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FLUOR

November 23, 2004

Fernald Closure Project
Letter No. SP:2004-0075

Mr. John M. Sattler
U. S. Department of Energy
Ohio Field Office - Fernald Closure Project
175 Tri-County Parkway
Cincinnati, Ohio 45246

Dear Mr. Sattler:

CONTRACT DE-AC24-01OH20115, SUBMITTAL OF NEVADA TEST SITE WASTE PROFILE ONLO-000000117, REVISION 7, THORIUM PROCESSING RESIDUES AND OTHER WASTES

Enclosed is a signed copy of Nevada Test Site (NTS) Waste Profile ONLO000000117, Revision 7, Thorium Processing Residues and Other Wastes. Revision 7 is the result of the annual profile review and is being submitted to update the profile to meet the requirements of the Nevada Test Site Waste Acceptance Criteria, Revision 5. To aid in the review, we have provided a detailed list of changes made to the profile and related documents.

A suggested cover letter for transmitting this Waste Profile to Nevada is enclosed for your convenience. Should you have any questions, or require additional information, please contact Steve Heffron at (513) 648-5650.

Sincerely,

Dennis Carr
Senior Project Director
Silos Project

DC:DSA:kl
Enclosure(s)

c: David S. Adkins, MS52-3
Terri L. Binau, DOE Contracting Officer, DOE-OH
Reinhard Friske, MS52-3
Steve Heffron, MS52-3
Ralph E. Holland, DOE Contracting Officer, DOE-OH/FCP
John Samples, MS52-3
Dennis Sizemore, Fluor Fernald, Inc. Prime Contract, MS 2
File Record Subject Submittal of Nevada Test Site Waste Profile ONLO000000117, Revision 7, Thorium Processing Residues and Other Wastes
Project Number 40600/1.1
WM Letter log copy
Administrative Record, MS 78

To: John B. Jones, NNSA/NSO

From: John Sattler

Subject: Submittal of Profile ONLO-000000117, Thorium Processing Residues and Other Wastes

Enclosed is a signed copy of Nevada Test Site (NTS) Waste Profile ONLO-000000117, Revision 7, Thorium Processing Residues and Other Wastes. Revision 7 is the result of the annual profile review and is being submitted to update the profile to meet the requirements of the Nevada Test Site Waste Acceptance Criteria, Revision 5. To aid in the review, we have provided a detailed list of changes made to the profile and related documents.

c: Without Enclosures
Reinhard Friske, MS52-3
Steve Heffron, MS52-3
John Samples, MS52-3

Fernald Closure Project Waste Profile
Thorium Processing Residues and Other Wastes
ONLO-000000117, Rev. 7
Detailed List of Changes

1. General- Completed new waste profile form as required by NTSWAC, Revision 5.

2. Section A.6- Changed WCO from Bruce Davis to Reinhard Friske.

3. Section B.2.b- Changed the profile revision number and date.

4. Section B.6- Provided annual and total volumes and changed to an on-going waste stream.

5. Section B.7- Added estimation of remaining shipments and frequency.

6. Section C.9- As required by the profile instructions, removed inert filler material from list of waste components.

7. Section E.1- Removed intermodal container as a shipping container.

8. Table E.3- Revised table to meet NTSWAC, Revision 5 format and content. The U-235 in this waste stream is normal at 0.711%. Therefore, as the NTSWAC specifies, the total FGE does not include U-235 grams.

9. Plutonium Gram Equivalent Calculations- Created table with calculations for maximum package activity and maximum container volume. Results are well below NTSWAC, Revision 5 requirements.

10. Process Knowledge Narrative, Page 7 – Removed reference in first paragraph to "thorium fuel rods". The rods have been shipped and have been removed from the profile. Removed drawing and thorium fuel rods paper from profile package.

