



Designation: C996 – 20

Standard Specification for Uranium Hexafluoride Enriched to Less Than 5 % ²³⁵U¹

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1. Scope

1.1 This specification covers nuclear grade uranium hexafluoride (UF₆) that either has been processed through an enrichment plant or has been produced by the blending of Highly Enriched Uranium with other uranium to obtain uranium of any ²³⁵U concentration below 5 % and that is intended for fuel fabrication. The objectives of this specification are twofold: (1) to define the impurity and uranium isotope limits for Enriched Commercial Grade UF₆ so that, with respect to fuel design and manufacture, it is essentially equivalent to enriched uranium made from natural UF₆, and (2) to define limits for Enriched Reprocessed UF₆ to be expected if Reprocessed UF₆ is to be enriched without dilution with Commercial Natural UF₆. For such UF₆, special provisions, not defined herein, may be needed to ensure fuel performance and to protect the work force, process equipment, and the environment.

1.2 This specification is intended to provide the nuclear industry with a standard for enriched UF₆ that is to be used in the production of sinterable UO₂ powder for fuel fabrication. In addition to this specification, the parties concerned may agree to other appropriate conditions.

1.3 The scope of this specification does not comprehensively cover all provisions for preventing criticality accidents or requirements for health and safety or for shipping. Observance of this specification does not relieve the user of the obligation to conform to all applicable international, federal, state, and local regulations for processing, shipping, or in any other way using UF₆ (see, for example, TID-7016, DP-532, and DOE O474.1).

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

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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1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

C761 Test Methods for Chemical, Mass Spectrometric, Spectrochemical, Nuclear, and Radiochemical Analysis of Uranium Hexafluoride

C787 Specification for Uranium Hexafluoride for Enrichment

C859 Terminology Relating to Nuclear Materials

C1052 Practice for Bulk Sampling of Liquid Uranium Hexafluoride

C1883 Practice for Sampling of Gaseous Enriched Uranium Hexafluoride

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 ANSI/ASME Standards:³

ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications

ANSI N14.1 Nuclear Materials—Uranium Hexafluoride—Packaging for Transport

2.3 U.S. Government Documents:⁴

ORO-671-1 Inspection, Weighing, and Sampling of Uranium Hexafluoride Cylinders, Procedure for Handling and Analysis of Uranium Hexafluoride, Vol 1, latest revision

TID-7016 Nuclear Safety Guide, Rev. 2

DP-532 Handbook of Nuclear Safety

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 Accountability Office (GAO), 441 G St., NW, Washington, DC 20548, <http://www.gao.gov>.

10 CFR 50 Code of Federal Regulations, Title 10, Part 50, (Appendix B)

2.4 Other Document:

USEC-651 The UF₆ Manual: Good Handling Practices for Uranium Hexafluoride United States Enrichment Corporation Report, latest revision⁵

3. Terminology

3.1 Definitions:

3.1.1 Terms shall be defined in accordance with Terminology C859, except for the terms listed below.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 Commercial Natural UF₆, *n*—UF₆ from natural unirradiated uranium (containing 0.711 ± 0.004 g ²³⁵U per 100 gU).

3.2.1.1 Discussion—It is recognized that some contamination with reprocessed uranium may occur during routine processing. This is acceptable provided that the UF₆ meets the requirements for Commercial Natural UF₆ as specified in Specification C787.

3.2.2 Derived Enriched UF₆, *n*—any UF₆ obtained from the blending of Highly Enriched Uranium with any other uranium.

3.2.3 Enriched Commercial Grade UF₆, *n*—UF₆ enriched from Commercial Natural UF₆ or Derived Enriched UF₆ that meets the specification limits for Enriched Commercial Grade UF₆.

3.2.4 Enriched Reprocessed UF₆, *n*—UF₆ enriched from Reprocessed UF₆, any mixture of Reprocessed UF₆ and Commercial Natural UF₆ or Derived Enriched UF₆, exceeding the applicable limits of Sections 4 and 5 for Enriched Commercial Grade UF₆. The wide range of irradiation levels, cooling times, reprocessing, conversion, and enrichment processes, and fuel cycle choices for combination with unirradiated UF₆, together with the varying acceptance limits of different fuel fabrication facilities, make it not practical to specify the exact radionuclide composition of Enriched Reprocessed UF₆.

