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Designation: ~~E777 – 17a~~ E777 – 23

Standard Test Method for
Carbon and Hydrogen in the Analysis Sample of Refuse-Derived Fuel[1]

This standard is issued under the fixed designation E777; 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 test method is for the determination of total carbon and hydrogen in a sample of refuse-derived fuel (RDF). Both carbon and hydrogen are determined in one analysis. This test method yields the total percentages of carbon and hydrogen in RDF as analyzed and the results include not only carbon and hydrogen in the organic matter, but also the carbon present in mineral carbonates and the hydrogen present in the free moisture accompanying the analysis sample as well as hydrogen present as water of hydration.

NOTE 1—It is recognized that certain technical applications of the data derived from this test procedure may justify additional corrections. These corrections could involve compensation for the carbon present as carbonates, the hydrogen of free moisture accompanying the analysis sample, and the calculated hydrogen present as water of hydration.

1.2 This test method may be applicable to any waste material from which a laboratory analysis sample can be prepared.

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

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements, see Section 8.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1193 Specification for Reagent Water
D5681 Terminology for Waste and Waste Management
E790 Test Method for Residual Moisture in Refuse-Derived Fuel Analysis Samples
E791 Test Method for Calculating Refuse-Derived Fuel Analysis Data from As-Determined to Different Bases
E829 Practice for Preparing Refuse-Derived Fuel (RDF) Laboratory Samples for Analysis

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[1] This test method is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.03 on Treatment, Recovery and Reuse.

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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.

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3. Terminology

3.1 For definitions of terms used in this test method, refer to Terminology D5681.

4. Summary of Test Method

4.1 The determination is made by burning the sample to convert carbon to carbon dioxide and hydrogen to water. The combustion is carried out using high-purity oxygen that has been passed through a purifying train. The carbon dioxide and water are recovered in an absorption train. Combustion tube packing is used to remove interfering substances. This test method gives the total percentage of carbon and hydrogen in the RDF as analyzed, including the carbon in carbonates and the hydrogen in water.

5. Significance and Use

5.1 This standard is intended to provide a method for determining the weight percent of carbon and hydrogen in an RDF analysis sample.

5.2 Carbon and hydrogen are components of RDF and, when determined, can be used for calculating RDF combustion characteristics.

6. Apparatus

6.1 *Oxygen Purifying Train*—High-purity oxygen is passed through water and carbon dioxide absorbers prior to use for combustion. The oxygen purifying train consists of the following three components in order of gas passage (see Fig. 1):

6.1.1 *First Water Absorber*—A container constructed such that oxygen must pass through a column of water-removing reagent. The container shall have a capacity for at least 45 cm^3 of solid reagent, and the minimum gas distance traveled through the reagent shall be at least 80 mm.

6.1.2 *Carbon Dioxide Absorber*—If solid reagents are used for carbon dioxide absorption, the container shall be as described in 6.1.1. If a solution is used, the container shall be a Vanier bulb. It shall provide a column of reagent adequate to remove carbon dioxide below the testing laboratory's analytic reporting limit.

6.1.3 *Second Water Absorber*—Same as specified in 6.1.1.

6.2 *Flow Meter,* used to permit volumetric measurement of the rate of flow of oxygen during the determination. It shall be suitable for measuring flow rates within the range from 50 to 100 mL/min. At least annual certification of the flow meter is recommended and may be required in some applications. The use of a double-stage pressure-reducing regulator with gage and needle valve is recommended to permit easy and accurate adjustment to the rate of flow.