Waste Profile Sheet

☒ NTS Only ☐ Hanford Only ☐ Both NTS and Hanford

A. Generator Information

1. Company name: **Fernald Closure Project**
2. Address: **P. O. Box 538704, Cincinnati, OH 45253-8704**
3. Generator facility: **Various**

4. Primary Technical Contact: **David S. Adkins** email: **david.adkins@fernald.gov** Phone: **513-648-4364** Fax: **513-648-4925**

5. DOE Contact: **John Sattler** email: **john.sattler@fernald.gov** Phone: **513-648-3145** Fax: **513-648-3076**

6. Waste Certification Official: **Reinhard Friske** email: **reinhard.friske@fernald.gov** Phone: **513-648-5477** Fax: **513-648-5131**

7. Generator's EPA Identification Number (If profile involves hazardous materials): **N/A**

B. General Waste Stream Information

1. Waste stream name: **Thorium Processing Residues and Other Wastes**

2.a. NTS Waste stream identification number: **ONLO-000000117** N/A ☐

2.b. Hanford Profile Sheet Tracking Number:_____ N/A ☒

☐ New Profile
☒ Revised Profile (attach summary of changes) Revision Number: **7** Profile Revision Date: **11/23/04**

3. Waste generating process description: *Describe the process that generated the waste stream identified by this profile sheet. Attach process flow charts and other available information if helpful in explaining the generating process.* **This waste consists of the following residues or wastes: Thorium tetrafluoride, ore concentrates, thorium dioxide, thorium hydroxide, thorium metal, dust collector bags and residues, and project associated trash. The attached process knowledge narrative describes this material as an intermediate to final product, with associated waste from the thorium metal production. See attached process knowledge narrative document for additional information.**

4. Waste management services requested:
   ☒ Disposal
   ☐ Storage (Available only at Hanford)
   ☐ Treatment (Available only at Hanford); describe:
   ☐ Other; describe:

5. Waste Category (Check all that apply)
   ☒ Low Level ☐ Mixed Low-Level
   ☐ Mixed Low-Level (Generated within Nevada Only)
   ☐ "Classified Waste" ☐ "Classified Waste" requiring protection from visual observation
   ☐ Asbestiform Low-Level Waste ☐ 11(e)2 By-product Material (Small Quantities)
   ☐ Transuranic Waste ☐ Hanford Category 1 LLW
   ☐ Hanford Category 3 LLW ☐ Exceeds Hanford Category 3 LLW
   ☐ DOE Equivalence GTCC ☐ Contains accountable nuclear material

6. Estimated volume: ☒On-going (m^3/yr):**4** Total remaining volume (m^3):**8**
   ☐One Time Only (m^3):

7. Estimated frequency of shipments per fiscal year: **1 shipment per fiscal year**

C. Physical/Chemical Characterization

1. Physical/Chemical process knowledge. Describe the process knowledge information used for physical/chemical characterization of this waste stream:

Waste Profile Sheet

☐ Material Safety Data Sheets. Attach MSDSs used to designate this waste stream (Hanford Site users can list Hanford MSDS numbers below in lieu of providing MSDSs).

☐ Mass balance from process inputs. Describe how process inputs are controlled and recorded:

☒ Historical process and analytical data. Describe: **This waste consists of thorium process residue. Years of historical production data such as stringent process control specifications, sampling and MC&A data were used for characterization of this waste.**

☐ Inert debris characterized by inventory control. Check this box when the waste stream consists largely of inert debris items that are characterized by inventory control procedures and recorded on inventory sheets. Briefly list or describe inventory procedures:

☐ Other. Describe:

☐ Physical/chemical characterization varies. Check this box when the characterization strategy varies from container to container. Describe below the strategy used to meet the acceptable knowledge requirements of the waste acceptance criteria.

2. Physical/chemical analysis. Describe the sampling and analysis performed to characterize this waste stream:

☐ No analysis performed.

