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## Standard Specification for Nuclear-Grade, Sinterable Uranium Dioxide Powder<sup>1</sup>

This standard is issued under the fixed designation C 753; 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 ( $\epsilon$ ) 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 sinterable uranium dioxide powder. It recognizes the diversity of manufacturing methods by which uranium dioxide powders are produced and the many special requirements for chemical and physical characterization which may be imposed by the end use of the powder in a specific reactor system. It is, therefore, anticipated that the buyer may supplement this specification with additional requirements for specific applications.

### 1. Scope

1.1 This specification covers nuclear-grade, sinterable uranium dioxide ( $UO_2$ ) powder. It applies to uranium dioxide powder containing uranium of any  $^{235}U$  concentration for use in nuclear reactors. ~~U concentration in the production of nuclear fuel pellets 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 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 unreprocessed 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 provisions for preventing criticality accidents or 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 international, national, or federal, state, and local regulations pertaining to possessing, shipping, processing, or using source or special nuclear material.

~~1.4 Special tests and procedures are given in Annex A1.~~

~~1.5 This specification refers expressly to  $UO$~~

1.4 This specification refers expressly to calcined  $UO_2$  powder before the addition of any die lubricant, binder, or pore former. If powder is sold with such additions or prepared as press feed, sampling procedures or, allowable impurity contents, or both, powder physical requirements may need to be modified by agreement between the buyer and the seller.

~~1.6 1.5 The following safety hazards caveat pertains to the test methods portion in the annexes 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 of regulatory limitations requirements prior to use.~~

### 2. Referenced Documents

2.1 ASTM Standards:<sup>2</sup>

B 329 Test Method for Apparent Density of Metal Powders of Refractory Metals and Compounds by Using the Scott Volumeter

C 696 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Uranium Dioxide Powders and Pellets

C 859 Terminology Relating to Nuclear Materials

C 996 Specification for Uranium Hexafluoride Enriched to Less than 5% Than 5%  $^{235}U$

C 1233 Practice for Determining Equivalent Boron Contents of Nuclear Materials

E 11 Specification for Wire Cloth Sieves for Testing Purposes Specification for Woven Wire Test Sieve Cloth and Test Sieves

E 105 Practice for Probability Sampling of Materials

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee E-26-C26 on Nuclear Fuel Cycle and is the direct responsibility of Subcommittee C26.02 on Fuel and Fertile Material Specifications.

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<sup>2</sup> 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, Vol 02.05, volume information, refer to the standard's Document Summary page on the ASTM website.

2.2 *ANSI Standard:*

~~ANSI/ASME NQA-1 Quality Assurance Program Requirements for Nuclear Facilities~~<sup>3</sup>  
ANSI/ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications

2.3 *Federal Regulation:*<sup>4</sup>

Code of Federal Regulations, Title 10, Chapter 1, Nuclear Regulatory Commission, Applicable Parts

**3. Terminology**

3.1 *Definitions*—Definitions of terms are as given in Terminology C 859.

**4. Chemical Requirements**

4.1 *Uranium Content*— The uranium content shall be determined on a basis to be agreed upon between the buyer and seller.

4.2 *Oxygen-to-Uranium Ratio (O/U)* —The O/U ratio may be specified as agreed upon between the buyer and seller. The determination of the O/U ratio shall be in accordance with Test Methods C 696 or a demonstrated equivalent.

4.3 *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/gU. 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. 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.

~~4.4 *Moisture Content*— The moisture content shall not exceed 0.40 g/100 g uranium dioxide (UO<sub>2</sub>). — The moisture content shall not exceed 0.40 weight percent of the powder.~~

4.5 *Isotopic Content:*

4.5.1 For UO<sub>2</sub> powder with an isotopic content of <sup>235</sup>U between that of natural uranium and 5 %, the isotopic limits of Specification C 996 shall apply, unless otherwise agreed upon between the buyer and the seller. ~~If the <sup>236</sup>U content is greater than enriched commercial grade UF<sub>6</sub>~~ <sup>U content is greater than Enriched Commercial Grade UF<sub>6</sub></sup> requirements, the isotopic analysis requirements of Specification C 996 shall apply. The specific isotopic measurements required by Specification C 996 may be waived, provided that the seller can demonstrate compliance with Specification C 996, for instance, through the seller’s quality assurance records. ~~A <sup>236</sup>U content greater than one that~~ <sup>A <sup>236</sup>U content greater than one that</sup> specified in C 996 for ~~Enriched Commercial grade~~ <sup>Grade</sup> UF<sub>6</sub> may be agreed between the buyer and the seller since it is not a safety concern.<sup>5</sup>

<sup>3</sup>Annual Book of ASTM Standards, Vol 12.01.

<sup>3</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

<sup>4</sup>Annual Book of ASTM Standards, Vol 14.02.

<sup>4</sup> Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://www.dodssp.daps.mil>.

<sup>5</sup> Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

<sup>5</sup> The intent of the C 996 isotope limits is to indicate possible presence of reprocessed UF<sub>6</sub>. Acceptance of UO<sub>2</sub> pellets with <sup>236</sup>U content above that specified for Enriched Commercial Grade UF<sub>6</sub> shall be based on fuel performance evaluation.