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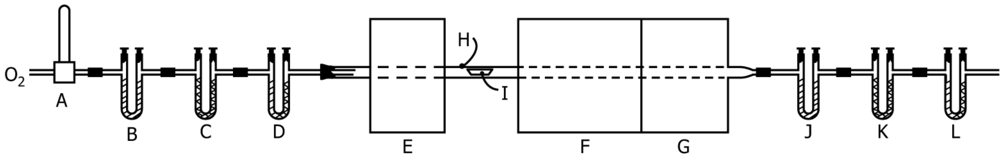

A = flowmeter (6.2)

B, C, D = oxygen purifying train (6.1)

B = first water absorber (6.1.1)
C = carbon dioxide absorber (6.1.2)
D = second water absorber (6.1.3)

E, F, G, H, I = combustion unit (6.3)

E = furnace 1 (6.3.1)

F = furnace 2 (6.3.2)
G = furnace 3 (6.3.3)
H = combustion tube (6.3.4)
I = combustion boat (6.3.5)

J, K, L = absorption train (6.4)
J = first water absorber (6.4.1)
K = carbon dioxide absorber (6.4.2)
L = guard tube (6.4.3)

NOTE 1—*C* and *K* can substitute a Vanier bulb if liquid absorbent is used.

FIG. 1 Construction of Oxygen Purifying Apparatus

6.3 *Combustion Unit,* consisting of three electrically heated furnace sections, individually controlled, which may be mounted on rails for easy movement. The upper part of each furnace may be hinged so that it can be opened for inspection of the combustion tube. The three furnace sections shall be as follows (see Fig. 1):

6.3.1 *Furnace Section 1*—Furnace 1 is nearest the oxygen inlet of the combustion tube, approximately 130 mm long and used to heat the inlet of the combustion tube and the sample. It shall be capable of rapidly attaining an operating temperature of 875 ± 25 °C.

NOTE 2—Combustion tube temperature shall be measured by means of a calibrated thermocouple placed immediately adjacent to the tube near the center of the appropriate tube section.

6.3.2 *Furnace Section 2*—Furnace 2 shall be approximately 330 mm in length and used to heat that portion of the tube filled with cupric oxide. The operating temperature shall be 850 ± 20 °C (see Note 2).

6.3.3 *Furnace Section 3*—Furnace 3 shall be approximately 230 mm long, and used to heat that portion of the tube filled with lead chromate or silver. The operating temperature shall be 500 ± 50 °C.

6.3.4 *Combustion Tube,* made of fused ~~quartz,~~quartz or high-silica glass, and having a nominal inside diameter which may vary within the limits of 19 to 22 mm and a minimum total length of 970 mm. The exit shall be tapered to provide a tubulated section for connection to the absorption train. The tubulated section shall have a length of 20 to 25 mm, an internal diameter of not less than 3 mm, and an external diameter of approximately 7 mm. The total length of the reduced end shall not exceed 60 mm. If a translucent fused quartz tube is used, a transparent section 190 mm long, located 250 mm from the oxygen inlet end of the tube, will be found convenient (see Fig. 2).

6.3.5 *Combustion Boat,* made of glazed porcelain, fused silica, or platinum. Boats with internal dimensions of approximately 70 by 8 by 8 mm have been found convenient to use in this analysis.

6.4 *Absorption Train,* identical to the oxygen absorption train described in 6.1. The absorption train shall consist of the following components arranged as listed which corresponds to the order of oxygen passage through the apparatus (see Fig. 1):

6.4.1 *First Water Absorber,* as described in 6.1.1.

6.4.2 *Carbon Dioxide Absorber,* as described in 6.1.2.

6.4.3 *Second Water Absorber,* as described in 6.1.3. The second water absorber is also known as a guard tube.

