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Standard Specification for Sintered Uranium Dioxide Pellets[1]

This standard is issued under the fixed designation C776; 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.

INTRODUCTION

This specification is intended to provide the nuclear industry with a general specification for uranium dioxide pellets. It recognizes the diversity of manufacturing methods by which uranium dioxide pellets are produced and the many special requirements for chemical and physical characterization which may be imposed by the operating conditions to which the pellets will be subjected in specific reactor systems. Therefore, it is anticipated that the purchaser may supplement this specification with additional requirements for specific applications.

1. Scope

1.1 This specification is for finished sintered uranium dioxide pellets. It applies to uranium dioxide pellets containing uranium of any ^{235}U concentration for use in nuclear reactors.

1.2 This specification recognizes the presence of reprocessed uranium in the fuel cycle and consequently defines isotopic limits for uranium dioxide pellets made from commercial grade UO_2. Such commercial grade UO_2 is defined so that, regarding fuel design and manufacture, the product is essentially equivalent to that made from unirradiated uranium. UO_2 falling outside these limits cannot necessarily be regarded as equivalent and may thus need special provisions at the fuel fabrication plant or in the fuel design.

1.3 This specification does not include *(a)* provisions for preventing criticality accidents or *(b)* requirements for health and safety. Observance of this specification does not relieve the user of the obligation to be aware of and conform to all federal, state, and local regulations pertaining to possessing, shipping, processing, or using source or special nuclear material. Examples of U.S. Government documents are Code of Federal Regulations (Latest Edition), Title 10, Part 50, Title 10, Part 71, and Title 49, Part 173.

1.4 The following precautionary caveat pertains only to the technical requirements portion, Section 4, of this specification: *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 or regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C696 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Uranium Dioxide Powders and Pellets

C753 Specification for Nuclear-Grade, Sinterable Uranium Dioxide Powder

C859 Terminology Relating to Nuclear Materials

C996 Specification for Uranium Hexafluoride Enriched to Less Than 5 % ^{235}U

C1233 Practice for Determining Equivalent Boron Contents of Nuclear Materials

E105 Practice for Probability Sampling of Materials

2.2 *ANSI Standard:*[3]

ANSI/ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications

2.3 *U.S. Government Documents:*

Code of Federal Regulations (Latest Edition), Title 10, Part 50, Energy (10 CFR 50) Domestic Licensing of Production and Utilization Facilities[4]

Code of Federal Regulations, Title 10, Part 71, Packaging and Transportation of Radioactive Material[4]

[1] This specification is under the jurisdiction of ASTM Committee C26 on Nuclear Fuel Cycle and is the direct responsibility of Subcommittee C26.02 on Fuel and Fertile Material Specifications.

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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] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

Code of Federal Regulations, Title 49, Part 173, General Requirements for Shipments and Packaging[4]

Regulatory Guide NUREG 1.126 An Acceptable Model and Related Statistical Methods for the Analysis of Fuel Densification, Rev. 1 March 1978[5]

3. Terminology

3.1 *Definitions*—For definitions of terms, refer to Terminology C859.

TABLE 1 Impurity Elements and Maximum Concentration Limits

Element	Maximum Concentration Limit (μg/g U)
Aluminum	250
Carbon	100
Calcium + magnesium	200
Chlorine	25
Chromium	250
Cobalt	100
Fluorine	15
Hydrogen (total from all sources)	1.3
Iron	500
Nickel	250
Nitrogen	75
Silicon	500
Thorium	10

4. Technical Requirements

4.1 *Chemical Requirements*—All chemical analyses shall be performed on portions of the representative sample prepared in accordance with Section 6. Analytical chemistry methods used shall be as stated in Test Methods C696 (latest edition) or demonstrated equivalent as mutually agreed upon between the seller and the buyer.

4.1.1 *Uranium Content*—The uranium content shall be a minimum of 87.7 weight % on a dry weight basis. (Dry weight is defined as the sample weight minus the moisture content.)

