800                   | 18 550                         | 18 536      | 18 522      | 18 507      | 18 493      |
| 6 000                   | 18 568                         | 18 553      | 18 539      | 18 525      | 18 511      |
| 6 200                   | 18 585                         | 18 571      | 18 557      | 18 543      | 18 528      |
| 6 400                   | 18 603                         | 18 589      | 18 574      | 18 560      | 18 546      |
| 6 600                   | 18 621                         | 18 606      | 18 592      | 18 578      | 18 564      |
| 6 800                   | 18 638                         | 18 624      | 18 610      | 18 595      | 18 581      |
| 7 000                   | 18 656                         | 18 642      | 18 627      | 18 613      | 18 599      |
| 7 200                   | 18 674                         | 18 659      | 18 645      | 18 631      | 18 616      |
| 7 400                   | 18 691                         | 18 677      | 18 663      | 18 648      | 18 634      |
| 7 600                   | 18 709                         | 18 695      | 18 680      | 18 666      | 18 652      |
| 7 800                   | 18 727                         | 18 712      | 18 698      | 18 684      | 18 669      |
| 8 000                   | 18 744                         | 18 730      | 18 716      | 18 701      | 18 687      |
| 8 200                   | 18 762                         | 18 748      | 18 733      | 18 719      | 18 704      |
| 8 400                   | 18 780                         | 18 765      | 18 751      | 18 736      | 18 722      |
| 8 600                   | 18 797                         | 18 783      | 18 768      | 18 754      | 18 740      |
| 8 800                   | 18 815                         | 18 800      | 18 786      | 18 772      | 18 757      |
| 9 000                   | 18 833                         | 18 818      | 18 804      | 18 789      | 18 775      |
| 9 200                   | 18 850                         | 18 836      | 18 821      | 18 807      | 18 792      |
| 9 400                   | 18 868                         | 18 853      | 18 839      | 18 824      | 18 810      |
| 9 600                   | 18 886                         | 18 871      | 18 857      | 18 842      | 18 828      |
| 9 800                   | 18 903                         | 18 889      | 18 874      | 18 860      | 18 845      |
| 10 000                  | 18 921                         | 18 906      | 18 892      | 18 877      | 18 863      |
| 10 200                  | 18 939                         | 18 924      | 18 909      | 18 895      | 18 880      |
| 10 400                  | 18 956                         | 18 942      | 18 927      | 18 912      | 18 898      |
| 10 600                  | 18 974                         | 18 959      | 18 945      | 18 930      | 18 915      |
| 10 800                  | 18 992                         | 18 977      | 18 962      | 18 948      | 18 933      |
| 11 000                  | 19 009                         | 18 995      | 18 980      | 18 965      | 18 951      |
| 11 200                  | 19 027                         | 19 012      | 18 998      | 18 983      | 18 968      |
| 11 400                  | 19 045                         | 19 030      | 19 015      | 19 001      | 18 986      |
| 11 600                  | 19 062                         | 19 048      | 19 033      | 19 018      | 19 003      |
| 11 800                  | 19 080                         | 19 065      | 19 050      | 19 036      | 19 021      |
| 12 000                  | 19 098                         | 19 083      | 19 068      | 19 053      | 19 039      |

**TABLE 6 Values of Q' for JP-4 Fuels Calculated from Eq 6 and Eq 10 in [Btu/lb]**

| Aniline-Gravity Product | Net Heat of Combustion, Btu/lb |             |             |             |             |             |
|-------------------------|--------------------------------|-------------|-------------|-------------|-------------|-------------|
|                         | 0% Sulfur                      | 0.2% Sulfur | 0.4% Sulfur | 0.6% Sulfur | 0.8% Sulfur | 1.0% Sulfur |
| 5 200                   | 18 526                         | 18 498      | 18 469      | 18 441      | 18 413      | 18 384      |
| 5 400                   | 18 547                         | 18 519      | 18 490      | 18 462      | 18 434      | 18 405      |
| 5 600                   | 18 568                         | 18 540      | 18 511      | 18 483      | 18 454      | 18 426      |
| 5 800                   | 18 589                         | 18 561      | 18 532      | 18 504      | 18 475      | 18 447      |
| 6 000                   | 18 611                         | 18 583      | 18 554      | 18 526      | 18 497      | 18 469      |
| 6 200                   | 18 632                         | 18 603      | 18 575      | 18 547      | 18 518      | 18 489      |
| 6 400                   | 18 653                         | 18 624      | 18 596      | 18 568      | 18 539      | 18 510      |
| 6 600                   | 18 674                         | 18 645      | 18 617      | 18 588      | 18 560      | 18 531      |
| 6 800                   | 18 695                         | 18 666      | 18 638      | 18 609      | 18 580      | 18 552      |
| 7 000                   | 18 716                         | 18 687      | 18 659      | 18 630      | 18 601      | 18 573      |
| 7 200                   | 18 737                         | 18 708      | 18 680      | 18 651      | 18 622      | 18 593      |
| 7 400                   | 18 758                         | 18 729      | 18 700      | 18 672      | 18 643      | 18 614      |
| 7 600                   | 18 779                         | 18 750      | 18 721      | 18 693      | 18 664      | 18 635      |
| 7 800                   | 18 800                         | 18 771      | 18 742      | 18 714      | 18 685      | 18 656      |
| 8 000                   | 18 821                         | 18 792      | 18 763      | 18 735      | 18 706      | 18 677      |

