Designation: C 776 – 00

Standard Specification for Sintered Uranium Dioxide Pellets[1]

This standard is issued under the fixed designation C 776; 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 ^{234}U concentration for use in nuclear reactors.

1.2 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.

1.3 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:*

C 696 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Uranium Dioxide Powders and Pellets[2]

C 753 Specification for Nuclear-Grade, Sinterable Uranium Dioxide Powder[2]

C 859 Terminology Relating to Nuclear Materials[2]

C 996 Specification for Uranium Hexafluoride Enriched to Less than 5 % ^{235}U[2]

C 1233 Practice for Determining the Equivalent Boron Content of Nuclear Materials[2]

E 105 Practice for Probability Sampling of Materials[3]

2.2 *ANSI Standard:*[4]

NQA-1 Quality Assurance Program Requirements for Nuclear Facilities

2.3 *U.S. Government Documents:*

Code of Federal Regulations, Title 10, Part 50, Energy (10 CFR 50) Domestic Licensing of Production and Utilization Facilities[5]

Code of Federal Regulations, Title 10, Part 71, Packaging and Transportation of Radioactive Material[5]

Code of Federal Regulations, Title 49, Part 173, General Requirements for Shipments and Packaging[5]

3. Terminology

3.1 *Definitions*—For definitions of terms, refer to 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 used shall be as stated in Test Methods C 696 (latest edition) or demonstrated equivalent as mutually agreed upon between the seller and the buyer.

[1] 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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[2] *Annual Book of ASTM Standards*, Vol 12.01.

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

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[5] Available from Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.

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 of Specification C 996 shall apply, unless otherwise agreed upon between the buyer and the seller. If the ^{236}U content is greater than enriched commercial grade UF_6 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.^{236}U content greater than one specified in Specification C 996 for Commercial grade UF_6 may be agreed between the buyer and the seller since it is not a safety concern.[6]

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 C 1233. For fast reactor use, the above limitation on EBC does not apply. The EBC of each element shall be calculated individually using the following equation:

$$\text{EBC of element} = (\text{EBC factor}) \times (\mu\text{g element/g uranium}) \quad (1)$$

[6] The intent of the C 996 isotope limits is to indicate possible presence of reprocessed UF_6. Acceptance of UO_2 pellets with ^{236}U content above that specified for Commercial Enriched UF_6, shall be based on fuel performance evaluation.

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

4.3 *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 C 753 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 is affected by their 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*—30% of the pellet length.

(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 shall 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 estimate of the stability shall consist of either *(a)* conformance to the thermal stability test as specified in US NUREG 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 C 753 using one set of process parameters.