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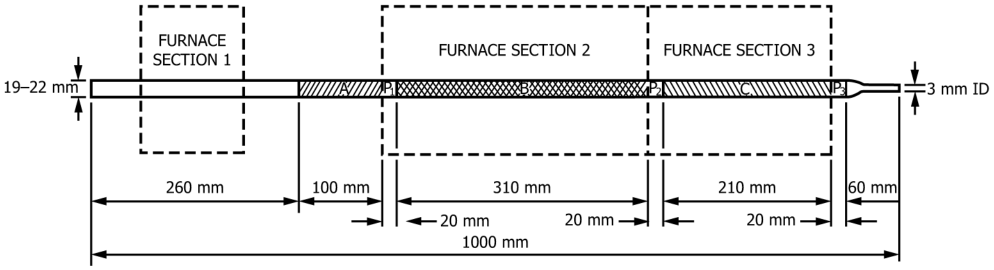
7. Reagents

7.1 *Purity of Reagents*—Reagent-grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all



A = clear fused quartz section (optional when a translucent quartz tube is used)
B = cupric oxide filling
C = lead chromate or silver gauze filling
P_1, P_2, P_3 = oxidized copper gauze plugs

NOTE 1—When furnace sections longer than those specified in 6.3 are to be used, changes in the above dimensions shall be in accordance with provisions of Note 5.

FIG. 2 Arrangement of Tube Filling for Combustion Tube

reagents shall conform to the specifications of the American Chemical Society, where such specifications are available.[3] Other grades may be used, provided it is first determined that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water, Type III, conforming to Specification D1193.

7.3 *Oxygen,* with minimum acceptable purity 99.5 %.

NOTE 3—If the blank tests for flow (see 10.3.2) indicate interfering impurities in the oxygen supply by consistent weight gain in the absorbers, eliminate these impurities by using a preheater furnace and tube, filled with cupric oxide. Operate this preheater at 850 ± 20 °C and insert in series between the supply tank of oxygen and the purification train.

7.4 *Combustion Tube Reagents:*

7.4.1 *Cupric Oxide* (CuO), wire form, dust-free.

7.4.2 *Fused Lead Chromate* ($PbCrO_4$), approximately 2.38 to 0.84 mm in size.

7.4.3 *Silver Gauze,* 99.9 % silver minimum purity, 0.84 mm, made from approximately No. 27 B&S gage wire.

7.4.4 *Copper Gauze,* 99.0 % copper minimum purity, 0.84 mm, made from approximately No. 26 B&S gage wire.

7.5 *Purification and Absorption Train Reagents:*

7.5.1 *Water Absorbent*—Anhydrous magnesium perchlorate ($Mg(ClO_4)_2$) approximately 2.38 to 0.35 mm in size.[4]

7.5.2 *Carbon Dioxide Absorbent*—If a solid reagent is used, it shall consist of either sodium or potassium hydroxide (NaOH or KOH) impregnated in an inert carrier of approximately 2.38 to 0.84 mm in size. Use of soda lime in place of the above or in admixture with them is permissible (Note 4). If a solution is used, it shall consist of 30 weight % potassium hydroxide (KOH).

NOTE 4—Acceptable carbon dioxide absorbing reagents using sodium or potassium hydroxide are sold under the trade name Ascarite. If soda lime is used in admixture with any of the foregoing, it should not exceed 30 weight % of the total reagent. In using Ascarite it may be necessary to add a few drops of water to this reagent to ensure complete absorption of carbon dioxide.

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8. Precautions

8.1 Due to the origins of RDF in municipal waste, safety precautions should be taken when conducting tests on samples. Safety practices include use of gloves for handling RDF samples; wearing NIOSH-approved type dust masks, especially while milling RDF samples; conducting tests under a negative pressure hood; and washing hands with soap and water after completing the analysis.

9. Sampling

9.1 RDF products are frequently inhomogeneous. For this reason, care should be exercised to ensure that a representative laboratory sample from the RDF lot to be characterized is obtained.

9.2 The sampling method for this procedure should be based on written agreement between the involved parties.

9.3 The laboratory sample must be air-dried and particle size reduced to pass through a ~~0.5-mm~~ 0.5 mm screen as described in Practice E829. This procedure must be carefully performed to preserve the sample's representativeness excepting particle size while preparing the analysis sample for analysis.

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[3] Reagent Chemicals, American Chemical Society Specifications, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see ~~*Annual*~~*Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

[4] Trade names of this reagent are Anhydrone or Dehydrite.