**TABLE 7 Values of Q' for JP-5 Fuels Calculated from Eq 7 and Eq 10 in [Btu/lb]**

| Aniline-Gravity Product | Net Heat of Combustion, Btu/lb |             |             |             |             |             |
|-------------------------|--------------------------------|-------------|-------------|-------------|-------------|-------------|
|                         | 0% Sulfur                      | 0.2% Sulfur | 0.4% Sulfur | 0.6% Sulfur | 0.8% Sulfur | 1.0% Sulfur |
| 4 200                   | 18 358                         | 18 330      | 18 302      | 18 274      | 18 246      | 18 218      |
| 4 400                   | 18 379                         | 18 351      | 18 323      | 18 295      | 18 267      | 18 239      |
| 4 600                   | 18 400                         | 18 372      | 18 344      | 18 316      | 18 288      | 18 260      |
| 4 800                   | 18 421                         | 18 393      | 18 365      | 18 337      | 18 309      | 18 280      |
| 5 000                   | 18 442                         | 18 414      | 18 386      | 18 358      | 18 329      | 18 301      |
| 5 200                   | 18 463                         | 18 435      | 18 407      | 18 378      | 18 350      | 18 322      |
| 5 400                   | 18 484                         | 18 456      | 18 428      | 18 399      | 18 371      | 18 343      |
| 5 600                   | 18 505                         | 18 477      | 18 448      | 18 420      | 18 392      | 18 364      |
| 5 800                   | 18 526                         | 18 498      | 18 469      | 18 441      | 18 413      | 18 384      |
| 6 000                   | 18 548                         | 18 520      | 18 491      | 18 463      | 18 435      | 18 406      |
| 6 200                   | 18 569                         | 18 541      | 18 512      | 18 484      | 18 455      | 18 427      |
| 6 400                   | 18 590                         | 18 562      | 18 533      | 18 505      | 18 476      | 18 448      |
| 6 600                   | 18 611                         | 18 583      | 18 554      | 18 526      | 18 498      | 18 469      |
| 6 800                   | 18 632                         | 18 604      | 18 575      | 18 547      | 18 519      | 18 490      |
| 7 000                   | 18 653                         | 18 625      | 18 596      | 18 568      | 18 540      | 18 511      |

**TABLE 8 Values of Q' for Aviation Turbine Fuels Jet A and A-1 (Specification D1655) Calculated from Eq 8 and Eq 10 in [Btu/lb]**

| Aniline-Gravity Product | Net Heat of Combustion, Btu/lb |              |              |              |              |
|-------------------------|--------------------------------|--------------|--------------|--------------|--------------|
|                         | 0% Sulfur                      | 0.05% Sulfur | 0.10% Sulfur | 0.15% Sulfur | 0.20% Sulfur |
| 4 200                   | 18 378                         | 18 371       | 18 364       | 18 357       | 18 350       |
| 4 400                   | 18 400                         | 18 393       | 18 386       | 18 379       | 18 372       |
| 4 600                   | 18 421                         | 18 414       | 18 407       | 18 400       | 18 393       |
| 4 800                   | 18 443                         | 18 436       | 18 429       | 18 422       | 18 415       |
| 5 000                   | 18 465                         | 18 458       | 18 451       | 18 444       | 18 437       |
| 5 200                   | 18 487                         | 18 480       | 18 473       | 18 466       | 18 459       |
| 5 400                   | 18 509                         | 18 502       | 18 495       | 18 488       | 18 481       |
| 5 600                   | 18 531                         | 18 524       | 18 517       | 18 509       | 18 502       |
| 5 800                   | 18 553                         | 18 545       | 18 538       | 18 531       | 18 524       |
| 6 000                   | 18 574                         | 18 567       | 18 560       | 18 553       | 18 546       |
| 6 200                   | 18 596                         | 18 589       | 18 582       | 18 575       | 18 568       |
| 6 400                   | 18 618                         | 18 611       | 18 604       | 18 597       | 18 590       |
| 6 600                   | 18 640                         | 18 633       | 18 626       | 18 619       | 18 611       |
| 6 800                   | 18 662                         | 18 655       | 18 647       | 18 640       | 18 633       |
| 7 000                   | 18 684                         | 18 676       | 18 669       | 18 662       | 18 655       |
| 7 200                   | 18 705                         | 18 698       | 18 691       | 18 684       | 18 677       |
| 7 400                   | 18 727                         | 18 720       | 18 713       | 18 706       | 18 699       |
| 7 600                   | 18 749                         | 18 742       | 18 735       | 18 728       | 18 720       |
| 7 800                   | 18 771                         | 18 764       | 18 757       | 18 749       | 18 742       |
| 8 000                   | 18 793                         | 18 786       | 18 778       | 18 771       | 18 764       |
| 8 200                   | 18 815                         | 18 807       | 18 800       | 18 793       | 18 786       |
| 8 400                   | 18 837                         | 18 829       | 18 822       | 18 815       | 18 808       |
| 8 600                   | 18 858                         | 18 851       | 18 844       | 18 837       | 18 829       |
| 8 800                   | 18 880                         | 18 873       | 18 866       | 18 858       | 18 851       |
| 9 000                   | 18 902                         | 18 895       | 18 888       | 18 880       | 18 873       |
| 9 200                   | 18 924                         | 18 917       | 18 909       | 18 902       | 18 895       |
| 9 400                   | 18 946                         | 18 938       | 18 931       | 18 924       | 18 917       |
| 9 600                   | 18 968                         | 18 960       | 18 953       | 18 946       | 18 938       |
| 9 800                   | 18 989                         | 18 982       | 18 975       | 18 968       | 18 960       |
| 10 000                  | 19 011                         | 19 004       | 18 997       | 18 989       | 18 982       |

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org). Permission rights to photocopy the standard may also be secured from the ASTM website (www.astm.org/COPYRIGHT/).