



Designation: E711 – 23^{ε1}

Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel by the Bomb Calorimeter¹

This standard is issued under the fixed designation E711; 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.

^{ε1} NOTE—Editorial corrections were made throughout in April 2023.

1. Scope

1.1 This test method covers the determination of the gross calorific value of a prepared analysis sample of solid forms of refuse-derived fuel (RDF) by the bomb calorimeter method.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific cautionary and precautionary statements, see 6.9 and Section 8.

1.4 *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

E1 Specification for ASTM Liquid-in-Glass Thermometers

E180 Practice for Determining the Precision of ASTM Methods for Analysis and Testing of Industrial and Spe-

cialty Chemicals (Withdrawn 2009)³

E775 Test Methods for Total Sulfur in the Analysis Sample of Refuse-Derived Fuel

E790 Test Method for Residual Moisture in Refuse-Derived Fuel Analysis Samples

E829 Practice for Preparing Refuse-Derived Fuel (RDF) Laboratory Samples for Analysis

3. Terminology

3.1 For definitions of general terms used in D34 Waste Management standards, refer to Terminology D5681.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *calorific value*—the heat of combustion of a unit quantity of a substance. It may be expressed in joules per gram (J/g), British thermal units per pound (Btu/lb), or calories per gram (cal/g) when required.

3.2.1.1 Discussion—The unit equivalents are as follows:

1 Btu (International Table) = 1055.06 absolute joules

1 Calorie (International Table) = 4.1868 absolute joules

1 Btu/lb = 2.326 J/g

1.8 Btu/lb = 1.0 cal/g

3.2.2 *calorimeter*—describes the bomb, the vessel with stirrer, and the water in which the bomb is immersed.

3.2.3 *energy equivalent*—the energy required to raise the temperature (see 3.2.3.1) of the calorimeter system 1 °C (or 1 °F) per gram of sample. This is the number that is multiplied by the corrected temperature rise in degrees and divided by the sample weight in grams to give the gross calorific value after thermochemical corrections have been applied.

3.2.3.1 *Discussion*—Temperature change is measured in thermal units. Temperature changes may also be recorded in electromotive force, ohms, or other units when other types of temperature sensors are used. Consistent units must be used in both the standardization and actual calorific determination. Time is expressed in minutes. Weights are measured in grams.

3.2.4 *gross calorific value*—the heat produced by combustion of a unit quantity of solid fuel, at constant volume, in an

¹ This test method is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.01 on Monitoring and Characterization.

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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.

³ The last approved version of this historical standard is referenced on www.astm.org.

oxygen bomb calorimeter under specified conditions such that all water in the products remains in liquid form.

3.2.5 *net calorific value*—a lower value calculated from the gross calorific value. It is equivalent to the heat produced by combustion of a unit quantity of solid fuel at a constant pressure of one atmosphere, under the assumption that all water in the products remains in the form of vapor.

3.2.6 *refuse-derived fuels*—solid forms of refuse-derived fuels from which appropriate analytical samples may be prepared are defined as follows in ASTM STP 832:⁴

RDF-1—Wastes used as a fuel in as-discarded form with only bulky wastes removed.

RDF-2—Wastes processed to coarse particle size with or without ferrous metal separation.

RDF-3—Combustible waste fraction processed to particle sizes, 95 % passing 2 in. square screening.

RDF-4—Combustible waste fraction processed into powder form, 95 % passing 10-mesh screening.

RDF-5—Combustible waste fraction densified (compressed) into the form of pellets, slugs, cubettes, or briquettes.

4. Summary of Test Method

4.1 Calorific value is determined in this method by burning a weighed analysis sample in an oxygen bomb calorimeter under controlled conditions. The calorific value is computed from temperature observations made before and after combustion, taking proper allowance for thermometer and thermochemical corrections. Either isothermal or adiabatic calorimeter jackets may be used.