**TABLE 1 Impurity Elements and Maximum Concentration Limits**

Element	Maximum Concentration Limit of Uranium, µg/gU
Aluminum	250
Carbon	100
Calcium + magnesium	200
Chlorine	100
Chromium	200
Cobalt	100
Copper	250
Fluorine	100
Iron	250
Lead	250
Manganese	250
Molybdenum	250
Nickel	200
Nitrogen	200
Phosphorus	250
Silicon	300
Tantalum	250
<del>Thorium<sup>A</sup></del>	<del>10</del>
Thorium <sup>A</sup>	10
Tin	250
Titanium	250
Tungsten	250
Vanadium	250
Zinc	250

<sup>A</sup> Thorium is primarily of concern because of the reactor production of <sup>233</sup>U.

4.5.2 For  $\text{UO}_2$  powder, not having an assay in the range set forth in 4.5.1, the isotopic requirements shall be as agreed upon between the buyer and the seller.

4.6 *Equivalent Boron Content*—For thermal reactor use, the total equivalent boron content (EBC) shall not exceed  $4.0 \mu\text{g/g}$  on a uranium weight basis. For purpose of EBC calculation B, Gd, Eu, Dy, Sm, and Cd shall be included in addition to elements listed in Table 1. The method of performing the calculation shall be as indicated in Practice C 1233. For fast reactor use, the above limitation on EBC does not apply.

4.7 *Cleanliness and Workmanship*—The powder shall be visually free of foreign material such as metallic particles and oil.

## 5. Physical Requirements

5.1 *Particle Size*—Based on visual observation, all of a representative sample of the  $\text{UO}_2$  shall pass through a  $425\text{-}\mu\text{m}$  (No. 40) standard sieve conforming to Specification E 11. Particle size distribution and method of determination shall be as agreed upon between the buyer and seller. Alternatively, as agreed upon between the buyer and the seller, the fraction not passing through a  $425\text{-}\mu\text{m}$  (No. 40) standard sieve shall be reported to the buyer.

5.2 *Bulk Density*—The bulk density of  $\text{UO}_2$  powder will depend on the processing method. Unless otherwise agreed upon between the buyer and seller, the bulk density shall be a minimum of  $0.625 \text{ kg/m}^3$  as determined by Test Method B 329, or an agreed upon alternative.

NOTE 1—For powder prepared as a press feed, a minimum bulk density of  $1.8 \text{ g/cm}^3$  is recommended.

5.3 *Sinterability*—Test pellets shall be produced and measured in accordance with a sintering performance test agreed upon between the buyer and seller. A sinterability performance test described in ~~Annex A1~~ Appendix X1 is presented as a guide.

## 6. Lot Requirements

### 6. Sampling

6.1 A lot is defined as a quantity of  $\text{UO}_2$  powder that is uniform in isotopic, chemical, physical, and sinterability characteristics.

~~6.2 The identity of a lot shall be retained throughout.~~

6.2 The identity of a lot shall be retained throughout its processing history.

6.3 A powder lot shall form the basis for defining sampling plans used to establish conformance to this specification.

~~6.4 Sampling plans and procedures shall be mutually agreed upon by the buyer and the seller. A suggested sampling procedure is given in Annex A2.~~

6.4 Sampling plans and procedures shall be mutually agreed upon by the buyer and the seller. Analytical confirmation of sampling plans shall be documented as part of the manufacturer's quality assurance and nuclear materials control and accountability program.

6.5  $\text{UO}_2$  may be hygroscopic and retain sufficient water after exposure to a moist atmosphere to cause detectable errors. Sample, weigh, and handle the sample under conditions that will ensure that the sample is representative of the lot.

### 7. Test Methods

~~7.1 The seller shall test the sample obtained per Annex A2 to ensure conformance of the powder to the requirements of Sections 4 and 5.~~

~~7.1.1 All chemical analyses shall be performed on portions of the representative sample prepared in accordance with Annex A2-sample. Analytical chemistry methods used shall be in accordance with Test Methods C 696 or demonstrated equivalent methods agreed upon between the buyer and seller.~~

7.2 *Lot Acceptance*—Acceptance testing may be performed by the buyer on either the sample provided by the seller or a sample taken at the buyer's plant by sampling one or more individual containers with a thief. Practice E 105 is referenced as a guide. Acceptance shall be on a lot basis and shall be contingent upon the material properties meeting the requirements of Sections 4 through 6.

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

### 8. Certification

8.1 The seller shall provide to the buyer documents certifying:

8.1.1 The isotopic content and identity of the starting material lot and

8.1.2 That the powder meets all the requirements of Sections 4 through 6.

8.2 Test data on the following characteristics shall be supplied upon request:

8.2.1 Uranium isotopic content,

8.2.2 Uranium content,

8.2.3 Individual impurity levels,

8.2.4 Moisture content,

8.2.5 Sinterability test results,

8.2.6 O/U ratio,