Designation: D 3176 – 89 (Reapproved 2002)

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

This standard is issued under the fixed designation D 3176; 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.

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 *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.*

1.3 The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 346 Practice for Collection and Preparation of Coke Samples for Laboratory Analysis[2]

D 2013 Method of Preparing Coal Samples for Analysis[2]

D 2234 Practice for Collection of a Gross Sample of Coal[2]

D 2361 Test Method for Chlorine in Coal[2]

D 2795 Test Methods for Analysis of Coal and Coke Ash[2]

D 3172 Practice for Proximate Analysis of Coal and Coke[2]

D 3173 Test Method for Moisture in the Analysis Sample of Coal and Coke[2]

D 3174 Test Method for Ash in the Analysis Sample of Coal and Coke from Coal[2]

D 3177 Test Methods for Total Sulfur in the Analysis Sample of Coal and Coke[2]

D 3178 Test Methods for Carbon and Hydrogen in the Analysis Sample of Coal and Coke[2]

D 3179 Test Methods for Nitrogen in the Analysis Sample of Coal and Coke[2]

D 4239 Test Methods for Sulfur in the Analysis Sample of Coal and Coke Using High Temperature Tube Furnace Combustion Methods[2]

D 5142 Test Methods for Proximate Analysis of the Analysis Sample of Coal and Coke by Instrumental Procedures[2]

D 5373 Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Laboratory Samples of Coal and Coke[2]

3. Terminology

3.1 *Definitions:*

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

NOTE 1—The determination of phosphorus or chlorine is not by definition a part of the ultimate analysis of coal or coke. See Test Method D 2361 for the determination of chlorine and Test Methods D 2795 for the determination of phosphorus.

NOTE 2—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 3—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 D 3172) 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 Practice D 2234, and sample preparation shall be in accordance with Method D 2013. Coke sampling and preparation shall be in accordance with Practice D 346.

6. Specific Requirements

6.1 *Carbon and Hydrogen*—The carbon and hydrogen determination shall be made in accord with Test Methods D 3178 or D 5373.

6.2 *Sulfur*—The sulfur determination shall be made in accordance with Test Methods D 3177 or D 4239.

[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] *Annual Book of ASTM Standards*, Vol 05.06.

6.3 *Nitrogen*—The nitrogen determination shall be made in accordance with Test Methods D 3179 or D 5373.

6.4 *Ash*—The ash determination shall be made in accordance with Test Method D 3174 or Test Methods D 5142.

6.5 *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.

6.6 *Moisture*—The moisture determination shall be made in accordance with Test Method D 3173 or Test Methods D 5142.

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 ussed 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.

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, weight %;
M = moisture, weight %;
P = a symbol used interchangeably in the table to refer to ash, or carbon, or nitrogen, or sulfur, weight %;
H = hydrogen, weight %;
Ox = oxygen, weight %;
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, weight %	60.08	66.02	46.86	46.86
Hydrogen, weight %	5.44	4.87	6.70	3.46
Nitrogen, weight %	0.88	0.97	0.69	0.69
Sulfur, weight %	0.73	0.80	0.57	0.57
Ash, weight %	7.86	8.64	6.13	6.13
Oxygen, weight % (by difference)	25.01	18.70	39.05	13.27
Total %	100.00	100.00	100.00	70.98
Total moisture, weight % (as-received)	...		(29.02)	29.02
Moisture weight % (samples as-determined)	9.00			Total % 100.00

(Air-dry loss in accordance with Method D 2013 = 22.00 %)