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Standard Specification for Uranium Hexafluoride Enriched to Less Than 5 % ^{235}U[1]

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1. Scope

1.1 This specification covers nuclear grade uranium hexafluoride (UF_6) 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 ^{235}U concentration below 5 % and that is intended for fuel fabrication. The scope of this specification includes specifications for UF_6 enriched from Commercial Natural UF_6, and UF_6 enriched from Reprocessed UF_6; enriched UF_6 derived from Highly Enriched Uranium is included in the specification for UF_6 enriched from Commercial Natural UF_6(see Note 1). Commercial Natural UF_6, Reprocessed UF_6, Highly Enriched UF_6, and Derived Enriched UF_6 are defined in Section 3. The objectives of this specification are twofold: (*1*) To define the impurity and uranium isotope limits for Enriched Commercial Grade UF_6 so that, with respect to fuel design and manufacture, it is essentially equivalent to enriched uranium made from natural UF_6; and (*2*) To define limits for Enriched Reprocessed UF_6 to be expected if Reprocessed UF_6 is to be enriched without dilution with Commercial Natural UF_6. For such UF_6, special provisions, not defined herein, may be needed to ensure fuel performance and to protect the work force, process equipment, and the environment.

NOTE 1—Due to limited experience with enriched UF_6 derived from Highly Enriched Uranium, such material must be carefully monitored to ensure compliance with this specification; when such Derived Enriched UF_6 is directly provided to the buyer, it shall be identified as such by the seller.

1.2 This specification is intended to provide the nuclear industry with a standard for enriched UF_6 that is to be used in the production of sinterable UO_2 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 UF_6 (see, for example, TID-7016, DP-532, ORNL-NUREG-CSD-6, and DOE 5633.3B).

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

2. Referenced Documents

2.1 *ASTM Standards:*

C 761 Test Methods for Chemical, Mass Spectrometric, Spectrochemical, Nuclear, and Radiochemical Analysis of Uranium Hexafluoride[2]

C 787 Specification for Uranium Hexafluoride for Enrichment[2]

C 859 Terminology Relating to Nuclear Materials[2]

C 1052 Practice for Bulk Sampling of Liquid Uranium Hexafluoride[2]

C 1295 Test Method for Gamma Energy Emission from Fission Products in Uranium Hexafluoride[2]

2.2 *ANSI Standards:*[3]

ANSI-ASME NQA-1 Quality Assurance Program Requirements for Nuclear Facilities

ANSI N14.1 Packaging of Uranium Hexafluoride for Transport

2.3 *U.S. Government Documents:*

Inspection, Weighing, and Sampling of Uranium Hexafluoride Cylinders, Procedure for Handling and Analysis of Uranium Hexafluoride, Vol. 1, DOE Report ORO-671-1, latest revision[4]

Uranium Hexafluoride: A Manual of Good Handling Practices, United States Enrichment Corporation Report USEC-651, latest revision[5]

Nuclear Safety Guide, U.S. NRC Report TID-7016, Rev. 2, 1978, and ORNL-NUREG-CSD-6[4]

Clarke, H. K., Handbook of Nuclear Safety, DOE Report DP-532[4]

Code of Federal Regulations, Title 10, Part 50, (Appendix B)[4]

Control and Accountability of Nuclear Materials, DOE Directive 5633.3B[4]

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

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

[5] Available from United States Enrichment Corporation, 6903 Rockledge Drive, Bethesda, MD 20817.

3. Terminology

3.1 *Definitions of Terms Specific to This Standard*—Terms shall be defined in accordance with Terminology C 859 except for the following:

3.1.1 *Commercial Natural UF_6*—UF_6 from natural unirradiated uranium (containing 0.711 ± 0.004 g ^{235}U per 100 g U).

3.1.1.1 *Discussion*—It is recognized that some contamination with reprocessed uranium may occur during routine processing. This is acceptable provided that the UF_6 meets the requirements for Commercial Natural UF_6 as specified in Specification C 787.

3.1.2 *Reprocessed UF_6*—any UF_6 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.