☐ Field screening performed. Describe the frequency and type of field screening performed:

☒ Laboratory analysis performed. Describe the sample source and sampling frequency and methods: **Sample source selected as required within sub-groups of waste, sampling frequency varies based on data needs, TCLP Test Method 1311. Table B-1 attached.**

List the analytical methods used, including upper confidence limits and explanations of anomalies for all analytes analyzed. Attach representative analytical sample result summary. For NTS, attach Table B-1 and data validation summary.

3. Regulatory status. Check all boxes below that describe the regulatory status of the waste stream:

☐ Federally regulated (RCRA) hazardous waste (40 CFR 261). List all RCRA U, P, F, K or D waste codes that could apply to the waste stream; place waste codes that do not apply to all containers in parentheses:

☐ For Hanford only, Washington State dangerous waste (WaAdminCode173-303), excluding W001. List all Washington waste codes that apply; place waste codes that do not apply to all containers in parentheses:

☐ For Hanford only, Washington State dangerous PCB waste (Waste code W001 of WaAdminCode173-303): Describe PCB source and concentration:

☐ TSCA regulated PCB (40 CFR 761). Describe category of PCB (i.e. PCB waste, PCB bulk product waste, PCB remediation waste, PCB analytical waste, etc). Describe PCB source and concentration:

☒ Waste generated from cleanup activities conducted under CERCLA

☐ Waste is not regulated under any of the above regulations.

☐ Waste is hazardous per state-of-generation regulations? If yes, identify hazardous components and state regulations.

4. Federal land disposal restrictions. Check all boxes that apply:

☒ Waste stream is not subject to federal land disposal restrictions

☐ Waste stream requires treatment to meet land disposal restrictions of 40 CFR Part 268.
If checked, provide the following information:
☐ Wastewater ☐ Nonwastewater ☐ Hazardous debris
☐ Waste contains Underlying Hazardous Constituents (applicable UHCs must be included in Item C.9)
Was the waste treated after August 24, 1998? Yes ☐ No ☐

☐ Waste stream meets some of the applicable land disposal restrictions of 40 CFR 268. Check this box if the waste has been treated to meet some federal land disposal restrictions or if it meets some federal land disposal restrictions as generated. If checked, describe the treatment performed and analytical data to support LDR determination:

Waste Profile Sheet

☐ Waste stream meets all applicable land disposal restrictions of 40 CFR 268. Check this box if the waste has been treated to meet all federal land disposal restrictions or if it meets the land disposal restrictions as generated. If checked, describe the treatment performed and analytical data to support LDR determination:

5. (For Hanford only) Waste characteristics. Check any of the boxes for regulated characteristics (WaAdminCode173-303-090) that apply to the waste stream:

☐ Flash point < 38°C ☐ Flash point 38°C - <60°C ☐ Flash point 60°C – 93.3°C
☐ Ignitable solid ☐ Oxidizer
☐ pH 2 or less ☐ pH 12.5 or greater
☐ Liquid that corrodes steel at a rate greater than or equal to 0.25 inches/year
☐ Reactive cyanide ☐ Reactive sulfide ☐ Water Reactive
☐ Explosive, unstable or pyrophoric ☐ Generates toxic gases, vapors or fumes

6. Physical state:
☐ Liquid ☐ Sludge ☐ Debris ☒ Solid
☒ Powder/Dust ☐ Sealed Source ☐ Encapsulated ☐ Solidified
☐ Other; describe:

7. Liquid form. If the waste stream contains liquid, check all that apply:
☐ Containerized liquid ☐ Absorbed Liquid ☐ Stabilized liquid

8. Other contents: Check any of the following that are components of the waste stream, and provide a description of how the waste acceptance criteria for each are met:

☐ Animal carcasses
☐ Infectious waste ☐ Vegetation ☐ Free liquids
☐ Chelating agents ☐ Organic liquids ☐ Asbestos waste ☒ Particulates
EW-1016
☐ Gases ☐ PCBs ☐ Explosives ☐ Pyrophorics
☐ Beryllium Dust ☒ Other
Hydrogen Gas Generation, WM:PKGG-T-0026 and EW-1016

