

Summary of Characterization of DUF₆ Reference Documents

1. American Society for Testing and Materials (ASTM) Standards:

a. ASTM Standard C787-11, *Standard Specification for Uranium Hexafluoride for Enrichment*

This is the latest ASTM designation for the specification that covers uranium hexafluoride (UF₆) intended for feeding to an enrichment plant. Included are specifications for UF₆ derived from unirradiated natural uranium and UF₆ derived from irradiated uranium that has been reprocessed and converted to UF₆ for enrichment and subsequent reuse.

b. ASTM Standard C996-10, *Standard Specification for Uranium Hexafluoride Enriched to Less Than 5 % ²³⁵U*

This is the latest ASTM designation for the specification that covers nuclear grade UF₆ that either has been processed through an enrichment plant or has been produced by the blending of highly enriched uranium (HEU) with other uranium to obtain uranium of any U-235 concentration below 5% and that is intended for fuel fabrication.

2. ORNL/TM-2000/242, *Strategy for Characterizing Transuranics and Technetium Contamination in Depleted UF₆ Cylinders, October 2000*

This report summarizes results of a study performed to develop a strategy for characterization of low levels of radioactive contaminants [plutonium (Pu), neptunium (Np), americium (Am) and technetium (Tc)] in support of a request for proposals to design, build, and operate facilities to convert depleted uranium hexafluoride (DUF₆) to more chemically stable forms. On page C-8 in the report the following statement that “the most significant mechanism by which transuranics end up in tails cylinders is by cross-contamination from the heels of unwashed, recycled feed and product cylinders, the former being the most significant” is made. This study was not intended to address impurities from the perspective of ASTM specifications. However, most of the historical data reviewed (219 samples tails cylinder for Tc, 153 tails cylinder samples for Np, and 152 tails cylinder for Pu) shows no measurable Tc, Np, or Pu dispersed in DUF₆ tails stream. Two tails cylinder samples, one for Np and the other for Tc, were measured and found to be at the limits of detection. The report does not address U-236, U-234, and U-232 impurities in tails cylinders.

3. POEF Document Listings with Assay U-234, U-235, and U-238 Results

This is a list of United States Enrichment Corporation (USEC) document numbers and the measured U-234, U-235, and U-238 concentrations in tails cylinders reported in those documents.

4. *Calculation of Uranium Isotopic Activity Composition Based on Data from Various Assay Methods, Science Applications International (SAIC), Oak Ridge, Tennessee, undated but written 1995 or later*

This report presents empirical equations for predicting U-234/U-235 ratios as a function of U-235 assay and provides a means of estimating the U-234 content of DUF₆.

5. BJC/PORTS-139/R1, *Recycled Uranium Mass Balance Project, Portsmouth, Ohio, Site Report, Bechtel Jacobs Company LLC, Piketon, OH, June 2000*

This mass balance project has been prepared as the Portsmouth Gaseous Diffusion Plant (PORTS) response to Deputy Secretary of Energy, T. J. Glauthier’s, memorandum of September 15, 1999, to address: (1) shipments and receipts of recycled uranium (RU); (2) levels of transuranic (TRU) and fission product (FP) contaminants in the PORTS flows and processes that had the potential to expose workers; and (3) information on mass balances for RU, TRU and FP to identify potential environmental, safety, and health (ES&H) concerns. The primary importance of the report in the

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framework of DUF₆ impurities is identification of the time periods when substantial amounts of RU were fed to the PORTS cascade and the years during which RU cascade flows were absent.

6. **BJC/PGDP-167, *Recycled Uranium Mass Balance Project, Paducah Gaseous Diffusion Plant Site Report, Jacobs Company LLC, Paducah, Ky, June 14, 2000 Final Draft***

This mass balance project has been prepared as a part of a U.S. Department of Energy (DOE) complex-wide initiative for the review of the mass flow characteristics of RU over the past 50 years. The authority for this initiative is documented in Deputy Secretary of Energy, T. J. Glauthier's, memorandum of September 15, 1999. The memorandum documents the following project goals applicable to the mass balance activity: (1) Identify the mass flow of DOE RU from early production to mid-1999, including ultimate use and disposition; (2) Identify the characteristics and contaminants in the major U streams, specifically, the Tc-99, Np, Pu, or other isotopic content of concern to worker or public health safety; and (3) Conduct site mass balance activities for potential personnel exposure or environmental contamination. The major usefulness of the report in the context of DUF₆ impurities is identification of the time periods when substantial amounts of RU were fed to the Paducah cascade and the years during which RU cascade flows were absent.