3.1.2.1 *Discussion*—The requirements for Reprocessed UF_6 given in Specification C 787 are intended to be typical of reprocessed spent fuel that has achieved burn-up levels of up to 50 000 MW days per tonne of uranium in light water reactors and has been cooled for ten years after discharge. It is recognized that different limits would be necessary to accommodate different fuel histories.

3.1.3 *Highly Enriched Uranium*—any form of uranium having a ^{235}U content of 20 % or greater, which may or may not have been derived from Commercial Natural UF_6.

3.1.4 *Enriched Commercial Grade UF_6*—UF_6 enriched from Commercial Natural UF_6 or Derived Enriched UF_6 that meets the specification limits for Enriched Commercial Grade UF_6.

3.1.5 *Enriched Reprocessed UF_6*—UF_6 enriched from Reprocessed UF_6 or any mixture of Reprocessed UF_6 and Commercial Natural UF_6, exceeding the applicable limits of Sections 4 and 5 for Enriched Commercial Grade UF_6. The wide range of irradiation levels, cooling times, reprocessing, conversion, and enrichment processes, and fuel cycle choices for combination with unirradiated UF_6, together with the varying acceptance limits of different fuel fabrication facilities, make it not practical to specify the exact radionuclide composition of Enriched Reprocessed UF_6.

3.1.6 *Depleted UF_6*—any unirradiated UF_6 with a ^{235}U content less than Commercial Natural UF_6.

3.1.7 *Derived Enriched UF_6*—any UF_6 obtained from the blending of Highly Enriched Uranium with Commercial Natural UF_6, Enriched Commercial Grade UF_6, or Depleted UF_6.

3.2 For enriched UF_6 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 UF_6 concentration shall not be less than 99.5 g UF_6 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 values given below:

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 UF_6, the vapor pressure shall not exceed the values given below:

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.

4.3 The total hydrocarbon, chlorocarbon, and partially substituted halohydrocarbon content shall not exceed 0.01 mol % of the UF_6. The reason for the exclusion of these materials is to prevent a vigorous reaction with UF_6 upon heating. It is essential that contamination of the UF_6 containers, such as by vacuum pump oil, be prevented since it is not practical to obtain a sample without heating the UF_6. An alternative means of demonstrating compliance with this requirement, other than by direct measurement, may be agreed upon between the parties concerned.

4.4 For Enriched Commercial Grade UF_6 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 set forth in Test Method C 1295; and (*2*) The alpha activity from neptunium and plutonium is expected to be below the detection limits of commonly used measurement methodology. Therefore, measurements are not required unless agreed upon between the buyer and seller.

4.5 For Enriched Reprocessed UF_6, the gamma radiation from fission products shall not exceed 4.4×10^5 MeVBq/kgU (4.4×10^5 MeV/sec kgU). The measurements are to be made in accordance with Test Method C 1295, or equivalent.

4.5.1 For Enriched Reprocessed UF_6, the alpha activity from neptunium and plutonium shall be less than 3300 Bq/kgU (200 000 dpm/kgU).

5. Chemical, Physical, and Isotopic Requirements

5.1 Both Enriched Commercial Grade UF_6 and Enriched Reprocessed UF_6 must meet the specification criteria except as differentiated in 4.4, 4.5, 5.4, and 5.5. For certain isotopes, including artificially created radioactive species, two groups of limits are set. Limits for Enriched Commercial Grade UF_6 are set so as to have no special impact on the use of this material in existing facilities. For Enriched Reprocessed UF_6, higher limits are indicated to correspond with Specification C 787, and lower limits may be agreed upon by the buyer and seller according to the composition of the feed material presented for enrichment.

5.2 The UF_6 content shall be reported as gUF_6/100 g sample.

5.3 The following impurity elements shall not exceed these values:

Element	µg/gU
Boron	4
Silicon	250

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

5.4 Enriched Commercial Grade UF_6 shall comply with the limits given in 5.5. For evaluating Enriched Commercial Grade UF_6, the measured concentration of ^{236}U will be used as an indicator for contamination with reprocessed uranium, on the assumption that there is no opportunity for contamination with irradiated uranium that has not been processed to remove the

majority of fission products. Uranium isotopic concentrations shall be determined and reported for ^{234}U, ^{235}U, and ^{236}U.