9. Waste composition. Describe the gross composition/component of the waste stream and all hazardous constituents that contribute to any waste codes or LDR treatment standards.
☐ If the chemical composition varies greatly from container to container, check this box and provide bounding values or ranges here. Further evaluation will occur on the specific package paperwork as it is provided for highly variable streams

CAS Number	Chemical constituent	Waste Component	Estimated weight percent ☐ Estimated volume percent ☒
		Thorium tetrafluoride (MEF 40215)	**1.0**
		Ore concentrates (MEF 40228)	**6.0**
		Thorium dioxide (MEFs 40218, 40220, 40221, 40222, and 40223)	**30.0**
		Thorium Metal (MEF 40206)	**35.0**
		Thorium Hydroxide (MEF 40219)	**25.0**
		Dust collector bags and residues (MEF 40224)	**2.0**
		Project associated trash	**1.0**

Waste Profile Sheet

D. Radiological Characterization

1. Radiological process knowledge. Describe the source(s) of the radioactive material in this waste stream (i.e., the radiological processes that introduced the radioactive material into the waste stream).
   This waste is comprised of thorium process residue. Refer to Process Knowledge Narrative.

2. Radiological characterization methods. Describe the analysis and characterization methods used to determine the radionuclide inventory of the waste stream. Check all that apply.

   ☒ Radionuclide material accountability. Describe the accounting methods used to help establish the radionuclide inventory: **Site MC&A material accounting methods**
   ☒ Radiochemical analysis. Describe type and frequency of sampling and analysis:For NTS, attach Table B-1 and data validation summary: **Historical process sampling and analysis data. Product grade thorium was sampled on a regular lot basis throughout the production years. Other components of this waste were sampled as required to obtain representative data. Alpha and gamma spectroscopy.**
   ☐ Nondestructive assay. Describe type and frequency of assay performed:
   ☐ Field measurement instruments. Describe the type of instruments and how they are used to help establish the radionuclide inventory:
   ☐ Scaling factors. Explain how the scaling factors were derived and how they are used:
   ☐ Computer models. Describe the computer model used and how it is used to establish the radionuclide inventory:
   ☒ Other. Describe method: **Ratios such as calculating U-234 and U-236 based on the uranium content and U-235 levels were used as part of the radiological characterization.**

   If several methods are checked above, describe how the methods are used together to establish the radiological inventory of the waste stream. For complex or highly variable waste streams, explain the strategy used to meet the acceptable knowledge requirements of the waste acceptance criteria. **MC&A records, based on historical process sampling, are used for % uranium and % U-235 enrichment. Historical process and specific waste directed sampling and analysis, along with the limited use of ratios, is used for all other radionuclides.**

3. Estimated Radiation Dose of disposal package (mSv/hr):

   Surface **0.9 to 1.8** 30 cm **0.7 to 1.5** One Meter **0.15 to 0.45**

4. (Section D4 need not be filled out for Hanford only profiles)
   ☒Yes ☐No Does the waste contain enriched uranium (^{235}U wt% ≥ 0.90), ^{233}U, ^{239}Pu, ^{241}Pu, ^{242m}Am, ^{243}Cm, ^{245}Cm, ^{247}Cm, ^{249}Cf, ^{251}Cf? If yes, answer the following and check those that apply for compliance with the criticality safety criteria of the NTSWAC. If no, skip to Section D.5.

4.1 ☒ Attach completed NTSWAC, Appendix E, Table E.3, ^{235}U FGE and ^{235}U Effective Enrichment, for each enrichment level or range.

4.2 ☒ Waste package contains 15 g of ^{235}U FGE or less.
Specify controlling document: **WM:CHAR-T-0001, waste contains natural uranium at 0.711% U-235 and small amounts of U-233. See Table E.3.**

4.3 ☐ Fissile material does not exceed 350 g of ^{235}U FGE per package nor does it exceed 2 g of ^{235}U FGE per kilogram of waste (mass of the package is not included in the mass of the waste) (graphite and beryllium must not exceed 1% of the mass of the waste).
Specify controlling document:

4.4 ☐ Waste complies with the limits and conditions as specified in NTSWAC, Appendix E, Table E.4.
Specify controlling document:

4.5 ☐ Graphite and beryllium exceeds 1% of the mass of the waste.