4.1.2 *Impurity Content*—The impurity content shall not exceed the individual element limit specified in Table 1 on a uranium weight basis. The summation of the contribution of each of the impurity elements listed in Table 1 shall not exceed 1500 μg/g. If an element analysis is reported as "less than" a given concentration, this "less than" value shall be used in the determination of total impurities.

4.1.3 *Stoichiometry*—The oxygen-to-uranium ratio of sintered fuel pellets shall be within the range from 1.99 to 2.02.

4.1.4 *Moisture Content*—The moisture content limit is included in the total hydrogen limit (see Table 1).

4.2 *Nuclear Requirements:*

4.2.1 *Isotopic Content:*

4.2.1.1 For UO_2 pellets with an isotopic content of ^{235}U between that of natural uranium and 5 %, the isotopic limits and radionuclide analytical requirements of Specification C996 shall apply, unless otherwise agreed upon between the buyer and the seller[6]. The specific isotopic measurements required by Specification C996 may be waived, provided that the seller can demonstrate compliance with Specification C996, for instance, through the seller's quality assurance records.

4.2.1.2 For UO_2 pellets not having an assay in the range set forth in 4.2.1.1, the isotopic requirements shall be as agreed upon between the buyer and the seller.

4.2.2 *Equivalent Boron Content*—For thermal reactor use, the total equivalent boron content (EBC) shall not exceed 4.0 μg/g on a uranium basis. The total EBC is the sum of the individual EBC values. For purpose of EBC calculation B, Gd, Eu, Dy, Sm, and Cd shall be included in addition to elements listed in Table 1 below. The method of performing the calculation shall be as indicated in Practice C1233. For fast reactor use, the above limitation on EBC does not apply.

4.3 *Physical Characteristics:*

4.3.1 *Dimensions*—The dimensions of the pellet shall be specified by the buyer. These shall include diameter, length, perpendicularity, and, as required, other geometric parameters including surface finish.

4.3.2 *Pellet Density*—The density of sintered pellets shall be as specified by the buyer. The theoretical density for UO_2 of natural isotopic content shall be considered as 10.96 g/cm^3. Density measurements shall be made by the geometric method stated in the Specification C753 Annex, an immersion method or by a demonstrated equivalent method as mutually agreed upon between the buyer and the seller.

4.3.3 *Grain Size and Pore Morphology*—The performance of UO_2 fuel pellets may be affected by the grain size and pore morphology. These characteristics shall be mutually agreed upon between the buyer and the seller.

4.3.4 *Pellet Integrity*—Pellets shall be inspected to criteria which maintain adequate fuel performance and ensure that excessive breakage will not occur during fuel-rod loading. Acceptable test methods include a visual (1×) comparison with pellet standards or other methods, for example, loadability tests, approved by both the buyer and the seller.

4.3.4.1 *Surface Cracks*—The suggested limits for surface cracks are defined as follows:

(1) Axial Cracks, including those leading to the Pellet Ends—½ the pellet length.

(2) Circumferential Cracks—⅓ of the pellet circumference.

4.3.4.2 *Chips*—The limits for chips (missing material) are as follows:

(1) Cylindrical Surface Chips

(a)*Cylindrical Surface Area*—the total area of all chips shall be less than 5 % of the pellet cylindrical surface area.

(b)*Maximum Linear Dimension*—the maximum linear dimension shall be established to maintain adequate fuel performance in the intended application and shall be agreed upon between the buyer and the seller.

[5] Available from U.S. Nuclear Regulatory Commission, Washington, DC 20555. Attention: Director, Division of Document Control.

[6] A ^{236}U content greater than the one specified in Specification C996 for Commercial grade UF_6 may be acceptable for the intended application since it is not a radiological safety concern. The intent of the C996 isotope limits is to indicate possible presence of reprocessed UF_6. Acceptance of UO_2 pellets with a ^{236}U content above that specified for Commercial Enriched UF_6, shall be based on a fuel performance evaluation.

(2) Pellet Ends—⅓ of the pellet end surface (may be inspected as ⅓ of missing circumference at the pellet end).

4.3.5 *Cleanliness and Workmanship*—The surface of finished pellets shall be visually free of macroscopic inclusions and foreign material such as oil and grinding media.