5.5 *Radionuclides*—The following values represent limits obtainable from the enrichment of UF_6 feed materials at the corresponding limits of Specification C 787.

	Enriched Commercial Grade UF_6	Enriched Reprocessed UF_6
^{232}U	0.0001 µg/gU, see 5.5.1, 5.5.2, and 5.5.3	0.050 µg/gU, see Note 2
^{234}U	10×10^3 µg/g^{235}U, see Note 3	2000 µg/gU, see Note 2
^{236}U	250 µg/gU, see 5.5.3	see Note 2
^{99}Tc	0.01 µg/gU, see 5.5.1, 5.5.2, and 5.5.3	5 µg/gU, see Note 2

5.5.1 If the ^{236}U measurement result is less than 125 µg/gU, then measurement of ^{232}U and ^{99}Tc is not required unless agreed upon between the buyer and seller.

5.5.2 If the ^{236}U measurement result is greater than 125 but less than 250 µg/gU, then measurement and reporting of ^{232}U and ^{99}Tc are required for routine acceptance of the UF_6.

5.5.3 The buyer may consider acceptance of the lot above 250 µg/gU on the basis of the total significance of all the measured levels of radionuclides to determine the suitability for intended use in the fuel fabrication and irradiation. If the ^{236}U measurement result is greater than 250 but less than 500 µg/gU, then measurement of ^{232}U and ^{99}Tc and notification of results before shipment are required.

NOTE 2—Enrichment of Reprocessed UF_6 feed material at the limit of Specification C 787 could be expected to reach these limits. Defining these limits does not imply that any fuel fabrication plant designed for Enriched Commercial Grade UF_6 could handle Enriched Reprocessed UF_6 without dilution with Enriched Commercial Grade UF_6 and other special precautions. With respect to the variability of Reprocessed UF_6 from various fuel histories and the demands that would be placed on the fuel fabricators and users, it could be necessary for the seller and buyer to agree on lower limits after enrichment than implied by Specification C 787 feed limits.

NOTE 3—Meeting the limit of 10×10^3 µg^{234}U/g^{235}U may impose restrictions on the allowable combinations of concentrations of ^{234}U in the feed material and ^{235}U in the enriched uranium and tails material. If the ^{234}U level is expected to be greater than 10×10^3 but less than 11×10^3 µg^{234}U/g^{235}U, then the parties may reach agreement in advance to accept the material.

6. Sampling

6.1 A representative sample of sufficient size to perform tests prescribed shall be taken while the material is liquid and homogeneous. Relevant sample procedures are given in Practice C 1052, USEC Report USEC-651, and DOE Report ORO-671-1.

6.2 All samples shall be clearly identified including the seller's lot number.

6.3 All containers used for a lot shall be positively identified as containing material from a particular homogeneous lot.

7. Test Methods for Chemical and Isotopic Analysis

7.1 Chemical and isotopic analysis shall conform to Test Methods C 761, or demonstrated equivalent, as mutually agreed upon between the buyer and seller.

8. Packaging, Handling, and Shipping

8.1 Procedures for packaging, handling, and shipping UF_6 are given in ANSI N14.1, USEC Report USEC-651, and DOE Report ORO-671-1 or appropriate national or international procedures.

8.2 Cylinders used for transport of Reprocessed UF_6 shall not be used for Enriched Commercial Grade UF_6 unless decontaminated internally before filling with Enriched Commercial Grade UF_6.

9. Quality Assurance

9.1 Quality assurance requirements shall be agreed upon between the buyer and the seller when specified in the purchase order. Code of Federal Regulations, Title 10, Part 50 (Appendix B) and NQA-1 are referenced as guides.

10. Keywords

10.1 low enriched uranium; nuclear fuel; uranium enrichment; uranium hexafluoride