4.6 ☐ Waste complies with the limits and conditions as specified in NTSWAC, Appendix E, Tables E.5 and E.6. Specify controlling document:

4.7 ☐ A waste specific nuclear criticality safety evaluation (NCSE) was performed to show compliance with the NTSWAC, Section 3.2.1. Attach NCSE for review and specify controlling document.

5. Reportable radionuclides. List the radionuclides that could be reportable in the waste stream:
☒ If the nuclides vary greatly from container to container, check this box and provide bounding values or ranges here. Further evaluation will occur on the specific package paperwork as it is provided for highly variable streams. *Note: For the NTS, concentrations must be entered in Becquerel/cubic meter.*

Isotope	Concentration Ci/m3 (**Bq/m3**); Range and Activity Representative of Final Waste Form			
	Activity Range			Representative
U-233	**(1.2E+01)**	**to**	**2.3E+09**	**4.2E+08**
U-234	**(1.2E+01)**	**to**	**3.5E+10**	**2.9E+08**
U-235	**(1.2E+01)**	**to**	**1.6E+09**	**1.3E+07**
U-238	**(1.2E+01)**	**to**	**3.5E+10**	**2.9E+08**
Th-230	**(1.2E+01)**	**to**	**3.4E+10**	**6.1E+09**
Th-232	**(1.2E+01)**	**to**	**4.8E+10**	**6.4E+09**
Pu-238	**(2.5E+01)**	**to**	**2.5E+09**	**4.5E+08**
Np-237	**(2.5E+01)**	**to**	**4.5E+07**	**8.1E+06**

6. Does the waste contain any alpha-emitting transuranic radionuclides with a half-life greater than 5 years, ^{241}Pu, or ^{242}Cm? **YES** If yes, list below.

Transuranic Nuclide	Concentration (nCi/g); Range and Activity Representative of Final Waste Form			
	Activity Range			Representative
Pu-238	**(2.0E-04)**	**to**	**8.3E+0**	**5.2E+0**
Pu-239	**(2.0E-04)**	**to**	**4.4E-01**	**2.8E-01**
Pu-241	**(2.0E-04)**	**to**	**1.0E+0**	**6.7E-01**
Am-241	**(2.0E-04)**	**to**	**1.2E-01**	**7.2E-02**
Np-237	**(2.0E-04)**	**to**	**1.6E-01**	**9.3E-02**

7. Are there any packages in this waste stream that exceed the Plutonium Gram Equivalent limits specified in NTSWAC, Section 3.2.2? Yes ☐ No ☒
Provide container type(s), quantity, and supporting PGE calculations. **PGE calculations attached.**

8. For Hanford only, Total FGE as defined in Hanford Site Solid Waste Acceptance Criteria, HNF-EP-0063.

E. Packaging

1. Packaging used. Check the applicable boxes.

☒ Drum; describe size(s), type, and weight range: **30 gal, metal drum, 21 kg to 227 kg; 55 gal, metal drum, 45 kg to 440 kg; all drums are either excepted packaging, IP2 or 7A packages**

☒ Metal box; describe size(s), type, and weight range **Nominal 4'x4'x7', 200 kg to 4082 kg, boxes are either excepted packaging, IP2 or 7A packages**

☐ Wood box; describe size(s), type, and weight range:
Do the Metal or Wood boxes meet the 3,375 lb/ft^2 strength test? Yes **X** No ☐ N/A ☐

☐ High integrity container; describe size(s), type, and weight range:

☐ Intermodal transport container; describe size(s), type, and weight range:

☐ Other container; describe size(s), type, and weight range:

