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Standard Specification for Sintered (Uranium-Plutonium) Dioxide Pellets[1]

This standard is issued under the fixed designation C 833; 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 standard for uranium-plutonium dioxide pellets for thermal reactor use. It recognizes the diversity of manufacturing methods by which uranium-plutonium 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. It does not recognize the possible problems associated with the reprocessing of such pellets. It is, therefore, anticipated that the purchaser may supplement this specification with additional requirements for specific applications.

1. Scope

1.1 This specification covers finished sintered and ground (uranium-plutonium) dioxide pellets for use in thermal reactors. It applies to uranium-plutonium dioxide pellets containing plutonium additions up to 15 % weight. This specification may not completely cover the requirements for pellets fabricated from weapons-derived plutonium.

1.2 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 applicable international, federal, state, and local regulations pertaining to possessing, processing, shipping, or using source or special nuclear material. Examples of U.S. government documents are Code of Federal Regulations Title 10, Part 50~~—~~—Domestic Licensing of Production and Utilization Facilities; Code of Federal Regulations Title 10, Part 71~~—~~—Packaging and Transportation of Radioactive Material; and Code of Federal Regulations Title 49, Part 173~~—~~—General Requirements for Shipments and Packaging.

1.3 The following safety hazards 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.*

~~1.4The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.~~

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 698 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Mixed Oxides ((U, Pu)O_2)

C 753 Specification for Nuclear-Grade, Sinterable Uranium Dioxide Powder

C 757 Specification for Nuclear-Grade Plutonium Dioxide Powder, Sinterable

C 859 Terminology Relating to Nuclear Materials

C 1165 Test Method for Determining Plutonium by Controlled-Potential Coulometry in H $_2SO_4$ ~~At~~at a Platinum Working Electrode

C 1204 Test Method for Uranium in ~~the~~ Presence of Plutonium by Iron(II) Reduction in Phosphoric Acid Followed by Chromium(VI) Titration

C 1206 Test Method for Plutonium by Iron (II)/Chromium (VI) Amperometric Titration

C 1233 Practice for Determining Equivalent Boron Contents of Nuclear ~~Material~~[2]Materials

[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* ~~, Vol 12.01.~~volume information, refer to the standard's Document Summary page on the ASTM website.

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2.2 *ANSI Standard:*[3]

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

2.3 *U.S. Government Documents:*[4]

USNRC Regulatory Guide 1.126 An Acceptable Model and Related Statistical Methods for the Analysis of Fuel Densification

Code of Federal Regulations Title 10, Part 50 Domestic Licensing of Production and Utilization Facilities

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

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

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology C 859.

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 shall be as stated in Test Methods C 698 (latest edition) or demonstrated equivalent as mutually agreed to between the buyer and the seller.

4.1.1 *Uranium and Plutonium Content* —Unless agreed upon by the buyer and seller, individual powders shall meet the requirements of Specifications C 753 and C 757, which also reference Test Methods C 1165, C 1204, and C 1206. The uranium and plutonium contents combined shall be a minimum of 87.7 % weight on a dry weight basis compensated for the Am-241 content. (Dry weight is defined as the sample weight minus the moisture content). The plutonium content shall be that specified by the buyer, up to the limits covered in this specification (15%).

4.1.2 *Impurity Content*— The impurity content shall not exceed the individual element limit specified in Table 1 based on the heavy metal content (uranium plus plutonium). The summation of the contribution of each of the impurity elements listed in Table 1 shall not exceed 1500 µg/g (U + P). 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.

NOTE 1—Higher impurity limits should be acceptable for restricted burnups and linear power ratings if there is evidence to substantiate the relaxation. Higher impurity levels of 450 ppm aluminum, 250 ppm carbon, 250 ppm nitrogen, and 450 ppm silicon have been supported for burnups of less than 35 000 MWd/t. The extension of the burnup limit may be determined by agreement between the buyer and seller as supporting data are accumulated.

4.1.3 *Stoichiometry*— The oxygen-to-heavy metal ratio of sintered fuel pellets shall be within the range from 1.98 to 2.02. The nominal value and allowable tolerance shall be agreed upon between the buyer and seller.

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

4.1.5 *Gas Content*— The gas content, exclusive of moisture, shall not exceed, at Standard Temperature and Pressure (0°C and one atmosphere), 0.05 L/kg of the heavy metal content.

4.1.6 *Americium-241 Content*—The americium-241 content shall be measured by the seller and reported to the buyer. The americium-241 content or activity is important in the handling of UO_2-PuO_2 pellets and will vary with time. The maximum acceptable americium-241 content on a given date along with the date of analysis shall be agreed upon between the buyer and

[3] ~~Annual Book of ASTM Standards, Vol 14.02.~~

[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 American National Standards Institute, 25 West 43rd St., 4th Floor, New York, NY 10036.~~

[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.

TABLE 1 Impurity Elements and Maximum Concentration Limits

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

seller. The dates of separation of plutonium from this isotope and the analysis dates shall be considered; methods of reporting shall be agreed upon between the buyer and seller.