4.4 *Identification*—Pellets may be identified as to enrichment by either marking or coding.

4.5 *Irradiation Stability (Densification)*—An estimate of the fuel pellet irradiation stability shall be obtained (maximum densification anticipated) unless adequate allowance for such effects is factored into the fuel rod design. The estimation of the stability shall consist of either *(a)* conformance to the thermal stability test as specified in US NRC Regulatory Guide NUREG 1.126, or *(b)* by adequate correlation of manufacturing process or microstructure to in-reactor behavior, or both.

5. Lot Requirements

5.1 A pellet lot is defined as a group of pellets made from a single uranium dioxide powder lot as defined in Specification C753 using one set of process parameters.

5.2 The identity of a pellet lot shall be retained throughout processing without mixing with other established lots.

5.3 Conformance to this specification shall be established for each pellet lot.

6. Sampling

6.1 Uranium dioxide pellets may be hygroscopic and retain sufficient water after exposure to a moist atmosphere. Sampling and handling the sample shall be done under conditions which assure that the sample is representative of the lot. Practice E105 is referenced as a guide.

6.2 The buyer shall have the option to take a representative sample of pellets from each pellet lot for the purpose of determining chemical, nuclear, or physical properties.

6.3 The lot sample shall be of sufficient size to perform quality assurance testing at the seller's plant, referee testing in the event it becomes necessary, and, when required, acceptance testing at the buyer's plant.

6.4 The lot sample for acceptance testing at the buyer's plant, when required, shall be packaged in a separate container, clearly identified by lot number, and shipped preceding or with the lot. The referee sample shall be clearly identified and retained at the seller's plant until the lot has been formally accepted by the buyer.

7. Testing and Certification

7.1 The seller shall test the sample described in Section 6 to assure conformance of the pellet lot to the requirements of Section 4. All testing shall be conducted by techniques mutually agreed to between the buyer and the seller.

7.2 The seller shall provide to the buyer documentation certifying that the pellets meet all the requirements of Section 4.

7.3 For a time period to be agreed upon by the buyer and the seller, the seller shall maintain and make available upon request all results used to certify that pellets meet the requirements of Section 4.

7.4 *Lot Acceptance*—Acceptance testing may be performed by the buyer on either the sample provided by the seller or on a sample taken at the buyer's plant. Acceptance shall be on a pellet lot basis and shall be contingent upon the material properties meeting the requirements of Section 4 as modified by contract documentation.

7.5 *Referee*—The buyer and seller shall agree to a third party as a referee in the event of a dispute in analytical results.

8. Packaging and Shipping

8.1 Uranium dioxide pellets shall be packaged in sealed containers to prevent loss or damage of material and contamination from airborne or container materials. The exact size and type of packaging shall be as mutually agreed upon between the buyer and the seller.

8.2 Each container in 8.1 shall bear labels on the lid and side that include the required to satisfy the appropriate transportation and regulatory requirements, including as a minimum the following:

8.2.1 Seller's name,
8.2.2 Material in container,
8.2.3 Lot number,
8.2.4 Uranium enrichment,
8.2.5 Gross, tare, net oxide weights,
8.2.6 Uranium weight,
8.2.7 Purchase order number, and
8.2.8 Container ( ) of ( ).

9. Quality Assurance

9.1 Quality assurance requirements shall be agreed upon between the buyer and the seller when specified in the purchase order. Code of Federal Regulations Title 10, Part 50, Appendix B and ANSI/ASME NQA-1 are referenced as guides.

10. Keywords

10.1 nuclear fuel; nuclear fuel pellets; urania; uranium dioxide

APPENDIX

(Nonmandatory Information)

X1. PELLET LOADABILITY TEST

X1.1 Randomly selected samples (the number of samples to be established by statistical considerations) shall be subjected to an axial load representative of fuel rod loading conditions at the fabrication plant. Each test sample shall consist of ten finished pellets. Samples shall be subjected to an axial load that is 125 % of the maximum load applied during pellet loading without producing a chip with a maximum linear dimension in excess of that agreed upon between the buyer and seller.