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Standard Specification for Uranium Hexafluoride for Enrichment[1]

This standard is issued under the fixed designation C 787; 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.

1. Scope

1.1 This specification covers uranium hexafluoride (UF_6) intended for feeding to an enrichment plant. Included are specifications for UF_6 derived from unirradiated natural uranium and UF_6 derived from irradiated uranium that has been reprocessed and converted to UF_6 for enrichment and subsequent reuse. The objectives of this specification are twofold: (*1*) To define the impurity and uranium isotope limits for Commercial Natural UF_6 feedstock so that the corresponding enriched uranium is essentially equivalent to enriched uranium made entirely from virgin natural UF_6; and (*2*) To define additional limits for Reprocessed UF_6(or any mixture of Reprocessed UF_6 and Commercial Natural UF_6). For such UF_6, special provisions may be needed to ensure that no extra hazard arises to the work force, process equipment, or the environment.

1.2 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 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 O 474.1).

1.3 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:* [2]

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

C 859 Terminology Relating to Nuclear Materials[3]

C 996 Specification for Uranium Hexafluoride Enriched to Less Than 5 % ^{235}U

C 1052 Practice for Bulk Sampling of Liquid Uranium Hexafluoride

C 1295 Test Method for Gamma Energy Emission from Fission Products in Uranium Hexafluoride and Uranyl Nitrate Solution

2.2 *ANSI Standard:*

N14.1 Packaging of Uranium Hexafluoride for Transport[4]

2.3 *U.S. Government Documents:*

Inspection, Weighing, and Sampling of Uranium Hexafluoride Cylinders, Procedures for Handling and Analysis of Uranium Hexafluoride, Vol. 1, Department of Energy Report ORO-671-1, latest revision[5]

The UF_6 Manual: Good Handling Practices for Uranium Hexafluoride, United States Enrichment Corporation Report USEC-651, latest revision[6]

Nuclear Safety Guide, U.S. Nuclear Regulatory Commission Report TID-7016, Rev. 2, 1978, and ORNL-NUREG-CSD-6[5]

Clarke, H. K., Handbook of Nuclear Safety, Department of Energy Report DP-532 [5]

Control and Accountability of Nuclear Materials, DOE Directive O 474.1 [5]

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

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

[3] Withdrawn.

[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.

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

processing. This is acceptable provided that the UF_6 meets the requirements for Commercial Natural UF_6.

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 this specification are intended to be typical of reprocessed spent fuel that has achieved burnup levels of up to 50,000 MWD/Metric tonne 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.

4. Safety, Health Physics, and Criticality Requirements

4.1 The UF_6 concentration shall be not 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, then 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 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. For fully substituted chlorofluorocarbons a maximum limit may be agreed upon between the parties concerned. 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 Reprocessed UF_6 the gamma radiation from fission products shall not exceed 1.1×10^5 MeV Bq/kgU (1.1×10^5 MeV/sec kgU). The measurements are made in accordance with Test Method C 1295 or equivalent. The purpose of this requirement is to limit the gamma dose from fission products to which plant workers might be exposed to a level less than 20 % of the gamma dose from aged natural uranium, and to limit the quantity of fission products in effluent from enrichment and fuel fabrication plants.

4.5 For Reprocessed UF_6, the alpha activity from neptunium (Np) and plutonium (Pu) isotopes may be specified in either of two ways as agreed upon between the parties concerned:

4.5.1 The total alpha activity from Np and Pu in the cylinder shall be limited to 25 000 Bq/kgU (1.5×10^6 disintegrations per minute per kilogram of uranium). This criterion is concerned with both the volatile components and those that remain on the inner surfaces and in the heel, so it can be measured practically only by sampling from the inflow during the filling of the shipping container; or

4.5.2 The volatile alpha activity from Np and Pu in the liquid sample from the shipping container shall be limited to 3300 Bq/kgU (0.2×10^6 disintegrations per minute per kilogram of uranium). To prevent nonvolatile particles from being included in this measurement, the liquid sample must be filtered through a porous nickel filter as described in Test Methods C 761.

5. Chemical, Physical, and Isotopic Requirements

5.1 Plants preparing UF_6 will have to control the purity of process chemicals and also employ low corrosion equipment to be successful in meeting the specifications for most impurities. Both Commercial Natural UF_6 and Reprocessed UF_6 will have to meet the same specification criteria for most elements. In addition, Reprocessed UF_6 must meet additional specification limits for artificially created radioactive species. For evaluating Commercial Natural 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. Provided that this isotope does not exceed the concentration limit for Commercial Natural UF_6 listed in 5.5, the expected concentrations of artificial isotopes would be so far below normal detection limits that measurements to determine compliance with the separate limits are not appropriate. Uranium hexafluoride that fails to meet Commercial Natural UF_6 limits would require further testing to determine its acceptability as Reprocessed UF_6.

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

5.3 The total of all the following listed elements that form nonvolatile fluorides, having a vapor pressure of 101.3 kPa or less at 300°C (1 atm or less at 572°F) shall not exceed 300 µg/g of uranium:

aluminum	iron	sodium
arsenic	iron	sodium
barium	lead	strontium
beryllium	lithium	thorium
bismuth	magnesium	tin
cadmium	manganese	zinc
calcium	nickel	zirconium
chromium	potassium	
copper	silver	

5.3.1 If the concentration of an impurity element is given as a less-than value (this is a concentration expressed as being less than the lower detection limit of the analytical method), this less-than value shall be taken as the concentration of that element in determining the total impurity content.

