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Standard Practice for Ultimate Analysis of Coal and Coke[1]

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1. Scope

1.1 This practice covers the term ultimate analysis as it is applied to the analysis of coal and coke. The information derived is intended for the general utilization by applicable industries, to provide the basis for evaluation, beneficiation, or for other purposes.

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

1.2.1 All percentages are percent mass fractions.

1.3 *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:*[2]

D346 Practice for Collection and Preparation of Coke Samples for Laboratory Analysis
D2013 Practice for Preparing Coal Samples for Analysis
D2234/D2234M Practice for Collection of a Gross Sample of Coal
D3172 Practice for Proximate Analysis of Coal and Coke
D3173 Test Method for Moisture in the Analysis Sample of Coal and Coke
D3174 Test Method for Ash in the Analysis Sample of Coal and Coke from Coal
D3302 Test Method for Total Moisture in Coal
D4239 Test Method for Sulfur in the Analysis Sample of Coal and Coke Using High-Temperature Tube Furnace Combustion
D4596 Practice for Collection of Channel Samples of Coal in a Mine
D5192 Practice for Collection of Coal Samples from Core
D5373 Test Methods for Determination of Carbon, Hydrogen and Nitrogen in Analysis Samples of Coal and Carbon in Analysis Samples of Coal and Coke
D6609 Guide for Part-Stream Sampling of Coal
D6883 Practice for Manual Sampling of Stationary Coal from Railroad Cars, Barges, Trucks, or Stockpiles
D7430 Practice for Mechanical Sampling of Coal
D7582 Test Methods for Proximate Analysis of Coal and Coke by Macro Thermogravimetric Analysis

3. Terminology

3.1 *Definitions:*

3.1.1 *ultimate analysis*—in the case of coal and coke, the determination of carbon, hydrogen, nitrogen, and sulfur in the material, as found in the gaseous products of its complete combustion, the determination of ash in the material as a whole, and the calculation of oxygen by difference.

NOTE 1—Moisture is not by definition a part of the ultimate analysis of coal or coke but must be determined in order that analytical data may be converted to bases other than that of the analysis sample.

NOTE 2—Inasmuch as some coals contain mineral carbonates, and practically all contain clay or shale containing combined water, a part of the carbon, hydrogen, and oxygen found in the products of combustion may arise from these mineral components.

4. Significance and Use

4.1 Summarizing the ash content and the content of the organic constituents in a specific format under the heading, *Ultimate Analysis*, provides a convenient and uniform system for comparing coals or cokes. This tabulation used with that of *Proximate Analysis* (Practice D3172) permits cursory valuation of coals for use as fuel or in other carbonaceous processes and of cokes for metallurgical purpose.

5. General Requirements

5.1 Coal sample collection shall be in accordance with any of the following Guides or Practices as appropriate: D7430, D2234/D2234M, D6609, D4596, D5192, and D6883.

5.2 For coal, sample preparations shall be in accordance with Practices D2013 or D7430. The analysis sample shall be the material pulverized to pass a 250 μm (No. 60) sieve in accordance with Practice D2013.

[1] This practice is under the jurisdiction of ASTM Committee D05 on Coal and Coke and is the direct responsibility of Subcommittee D05.21 on Methods of Analysis.

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[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.

5.3 Coke sampling and preparation shall be in accordance with Practice D346.

6. Specific Requirements

6.1 *Carbon, Hydrogen, and Nitrogen*—The carbon, hydrogen, and nitrogen determination shall be made in accordance with Test Method D5373.

6.2 *Sulfur*—The sulfur determination shall be made in accordance with Test Methods D4239.

6.3 *Ash*—The ash determination shall be made in accordance with Test Methods D3174 or D7582.

6.4 *Oxygen*—There being no satisfactory direct ASTM test method for determining oxygen, it shall be calculated by subtracting from 100 the sum of the other components of the ultimate analysis. The result so obtained is affected by errors incurred in the other determinations of the ultimate analysis and also by the changes in weight of the ash-forming constituents on ignition. By definition, oxygen calculated as a weight percentage of the analysis sample according to this procedure does not include oxygen in the mineral matter or in the ash, but does include oxygen in the free water (moisture) associated with the analysis sample. See Section 7 of this practice for calculating and reporting results on other bases.

6.5 *Moisture*—The moisture determination shall be made in accordance with Test Methods D3173 or D7582.

6.6 The air-dry loss or total moisture determination shall be made in accordance with Practice D3302.

7. Calculation and Report

7.1 The results of an ultimate analysis may be reported on any of a number of bases, differing from each other in the manner by which moisture is treated.

7.2 To avoid ambiguity and provide a means for conversion of data to bases other than the reported basis, it is essential that except for data reported on a dry basis, an appropriate moisture content be given in the data report.

7.3 It is recommended that, for data reported on the as-received basis (or any other moist basis), a footnote or some other means be used in the report to indicate whether the hydrogen and oxygen values reported do or do not include the hydrogen and oxygen in the free water (moisture) associated with the sample.

