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Standard Specification for Uranium Hexafluoride for Enrichment[1]

This standard is issued under the fixed designation C787; 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*) Toto define the impurity and uranium isotope limits for Commercial Natural UF_6 feedstock;feedstock, and (*2*) Toto 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 (for example, see 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.after SI units are provided for information only and are not considered standard.

1.4 *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

C859 Terminology Relating to Nuclear Materials

C996 Specification for Uranium Hexafluoride Enriched to Less Than 5 % ^{235}U

C1052 Practice for Bulk Sampling of Liquid Uranium Hexafluoride

C1295 Test Method for Gamma Energy Emission from Fission and Decay Products in Uranium Hexafluoride and Uranyl Nitrate Solution

C1703 Practice for Sampling of Gaseous Uranium Hexafluoride for Enrichment

2.2 *ANSI Standard:*[3]

N14.1 Packaging of Uranium Hexafluoride for Transport

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

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

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

[3] Available from American National Standards Institute, 11 W. 42nd St., 13thInstitute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.10036, http://www.ansi.org.

[4] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.

The UF_6 Manual: Good Handling Practices for Uranium Hexafluoride, United States Enrichment Corporation Report USEC-651, latest revision[5]

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

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

Control and Accountability of Nuclear Materials, DOE Directive DOE O 474.1 Control and Accountability of Nuclear Materials, DOE Directive

2.4 *Other Document:*[5]

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

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:*

3.1.1 Terms shall be defined in accordance with Terminology C859, except for the following:

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

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 UF_6 meets the requirements for Commercial Natural UF_6.

3.2.2 *Reprocessed* UF_6—, *n*—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.

3.2.2.1 *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 Megawattmegawatt days per tonneton 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 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)

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 following values:

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

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.

4.2.1 If the temperature differs from 20°C20 or 35°C,35 °C, a temperature correction must be performed which takes the change in vapor pressure of UF_6 into account. For example, an acceptable correction would be that the pressure must remain below $P_{UF6}(T)$ + 39.3 kPa, where $P_{UF6}(T)$ is the vapor pressure of pure UF_6 over solid at temperature T and $P_{UF6}(T)$ is given according

[5] Available from United States Enrichment Corporation, 6903Centrus Energy Corporation, 6901 Rockledge Drive, Bethesda, MD 20817.

~~to~~ in accordance with Log P_{UF6} = 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 UF_6. The reason for the exclusion of these materials is to prevent a vigorous reaction with UF_6 upon heating or with stronger-fluorinating agents which may be present in enrichment plants. 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.

4.3.1 Measures should be taken to minimize contamination by hydrocarbons, chlorocarbons, and partially substituted halohydrocarbons in the receiving cylinder before filling and it is good practice to minimize such contact during UF_6 processing.

4.3.2 If UF_6 has been liquefied, either during filling or during sampling of the final shipping container, compliance can be assumed. If the UF_6 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.

4.4 For Reprocessed UF_6 the gamma radiation from fission products shall not exceed 1.1×10^5 ~~MeV~~ MeV Bq/kgU (1.1×10^5 MeV ~~MeV/sec~~ /s kgU). The measurements are made in accordance with Test Method C1295 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 C761.

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 g of sample.

5.3 The total of all the following listed elements that form nonvolatile fluorides shall not exceed 300 µg/g of uranium:

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

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

[6] ~~*Comprehensive Nuclear Materials*, Volume 2, The U-F System, Ed. R.J.M. Konings, p. 209, Elsevier 2012.~~ Konings, Rudy J. M., ed., "The U-F System," in *Comprehensive Nuclear Materials*, Vol 2, Elsevier, New York, NY, 2012, p. 209.