Waste Profile Sheet

- ☐ Bulk waste – bulk package and shipment dimensions and weight ranges – describe (supersack, burrito wraps, equipment, etc.):
- ☒ Vented; describe type of venting: **As required, 3/4" to 2" NucFil for drums, 2" NucFil for boxes.**
- ☐ Shielded; describe type of shielding:
- ☒ Sorbents; describe type and amount used: **As required in procedure PT-0011 and/or WM:PKGG-A-0002. Three types of absorbents acceptable: lime (8-104 lbs.), QuikSolid granular (1-12 lbs.) or Stergo/Quiksolid pads (2 layers).**
- ☐ Radiologically stabilized in concrete or other stabilization agent; describe type and amount of material used and provide data to demonstrate waste meets stabilization criteria:

2. Maximum container size: **1.22m x 1.22m x 2.44m**

3. Maximum container gross weight: **4082 kg**

4. Describe any liners/protective coatings used to ensure that the container is compatible with the waste: **NA**

5. Does each container meet each of the package criteria as defined in the waste acceptance criteria?
   ☒ Yes ☐ No
   List documentation that demonstrates compliance with waste acceptance criteria.

The Fernald controlling document is PT-0014, Procurement of Storage and Shipping Containers. Container specific test data is available upon request.

6. Reference any special handling procedures and ALARA documentation, if applicable. **Occupational ALARA Plan - FEMP Thorium Legacy Waste Project (TLWP) LLW Operations 80100-PL-0012**

F. Additional Information

1. Comments: **NA**

2. Exception or Deviation Request to waste acceptance criteria: Complete if needed
   a) Identify specific requirement for which an exception or deviation is desired:
   b) Provide reason an exception or deviation is needed:
   c) Describe any proposed alternative methods to meet the general intent of the requirement:

3. Attachments. List any attachments provided with this profile: **Document Reference List, Table E.3, PE-g Calculations, Process Knowledge Narrative, Table B-1, Chemical Form of Radionuclide List**

G. Generator Signatures

To the best of my knowledge, the information provided on this form and the attached documentation is a full, true and accurate description of the waste stream. Willful and deliberate omissions have not been made. All known and suspected hazardous materials have been disclosed.

Technical Contact Name: **David S. Adkins** Date: 11/23/04

Signature: David S. Adkins

Waste Certification Official Name: **Reinhard Friske** Date: 11-23-04

Signature: Reinhard Friske

Profile ONLO-000000117, Revision 7

Table 1
Analytical Results

The analytical data in this table are supported by the analytical data found in MEFs 40215, 40218, 40219, 40220, 40221, 40222, 40223, 40224 and 40228. The sampling and analysis plans involved are 95-991, 95-993, 96-1344, 96-1335, 96-1347, 96-1338, 96-1334, 96-1332, 96-1333, 96-1325, 96-1330, 96-1339, 96-1345, 96-1346, 97-1419, 96-1326, 96-1341, 96-1340, 96-1327 and Th-08. The values used in this table were selected from the highest detected values for each metal from the listed sample plans.

TCLP Metals	**Mean Concentration (mg/l)**	**90% Upper Confidence Limit for the Mean Concentration (mg/l)**
Arsenic	Non-detect*	Non-detect*
Barium	15.94	27.081
Cadmium	0.1202	0.2344
Chromium	0.7965	1.1121
Lead	0.7809	1.2499
Mercury	0.0239	0.0597
Selenium	0.2640	0.4883
Silver	0.5094	1.0927
TCLP Volatiles: Analyses not performed based on process knowledge of the material.		
TCLP Semi-volatiles: Analyses not performed based on process knowledge of the material.		
TCLP Pesticides and Herbicides: Analyses not performed based on Process knowledge of the material.		
*** Contract required detection limit is 0.5 mg/l**		