5.4 The volatile component of the following elements shall not exceed the values listed below:

Element	Value, µg/g of uranium
antimony	1
arsenic	3 (see Note 1)
boron	1
bromine	5

chlorine	100
chromium	10 (see Note 1)
molybdenum	1.4
niobium	1
phosphorus	50
ruthenium	1
silicon	100
tantalum	1
titanium	1
tungsten	1.4
vanadium	1.4

NOTE 1—Total chromium and total arsenic are usually expected to be well below 10μg/gU and 3μg/gU, respectively. If the total value of the element (noted hereafter as $E_{(total)}$) is found to be above the limit in 5.4, the volatile component may be determined by either of the following techniques as described in Test Method C 761:

by measuring the insoluble component of the Element, and deducing the volatile component by: $E_{(volatile)} = E_{(total)} - E_{(nonvolatile)} = E_{(total)} - E_{(insoluble)}$

or, by vapor transfer of a sample UF_6(taken according to Practice C 1052) from its original sample container to a new container. Measuring the Element in the hydrolysed UF_6 of the new container will yield the volatile component of the Element initially present, providing the transfer has been made in the vapor phase $E_{(volatile)} = E_{(total)} - E_{(nonvolatile)} = E_{(after\ gas\ transfer)}$

If $E_{(total)}$ exceeds the value in 5.4, then agreement in advance between the parties (for example, suppler, receiver) shall be required to accept the material.

5.5 *Minor Isotopes*—These items shall not exceed the limits given as micrograms per gram of total uranium (μg/gU).

	Commercial Natural UF_6	Reprocessed UF_6
^{232}U	0.00001	0.005
^{234}U	62	480.0
^{236}U	20	8400.0

5.5.1 It is recognized that variability in natural uranium does occur and affects the ^{234}U level. ^{234}U levels in the range of 56–62 μg/gU have been identified in a small part of natural uranium production. For compliance with Specification C 996 after enrichment, a^{234} U content of 56 μg/gU or less in Commercial Natural UF_6 is generally required to yield Enriched Commercial Grade UF_6 that does not exceed $10.0 \times 10^3 \mu g^{234}$ U/g^{235}U (Specification C 996 requires agreement in advance between the parties to accept Enriched Commercial Grade UF_6 above $10.0 \times 10^3 \mu g^{234}$ U/g^{235}U). A ^{234}U content of 57–62 μg/gU will yield Enriched Commercial Grade UF_6 that may exceed this level, but will generally comply with the limit in Specification C 996 of $11.0 \times 10^3 \mu g^{234}$ U/g^{235}U. Therefore, prior to any delivery of Commercial Natural UF_6 containing $_{234}$U above 56 μg/gU,
the ^{234}U level shall be reported and shall require agreement in advance between the parties (for example, converter, enricher) to accept the material.

5.5.2 Values at or below the above limit for ^{232}U in Commercial Natural UF_6 may be assumed without measurement provided that it can be demonstrated that the material meets the ^{236}U limits.

5.5.3 For Commercial Natural UF_6, isotopic concentrations shall be reported for ^{234}U, ^{235}U, and ^{236}U unless it can be otherwise demonstrated that the UF_6 conforms to the appropriate isotopic specifications (for example, through the seller's quality assurance records). For Commercial Natural UF_6 from verifiable virgin natural uranium sources the analysis of ^{236}U is not normally required unless otherwise agreed upon between the buyer and seller.

5.5.4 Unirradiated UF_6 at any ^{235}U concentration other than that of Commercial Natural UF_6 might be delivered as feed material if this is acceptable to the enricher. Renegotiation of the impurity limits may be needed under these circumstances.

5.5.5 For Reprocessed UF_6, isotopic concentrations shall be measured and reported for ^{232}U, ^{234}U, ^{235}U, and ^{236}U.

5.6 *Technetium*—^{99}Tc shall not exceed the following limits given as micrograms per gram of total uranium (μg/gU).

	Commercial Natural UF_6	Reprocessed UF_6
^{99}Tc	0.001	0.500

5.6.1 For Commercial Natural UF_6 from verifiable (for example, through the seller's quality assurance records) virgin natural uranium sources, the analysis of ^{99}Tc is not normally required unless otherwise agreed upon between the buyer and seller.

5.6.2 For Reprocessed UF_6 the concentration of ^{99}Tc shall be measured and reported.

6. Sampling

6.1 A representative sample of sufficient size to perform the 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. Methods of 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 Reprocessed UF_6 traffic shall not be used for Commercial Natural UF_6 unless decontaminated internally before filling with Commercial Natural UF_6. The heels in cylinders that have contained Reprocessed UF_6 may contain significant levels of gamma emitters such as ^{232}U daughters. The resulting gamma radiation level may be too high to allow immediate shipping, so decontamination or some additional decay time may be needed.

9. Keywords

9.1 low enriched uranium; natural uranium; nuclear fuel; reprocessed uranium; uranium enrichment; uranium hexafluoride