7. **BJC/OR-548, *Recycled Uranium Mass Balance Project, Oak Ridge Gaseous Diffusion Plant (Currently Known as East Tennessee Technology Park) Site Report, Oak Ridge, Tennessee, June 2000***

This mass balance project has been prepared to support DOE efforts to assess the potential for health and environmental issues resulting from the presence of TRU elements and fission products in RU from reactor returns that was processed by DOE and its predecessor agencies. It represents an effort to collect, verify, analyze, and interpret available data to provide an overall accountability, or site mass balance, for Oak Ridge Gaseous Diffusion Plant (ORGP) RU streams. The primary value of the report in the context of DUF₆ impurities is identification of the time periods when substantial amounts of RU were fed to the ORGPD cascade and the years during which RU cascade flows were absent.

8. **Laboratory Specification Code Results of Post-1996 Data for 167 DUF₆ Cylinders for Tc-99 Analyses**

This is the PORTS database for 167 post-1996 DUF₆ cylinder sample results for Tc-99 from USEC and shows a mean of less than 0.43 ppb ± 0.2 ppb (U basis) at the 95 % confidence limit. Descriptive statistics demonstrate that 4 cylinders out of the 167 exceeded the ASTM specification limit of 1 ppb. There is one sample which has a reported value of 0.0001 that below the detection limit of the other samples. The value is correct and this is due to either increase in the sample mass tested or increased count time. Changes to testing parameters will increase or decrease the limit of detection for lab instrumentation.

9. **Analytical Results of Statistical Samples for 145 DUF₆ Cylinder Samples for U-234 and U-236**

This is a PDF document of the USEC Production Automated Scheduling System (PASS) for 145 post- and some pre-1997 DUF₆ cylinder sample results for U-234 and U-236 and shows all results meet the ASTM specifications for ²³⁴U and ²³⁶U.

10. **PORTS 4G Cylinders Verified List**

This is an inventory of Portsmouth cylinders that have been researched for fill dates, assays, and status. The cylinders listed were determined to have held only DUF₆.

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11. Historical Depleted Cylinder Research

This document explains the methodology for examining the Nuclear Material Control and Accountability (NMC&A) records to determine the fill status and assay ranges of the cylinders at Portsmouth. It is a companion to item #10.

12. DUF₆-G-G-STU-003, *Contents Categorization of Paducah DUF₆ Cylinders Using Cylinder History Cards – Phase II*, DUF₆-G-G-STU-003, Henson Technical Projects, LLC, Clinton Tennessee, Draft of UDS Review, September 30, 2006

This Phase II report covers results of the categorization of the contents of individual cylinders for conversion feeding based on retrieval and analyses of the cylinder history cards stored at Paducah. The objective of the study was to identify by cylinder number, DUF₆ cylinders containing material enriched to greater than one percent U-235, TRU, and/or Tc (including heel quantities of material), and conversely to clear cylinders containing only UF₆. A total of 13,240 cylinders were cleared as DUF₆-storage only, natural normal UF₆ storage only, and/or cleaned with tails or natural normal only use. A remaining 22,430 other cylinders need to be evaluated as of the report date.

13. PAD Cleared Cylinders

This is a PDF document of three separate spreadsheets in one excel workbook, which documents the history of 8,010 4G cylinders, 4,736 OM cylinders, and 208 other large cylinders such as 48X, 48T, 48O, 48HX, and 48H that were determine to be single fill with tails/natural or multi-filled with tails/natural.

14. PAD 30A Cylinders

This is a PDF document of a spreadsheet on 1,825 30A cylinders which were screened, where possible, for feed plant service; product withdrawal; and single fill with tails/natural or multi-filled with tails/natural; received from ORGPD or PORTS; and any noted inspection/rejection.