4.2 *Nuclear Requirements*:

4.2.1 *Isotopic Content*— The isotopic content of the americium, uranium, and plutonium in the (uranium-plutonium) dioxide pellets shall be determined and the date of the determination recorded. The ^{234}U, ^{235}U, ^{236}U, and ^{238}U content of the uranium shall be reported as a mass percentage with respect to total uranium, and the ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, and ^{242}Pu content of the plutonium shall be reported on a Pu mass % or on (Pu + Am) mass % basis. The equivalent plutonium content based on uranium and plutonium isotopic concentrations shall be as agreed upon between the buyer and seller.

4.2.2 *Plutonium Equivalent at a Given Date*—(uranium-plutonium) dioxide fuel shall be considered as defined by the plutonium content with adjustment (credit or debit) for the actual isotopic composition of plutonium, americium, and uranium. The dates of isotopic analyses in support of these determinations shall be recorded by the seller and reported to the buyer. The allowable tolerances tolerances of the plutonium equivalent content (either as uranium plus plutonium or as the individual elements) shall be as agreed upon between the buyer and seller.

4.2.3 *Equivalent Boron Content*—For thermal reactor use, the total equivalent boron content (EBC) shall not exceed 4.0 μg/g on a heavy metal basis. The method of performing the calculation shall be as indicated in Practice C 1233. For the purposes of EBC calculation, B, Gd, Eu, Dy, Sm, and Cd shall be included.

4.2.4 *Reactivity*—An integral test of reactivity may be performed and correlated to total EBC by a method agreed upon between the buyer and the seller. If this is done, a total EBC need not be determined.

4.3 *Physical Characteristics*:

4.3.1 *Dimensions*—The dimensions and their tolerances 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 and tolerance of sintered pellets shall be as specified by the buyer. The theoretical density for UO_2 shall be considered to be 10.96 g/cm^3. The theoretical density for PuO_2 shall be considered to be 11.46 g/cm^3. The theoretical density for the (U, Pu)O_2 pellets shall be calculated by linear interpolation between these values. Density measurements shall be made by the method stated in Specification C 753 (for the geometric method) by an immersion density technique, or by demonstrated equivalent method as mutually agreed upon between the buyer and the seller.

4.3.3 *Grain Size and Pore Morphology* —Because there is no unique structure for ensuring satisfactory performance, the pellet grain size and pore morphology shall be mutually agreed upon between the buyer and the seller.

4.3.4 *Plutonium-Oxide Homogeneity and Size*:

4.3.4.1 *Plutonium Homogeneity Within a Pellet Lot*—Homogeneity of the Pu content shall be demonstrated through analyses of multiple pellets. Each sample for analysis should be one pellet or a fragment thereof. The range of the equivalent Pu content shall not exceed ±5.0% relative or ±0.2% absolute, whichever is less restrictive. Alternative methods and criteria that may be agreed upon between the buyer and the seller are possible for evaluation of plutonium homogeneity within a lot.

4.3.4.2 *Plutonium-Oxide Particle Size and Distribution Within a Pellet*—The maximum equivalent diameter of Pu-rich particles shall be less than 400 μm. The distribution of Pu-rich particles shall satisfy either of the following requirements: (a) No more than 5 % of the nominal PuO_2 shall be present in Pu-rich particles with equivalent diameters of 200 μm or greater, or (b) No more than 5 % of the Pu-rich particles shall be greater than 100 μm in diameter and the average diameter of Pu-rich particles will be less than 50 μm. The method for determining the Pu homogeneity and what constitutes a Pu-rich particle shall be agreed upon between the buyer and seller. The area percentage and the volume percentage shall be regarded as equivalent provided the homogeneity requirements of ~~4.3.4.1~~ 4.3.4.1 are satisfied.

NOTE 2—These limits are based on PuO_2 that has a nominal 65% fissle plutonium content. Smaller particle size may be required for greater fissle plutonium content.

4.3.5 *Pellet Integrity*— Pellets shall be inspected according 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 (1X) comparison with pellet standards or other methods, for example, loadability tests, approved by both the buyer and the seller.

4.3.5.1 *Surface Cracks*— The limits for surface cracks are as follows:

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

(*2*) *Circumferential Cracks*—1/23 of the pellet circumference.

4.3.5.2 *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*—30 % of the pellet length.

(*2*) *Pellet Ends*—1/3 of the pellet end surfaces (may be inspected as 1/3 of the missing circumference at the pellet end).

4.3.6 *Cleanliness and Workmanship* —The surfaces of finished pellets shall be visually (1X) free of loose chips, oil, macroscopic inclusions, and foreign materials.

4.4 *Identification*— It shall be possible to identify pellets as to total fissile and total plutonium content by, for example, marking or coding or other administrative controls. Other identification can be used (for example, total plutonium and "reference date").

4.5 *Irradiation Stability (Densification)* —An estimate of the fuel pellet irradiation stability shall be obtained unless adequate