Document Reference List
for
Profile ONLO000000117, Revision 7

EW-0001	MEF Characterization Process Procedure
EW–1016	Waste Management Work Authorization Program
RM-0053	Waste Characterization Information Manual
PL-3048	Prototype Sampling and Analysis Plan for Waste at the FCP
PT-0014	Procurement of Storage and Shipping Containers
PT-0018	Preparation of Documentation for Off- Site Shipment of Hazardous Material
WM:CHAR-T-0001	Radiological Characterization for Waste Disposal
WM:PKGG-A-0001	Certification of Low Level Radioactive Waste and Supporting Paper Work
WM:PKGG-A-0002	Absorbent Determination
WM:PKGG-T-0026	Safeguards for Handling Hydrogen and Methane Gas-Generating Materials, Pyrophoric Materials, and Bulging/Pressurized Containers
WM:SHIP-T-0003	Inspection of Waste Packages and Loaded Transport Vehicles
80100-PL-0012	Occupational ALARA Plan, FEMP Thorium Legacy Waste Project (TLWP) LLW Operations

PROFILE ONLO-000000117, Revision 7
Section E.5 - Chemical Form of Radionuclide List

1. MEF 40206	Thorium Metal
2. MEF 40215	Thorium Tetrafluoride Powder
3. MEF 40218	Thorium Dioxide Pellets
4. MEF 40219	Thorium Hydroxide Powder
5. MEF 40220	Thorium Dioxide Powder
6. MEF 40221	Thorium Dioxide Powder
7. MEF 40222	Thorium Dioxide Scrap
8. MEF 40223	Thorium Dioxide Miscellaneous
9. MEF 40224	Thorium Dioxide Dust Collector Residues
10. MEF 40228	Thorium Ore Concentrates

Table E.3: Calculation of U^{235} Fissile Gram Equivalence and Effective U^{235} Enrichment for LLW Packages

Nuclide (A)	High Activity Conc. (Bq/m3) (B)	Volume of Package (m^3) (C)	Activity (Bq) (D)	Specific Activity (Bq/g) (E)	Mass of Isotope (g) (D/E=F)	U^{235} FGE Factors (G)	U^{235} FGE (FxG=H)	If FGE is >1% of U^{235} Mass, then include (I)
U^{233}	2.30E+09	6.90E-01	1.6E+09	3.6E+08	4.4E+00	1.4E+00	6.2E+00	6.2E+00
U^{235}	0.00E+00	6.90E-01	0.0E+00	8.1E+04	0.0E+00	1.0E+00	0.0E+00	
Pu^{239}			0.0E+00	2.3E+09	0.0E+00	1.6E+00	0.0E+00	
Pu^{241}			0.0E+00	3.8E+12	0.0E+00	3.5E+00	0.0E+00	
Am^{242m}			0.0E+00	3.6E+11	0.0E+00	5.4E+01	0.0E+00	
Cm^{243}			0.0E+00	1.9E+12	0.0E+00	7.8E+00	0.0E+00	
Cm^{245}			0.0E+00	6.4E+09	0.0E+00	2.3E+01	0.0E+00	
Cm^{247}			0.0E+00	3.5E+06	0.0E+00	7.8E-01	0.0E+00	
Cf^{249}			0.0E+00	1.5E+11	0.0E+00	7.0E+01	0.0E+00	
Cf^{251}			0.0E+00	5.9E+10	0.0E+00	1.4E+02	0.0E+00	
Effective U^{235} Enrichment =			**Total U^{235} FGE/Total grams uranium**				**TOTAL U^{235} FGE**	**6.2E+00**
			Effective U235 Enrichment =			**1.51**		

Waste volume of 0.69 m3 represents maximum placed in a box before weight limit is reached. Uranium in this waste is natural at 0.711% U-235. Effective U-235 enrichment calculation is worse case with U-233 at max and uranium at minimum (6.2/(9000 • 0.0001 • 453.49) • 100).

