



Designation: C 922 – 00

## Standard Specification for Sintered Gadolinium Oxide-Uranium Dioxide Pellets<sup>1</sup>

This standard is issued under the fixed designation C 922; 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

### INTRODUCTION

This specification is intended to provide the nuclear industry with a general specification for gadolinium oxide-uranium dioxide pellets. It recognizes the diversity of manufacturing methods by which gadolinium oxide-uranium dioxide pellets are produced and the many special requirements for chemical and physical characterization that 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 gadolinium oxide-uranium dioxide pellets for use in light-water reactors. It applies to gadolinium oxide-uranium dioxide pellets containing uranium of any  $^{235}\text{U}$  concentration and any concentration of gadolinium oxide.

1.2 This specification recognizes the presence of reprocessed uranium in the fuel cycle and consequently defines isotopic limits for gadolinium oxide-uranium dioxide pellets made from commercial grade  $\text{UO}_2$ . Such commercial grade  $\text{UO}_2$  is defined so that, regarding fuel design and manufacture, the product is essentially equivalent to that made from unprocessed uranium.  $\text{UO}_2$  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 (1) provisions for preventing criticality accidents or (2) 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, federal, state, and local regulations pertaining to possessing, shipping, processing, or using source or special nuclear material. Examples of U.S. Governmental 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 of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- C 696 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Uranium Dioxide Powders and Pellets<sup>2</sup>
- C 753 Specification for Nuclear-Grade, Sinterable Uranium Dioxide Powder<sup>2</sup>
- C 859 Terminology Relating to Nuclear Materials<sup>2</sup>
- C 888 Specification for Nuclear-Grade Gadolinium Oxide ( $\text{Gd}_2\text{O}_3$ ) Powder<sup>2</sup>
- C 968 Test Methods for Analysis of Sintered Gadolinium Oxide-Uranium Dioxide Pellets<sup>2</sup>
- C 996 Specification for Uranium Hexafluoride Enriched to Less than 5 %  $^{235}\text{U}$ <sup>2</sup>
- C 1233 Practice for Determining the Equivalent Boron Content of Nuclear Materials<sup>2</sup>
- E 105 Practice for Probability Sampling of Materials<sup>3</sup>

#### 2.2 ANSI Standard:

- NQA-1 Quality Assurance Program Requirements for Nuclear Facilities<sup>4</sup>

#### 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<sup>5</sup>
- Code of Federal Regulations, Title 10, Part 71, Packaging

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee C-26 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> Annual Book of ASTM Standards, Vol 12.01.

<sup>3</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>4</sup> Available from the American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

<sup>5</sup> Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

and Transportation of Radioactive Material<sup>5</sup>  
Code of Federal Regulations, Title 49, Part 173, General  
Requirements for Shipments and Packaging<sup>5</sup>  
Regulatory Guide NUREG 1.126, An Acceptable Model  
and Related Statistical Methods for the Analysis of Fuel  
Densification, Rev. 1 March 1978<sup>6</sup>

### 3. Terminology

3.1 *Definitions*—For definitions of terms, refer to Terminology C 859.

### 4. Technical Requirements

4.1 *Major Constituents*—Gadolinium oxide-uranium dioxide pellets shall be fabricated using major constituents that meet the requirements of Specifications C 753 and C 888.

4.2 *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 C 968 (latest edition) or demonstrated equivalent as mutually agreed to between the seller and the buyer.

4.2.1 *Impurity Content*—The impurity content shall not exceed the individual element limit specified in Table 1 on a

**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
Fluorine	15
Hydrogen (total from all sources)	1.3
Iron	500
Nickel	250
Nitrogen	75
Silicon	500
Thorium	10

uranium weight basis. The summation of the contribution of each of the impurity elements listed in Table 1 shall not exceed 1500 µg/g U. 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. The thorium measurements required by Table 1 may be waived, provided that the seller can otherwise demonstrate compliance with this specification, for instance, through the seller’s quality assurance records.

4.2.2 *Stoichiometry*—The oxygen-to-metal ratio of sintered fuel pellets shall be within the range from 1.98 to 2.02.

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

4.2.4 *Gd<sub>2</sub>O<sub>3</sub> Concentration*—The gadolinium oxide (Gd<sub>2</sub>O<sub>3</sub>) concentration shall be as specified in the purchase order.

#### 4.3 Nuclear Requirements:

##### 4.3.1 Isotopic Content:

For (U,Gd)O<sub>2</sub> pellets 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> 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 otherwise demonstrate compliance with Specification C 996, for instance, through the seller’s quality assurance records.<sup>236</sup>U content greater than one specified in Specification C 996 for Commercial grade UF<sub>6</sub> may be agreed between the buyer and the seller since it is not a safety concern.<sup>7</sup>

4.3.2 For (U,Gd)O<sub>2</sub> pellets not having an assay in the range set forth in 4.3.1, the isotopic requirements shall be as agreed upon between the buyer and the seller.

##### 4.4 Physical Characteristics:

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

4.4.2 *Pellet Density*—The density of sintered pellets shall be as specified by the buyer. The theoretical density for UO<sub>2</sub> of natural isotopic content shall be considered to be 10.96 g/cm<sup>3</sup>. The theoretical density for the (U,Gd)O<sub>2</sub> shall be determined as agreed upon between the buyer and the seller.<sup>8</sup> Density measurements shall be made by the method stated in Specification C 753 for the geometric method, an immersion density technique, or by a demonstrated equivalent method as mutually agreed upon between the buyer and the seller.

4.4.3 *Grain Size and Pore Morphology*—The behavior of gadolinium oxide-uranium dioxide 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.

4.4.4 *Pellet Homogeneity*—The homogeneity of Gd<sub>2</sub>O<sub>3</sub> in UO<sub>2</sub> shall be determined for the sintered pellets by a procedure and to a standard and specification mutually agreed upon between the buyer and the seller. The characteristics to be measured in order to verify this homogeneity (for instance, the fractions of Gd<sub>2</sub>O<sub>3</sub>, UO<sub>2</sub>, and UO<sub>2</sub>/Gd<sub>2</sub>O<sub>3</sub> solid solution regions, or the maximum particle size of Gd<sub>2</sub>O<sub>3</sub> and UO<sub>2</sub> particles, or some combination there of, or any other characteristic representative of the homogeneity of the pellets) shall be defined by agreement between the buyer and the seller, and their values shall be as specified.

4.4.5 *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

<sup>7</sup> The intent of the C 996 isotopic limits is to indicate possible presence of reprocessed UF<sub>6</sub>. Acceptance of (U,Gd)O<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.

<sup>8</sup> X-ray diffraction studies may be used to establish the theoretical density of (U,Gd)O<sub>2</sub>. In lieu of x-ray diffraction data, the theoretical density of the (U,Gd)O<sub>2</sub> pellets is often taken as the molar interpolation of the values for UO<sub>2</sub> and Gd<sub>2</sub>O<sub>3</sub>. Both 8.33 g/cc and 7.41 g/cc values for the density of Gd<sub>2</sub>O<sub>3</sub> have been used for this interpolation.

<sup>6</sup> Available form U.S. Nuclear Regulatory Commission, Washington, DC 20555. Attention: Director, Division of Document Control.