15. PAD 48G Cylinders

This is a PDF document of a spreadsheet on 22,215 48G cylinders of which 8,010 were determined to have been single-fill with tails/natural or multi-filled with tails/natural. Where possible, screening included use for feed plant service, product withdrawal, receipts from ORGDP or PORTS and any noted inspections/rejections.

16. PAD CV AND 12-Inch Cylinders

This is a PDF document of a spreadsheet on 287 CV and 61 12A cylinders which were screened, where possible, for feed plant service; product withdrawal; and single-fill with tails/natural or multi-filled with tails/natural, received from ORGDP or PORTS, and any noted inspection/rejection. CV is a term which describes excess convertors from the enrichment facilities that were re-purposed as storage for DUF₆.

17. PAD Miscellaneous 48-Inch Cylinders

This is a PDF document of a spreadsheet on 6,322 cylinders (48A, 48X, 48T, 48Y, 48O, 48HX, ,48H) that were cleared, where possible, and single-fill with tails/natural or multi-filled with tails/natural.

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18. PAD OM Cylinders

This is a PDF document of a spreadsheet on 7,428 OM cylinders of which 4,736 were determined to be single-fill with tails/natural or multi-filled with tails/natural.

19. LEU Laboratory Specification Code Results Sorted by Assay List

This is a PDF of post-1996 data from the PASS database for 2,921 LEU UF₆ cylinders that shows results meet the specification for enriched product. DUF₆ withdrawn during the same period would likely meet the specification for feed based on the separative capacity of the cascade.

20. Pre-1996 LEU Cylinder Sampling Data with Uranium Isotope Analysis Results

This is a PDF document of USEC PASS database of more than 300 pre-1994 LEU cylinders showing that all cylinders analyzed met the ASTM U-234 limit for LEU. Additionally, U-232 results are shown for 199 of the cylinders and 190 of the cylinders were below detection limits. Of the 190 below detection limits for U-232, 25 cylinders would have met the ASTM C787 specification if it had applied, while the other 165 cylinder results were not measured to the required sensitivity for C787, although the C996 standard was realized. U-232 was detected in nine cylinders of which four were within and five exceeded the C787 specification. Although the data are not strictly applicable to DUF₆, it reveals that U-232 is not commonly detected in LEU, and its presence in DUF₆ is even less likely because it tends to be stripped from tails by the enrichment cascade.

21. United States Department of Energy Uranium Inventories, Linda Gunter, U.S. Department of Energy (DOE), January 2006

This is a status report from the Office of Nuclear Energy which is responsible for monitoring the uranium, conversion, and enrichment markets as well as monitoring the implementation of the U.S./Russia HEU Purchase Agreement and overseeing the DOE's inventory of surplus natural uranium. The contents of the report include the Bonneville Power Administration's Pilot Project involving an agreement and sale by DOE of 8,500 MTU of higher assay (above 0.4 % U-235) tails UF₆ to the utility for enrichment and use as nuclear fuel.

22. Purity of Cascade Tails UF₆ for FY-84, Table 2A – Impurities in Paducah Cascade Tails UF₆

This PDF document consists of the analytical contaminant results for 126 tails cylinders measured from FY 1984 to FY 1993. Approximately 12 to 15 cylinder results per year are given. With the exception of one cylinder value, which was measured at 0.01 ppm, all Tc-99 results were below 0.01 ppm (10 ppb) which was the detection limit during this period. TRU results were given for 125 of the 126 tails cylinders; and with one exception of 5 ppb for Np-237, all results are less than 5 ppb for Np and less than 0.01 ppb for Pu. No results are given for U-232. All other impurities are within ASTM specification C787-11.

23. Characterization of Depleted Uranium Hexafluoride (DUF₆) at the Portsmouth/Paducah Gaseous Diffusion Plants

The purpose of this report is to document the findings from a review of DUF₆ for the presence of impurities that could adversely affect prospects for direct sale. The effort examines three types of information: process knowledge, cylinder records, and sample records.