7.4 Procedures for converting ultimate analysis sample data to other bases are presented in Table 1.

7.4.1 Hydrogen and oxygen on the as-determined basis include hydrogen and oxygen in free water (moisture) associated with the analysis sample. However, hydrogen and oxygen values reported on other moisture-containing bases may be reported either as containing or as not containing the hydrogen and oxygen in water (moisture) reported on that basis. Alternative conversion procedures are shown in Table 1.

7.5 An example of ultimate analysis data tabulated for a hypothetical coal on various bases is given in Table 2.

8. Precision

8.1 The permissible differences between two or more determinations shall not exceed the values listed in the precision section of the specific test method for the parameter determined.

9. Keywords

9.1 ash; carbon; coal; coke; hydrogen; nitrogen; oxygen; sulfur; ultimate analysis

TABLE 1 Procedures for Converting As-Determined Values to Other Bases[A]

Reporting Basis Parameter[B]	As-Determined[C]	Dry	As-Received[D,E]	
			H_{ar} and Ox_{ar} Include H and Ox in Moisture (M_{ar})	H_{ar} and Ox_{ar} Do Not Include H and Ox as M_{ar}
Ash Carbon Nitrogen (P) Sulfur	No corrections (See standard method)	$P_d = P_{ad} \times \left(\frac{100}{100 - M_{ad}}\right)$	$P_{ar} = P_{ad} \times \left(\frac{100 - M_{ar}}{100 - M_{ad}}\right)$	same as column at left
Hydrogen (H)	No corrections (See standard method)	$H_d = (H_{ad} - 0.1119M_{ad}) \times \left(\frac{100}{100 - M_{ad}}\right)$	$H_{ar} = [(H_{ad} - 0.1119M_{ad}) \times \left(\frac{100 - M_{ar}}{100 - M_{ad}}\right)] + 0.1119M_{ar}$	$H_{ar} = (H_{ad} - 0.1119M_{ad}) \times \left(\frac{100 - M_{ar}}{100 - M_{ad}}\right)$
Oxygen (Ox)	$Ox_{ad} = 100 - A_{ad} - C_{ad} - H_{ad} - N_{ad} - S_{ad}$	$Ox_d = (Ox_{ad} - 0.8881M_{ad}) \times \left(\frac{100}{100 - M_{ad}}\right)$ or $Ox_d = 100 - A_d - C_d - H_d - N_d - S_d$	$Ox_{ar} = [(Ox_{ad} - 0.8881M_{ad}) \times \left(\frac{100 - M_{ar}}{100 - M_{ad}}\right)] + 0.8881M_{ar}$	$Ox_{ar} = (Ox_{ad} - 0.8881M_{ad}) \times \left(\frac{100 - M_{ar}}{100 - M_{ad}}\right)$

[A] A = ash, %;
M = moisture, %;
P = a symbol used interchangeably in the table to refer to ash, or carbon, or nitrogen, or sulfur, %;
H = hydrogen, %;
Ox = oxygen, %;
ad = as-determined from analysis sample;
ar = as received or any other moisture-containing basis (that is, equilibrium capacity moisture basis, as-shipped moisture basis, bed moisture basis) if the appropriate moisture value is substituted for M_{ar} in the formulae; and
d = dry basis.

[B] All parameters expressed on a weight percent basis.

[C] Hydrogen and oxygen reported on as-determined basis include hydrogen and oxygen in free moisture associated with analysis sample.

[D] Alternative procedures are shown, differing on the basis of whether hydrogen and oxygen in the moisture are included or are not included in the report values. A footnote or other means should be employed to indicate the basis used.

[E] To convert results to a moisture-containing basis other than as-received, as for example, equilibrium capacity moisture, substitute the appropriate moisture value for M_{ar} in the equations.

TABLE 2 Ultimate Analysis Data

Test Parameter	As-Determined	Dry Basis	As-Received Basis	
	Hydrogen and Oxygen Include H and Ox in Sample Moisture (M_{ad})		Hydrogen and Oxygen Include H and Ox in Sample Moisture (M_{ar})	Hydrogen and Oxygen Do Not Include H and Ox in Sample Moisture (M_{ar})
Carbon, %	60.08	66.02	46.86	46.86
Hydrogen, %	5.44	4.87	6.70	3.46
Nitrogen, %	0.88	0.97	0.69	0.69
Sulfur, %	0.73	0.80	0.57	0.57
Ash, %	7.86	8.64	6.13	6.13
Oxygen, % (by difference)	25.01	18.70	39.05	13.27
Total %	100.00	100.00	100.00	70.98
Total moisture, % (as-received)	...		(29.02)	29.02
Moisture % (samples as-determined)	9.00			Total % 100.00

(Air-dry loss in accordance with Test Method D3302 = 22.00 %)