3.2.5 Highly Enriched Uranium, *n*—any form of uranium having a ²³⁵U content of 20 % or greater.

3.2.6 Reprocessed UF₆, *n*—any UF₆ made from uranium that has been exposed in a neutron irradiation facility and subsequently chemically separated from the fission products and transuranic isotopes so generated.

3.3 For enriched UF₆ transactions, “buyer” usually represents the electric power utility company or the fuel fabricator, and “seller” usually represents the isotopic enrichment facility.

4. Safety, Health Physics, and Criticality Requirements

4.1 The UF₆ concentration shall not be less than 99.5 g UF₆ per 100 g of sample in order to limit the potential hydrogen content for nuclear criticality safety.

4.2 The total absolute vapor pressure shall not exceed the following values:

380 kPa at 80 °C (55 psia at 176 °F), or
517 kPa at 93 °C (75 psia at 200 °F), or
862 kPa at 112 °C (125 psia at 235 °F)

Additionally, if a measurement is taken over solid UF₆, the vapor pressure shall not exceed the following values:

50 kPa at 20 °C (7 psia at 68 °F), or
69 kPa at 35 °C (10 psia at 95 °F)

The purpose of the pressure check is to limit the hydrogen fluoride, air, or other volatile components that might cause overpressure when heating the shipping container, such as to obtain a liquid sample or withdraw the contents.

4.2.1 If the temperature differs from 20 or 35 °C, a temperature correction must be performed which takes the change in vapor pressure of UF₆ into account. For example, an acceptable correction would be that the pressure must remain below $P_{UF_6}(T) + 39.3$ kPa, where $P_{UF_6}(T)$ is the vapor pressure of pure UF₆ over solid at temperature T and $P_{UF_6}(T)$ is given in accordance with $\text{Log } P_{UF_6} = 12.77 - (2562.46/T)$, with P in Pascal and T in K.⁶ Other methods or equations to assure that the pressure limits above are met are acceptable provided that validated temperature compensation is made.

4.3 The total hydrocarbon, chlorocarbon, and partially substituted halohydrocarbon content shall not exceed 0.01 mol % of the UF₆. The reason for the exclusion of these materials is to prevent a vigorous reaction with UF₆ upon heating. It is essential that contamination of the UF₆ containers, such as by vacuum pump oil, be prevented since it is not practical to obtain a sample without heating the UF₆. An alternative means of demonstrating compliance with this requirement, other than by direct measurement, may be agreed upon between the parties concerned.

4.3.1 Measures should be taken to minimize contamination by hydrocarbons, chlorocarbons, and halohydrocarbons in the receiving cylinder before filling.

4.3.2 Also, it is good practice to minimize contact of hydrocarbon, chlorocarbon, and partially substituted halohydrocarbon during UF₆ processing.

4.3.3 If UF₆ has been liquefied, either during filling or during sampling of the final shipping container, compliance can be assumed. If the UF₆ has not been liquefied, compliance must be demonstrated. An alternative means of demonstrating compliance with this requirement, other than by direct measurement, may be agreed upon between the parties concerned.

4.3.4 For fully substituted chlorofluorocarbons, a maximum limit may be agreed upon between the parties concerned.

4.4 For Enriched Commercial Grade UF₆ meeting the requirements of Section 5, (1) the gamma activity from fission products is expected to be below the detection limits of the measurement methodology, and (2) the alpha activity from neptunium and plutonium is expected to be below the detection limits of commonly used measurement methodology. Therefore unless otherwise agreed upon between the buyer and

⁵ Available from Centrus Energy Corporation, 6901 Rockledge Drive, Bethesda, MD 20817.

⁶ Konings, Rudy J. M., ed., “The U-F System,” in *Comprehensive Nuclear Materials*, Vol 2, Elsevier, New York, NY, 2012, p. 209.