5. Significance and Use

5.1 The calorific value, or heat of combustion, is a measure of the energy available from a fuel. Knowledge of this value is essential in assessing the commercial worth of the fuel and to provide the basis of contract between producer and user.

6. Apparatus

6.1 *Test Room*—The apparatus should be operated in a room or area free of drafts that can be kept at a reasonably uniform temperature and humidity for the time required for the determination. The apparatus should be shielded from direct sunlight and radiation from other sources. Controlled room temperature and humidity are highly desirable.

6.2 *Oxygen Bomb*, constructed of materials that are not affected by the combustion process or products sufficiently to introduce measurable heat input or alteration of end products. If the bomb is lined with platinum or gold, all openings shall be sealed to prevent combustion products from reaching the base metal. The bomb shall be designed so that all liquid combustion products can be completely recovered by washing the inner surfaces. There shall be no gas leakage during a test. The bomb shall be capable of withstanding a hydrostatic pressure test to 21 MPa (3000 psig) at room temperature without stressing any part beyond its elastic limit.

6.3 *Calorimeter*, made of metal (preferably copper or brass) with a tarnish-resistant coating and with all outer surfaces highly polished. Its size shall be such that the bomb will be completely immersed in water when the calorimeter is assembled. It shall have a device for stirring the water thoroughly and at a uniform rate, but with minimum heat input. Continuous stirring for 10 min shall not raise the calorimeter temperature more than 0.01 °C (0.02 °F) starting with identical temperatures in the calorimeter, room, and jacket. The immersed portion of the stirrer shall be coupled to the outside through a material of low heat conductivity.

6.4 *Jacket*—The calorimeter shall be completely enclosed within a stirred water jacket and supported so that its sides, top, and bottom are approximately 10 mm from the jacket walls. The jacket may be arranged so as to remain at constant temperature or with provisions for rapidly adjusting the jacket temperature to equal that of the calorimeter for adiabatic operation. It shall be constructed so that any water evaporating from the jacket will not condense on the calorimeter.

6.5 *Thermometers*—Temperatures in the calorimeter and jacket shall be measured with the following thermometers or combinations thereof:

6.5.1 *Beckmann Differential Thermometer*, having a range of approximately 6 °C in 0.01 °C subdivisions reading upward and conforming to the requirements for Thermometer 115 °C, as prescribed in Specification E1. Each of these thermometers shall be tested for accuracy against a known standard at intervals no larger than 1 °C over the entire graduated scale. The maximum difference between any two test points shall not be more than 0.02 °C.

6.5.2 *Calorimetric-Type Platinum Resistance Thermometer*, 25-, tested for accuracy against a known standard.

6.5.3 *Other Thermometers*—A high precision electronic thermometer employing balanced thermistors, or a quartz thermometer may be used, provided the temperature rise indication is accurate within ± 0.003 °C per 1 °C rise.

6.6 *Sample Holder*—Samples shall be burned in an open crucible of platinum, quartz, or acceptable base-metal alloy. Base-metal alloy crucibles are acceptable if after a few preliminary firings the weight does not change significantly between tasks.

6.7 *Firing Wire* shall be 100 mm of No. 34 B&S nickel-chromium alloy wire or 100 mm of No. 34 B&S iron wire. Equivalent platinum or palladium wire may be used provided constant ignition energy is supplied or measured, and appropriate corrections made.

6.8 *Firing Circuit*—A 6 to 16 V alternating or direct current is required for ignition purposes with an ammeter or pilot light in the circuit to indicate when current is flowing. A stepdown transformer connected to an alternating current lighting circuit or batteries may be used.

6.9 **CAUTION:** The ignition circuit switch shall be of momentary double-contact type, normally open, except when held closed by the operator. The switch should be depressed only long enough to fire the bomb.

⁴ *Thesaurus on Resource Recovery Terminology*, ASTM STP 832, ASTM International, 1983, p. 72.