Plutonium Gram Equivalent Calculations for
Reportable Isotopes included in NTS Profile ONLO-000000117, Rev.7

Isotope	Package Activity, Bq/m3	PE-g Conversion Factors	PE-g/m3
U-238	3.50E+10	1.02E-10	3.57E+00
U-235	1.60E+09	1.05E-10	1.68E-01
U-234	3.50E+10	1.13E-10	3.96E+00
U-233	2.30E+09	1.15E-10	2.65E-01
Th-232	4.80E+10	1.39E-09	6.67E+01
Th-230	3.40E+10	2.77E-10	9.42E+00
Pu-238	2.50E+09	3.90E-10	9.75E-01
Np-237	4.50E+07	4.60E-10	2.07E-02
		PE-g/m^3 =	**8.51E+01**
			< 190.5 PE-g/m^3
Drum (30 gal) Waste Volume (m^3) =	4.00E-02	**Drum Total PE-g =**	**3.40E+00**
			<< 300 PE-g total
Drum (55 gal) Waste Volume (m^3) =	7.00E-02	**Drum Total PE-g =**	**5.96E+00**
			<< 300 PE-g total
Box Waste Volume (m^3) =	6.90E-01	**Box Total PE-g =**	**5.87E+01**
			< 300 PE-g total
Used profile max and container max. Containers set at max weight. With projected volume of 4 cubic meters per year, cannot exceed 750 PE-g per shipment.			
Meets package activity limits in 3.2.2 of NTSWAC, rev.5.			

ONLO-000000117, Revision 7 Process Knowledge File Narrative

Determination:

Low-level radioactive, thorium waste

Description:

Profile number ONLO-000000117 represents the thorium waste inventory stored at the Fernald Closure Project (FCP). This profile addresses miscellaneous thorium metal, thorium compounds, process residues, dust collector bags/residue and thorium-contaminated materials such as personal protective equipment and associated project trash. The profile incorporates the FCP inventory of thorium waste that is characterized under MEFs 40206 40215, 40218, 40219, 40220, 40221, 40222, 40223, 40224, and 40228. These materials were generated from various facilities within the DOE complex and thorium processing and thorium waste handling operations at the FCP.

Process Generating the Waste:

Historical Overview

In 1942, a new fissionable isotope of uranium (U-233) was discovered from the thermal neutron irradiation of natural thorium. Reactor tests were conducted as part of the Manhattan Project to study U-233 production because U-233 has a fission cross-section comparable to U-235. The role of the FCP, during the 1950s, was to provide the thorium metal products for this nuclear research. In the early 1960's, development work was begun for the Light Water Breeder Reactor (LWBR), which required a large quantity of very pure dense thorium dioxide (thoria). Thorium processing operations were conducted at the FCP to produce metal, high-purity thorium dioxide, and a variety of other compounds and forms during a twenty-five year period ending in 1979.

FCP Thorium Products, Intermediate Compounds, and Process Residues

Thorium process operations were conducted primarily for the production of thorium metal for the Savannah River Site, thorium metal derbies for Y-12 at the Oak Ridge Site, thorium dioxide initially for Hanford and later for the Bettis Atomic Power Laboratory, and a variety of intermediate pure thorium compounds. The source of thorium feed materials to support these programs was either in the form of high-grade thorium tetrafluoride (ThF_4) or impure thorium nitrate tetrahydrate crystals received from offsite. Thorium nitrate was purified by

solvent extraction. The purified solution became the starting point for producing thorium oxide via either the sol-gel or oxalate processes for eventual conversion to thorium dioxide and thorium tetrafluoride for metal production.

Process operations generated various forms of thorium scraps and residue byproducts that were either retained in storage for potential future use, discarded to the waste pits, sent offsite for burial because of low intrinsic value, or discharged as liquid effluents after treatment in the General Sump. Process residue recovery operations were performed, as required, to maintain the inventory of stored materials.

As the designated national repository for surplus thorium materials, the FCP received a variety of unirradiated thorium metal, thorium compounds, scraps, and solutions held in storage at other DOE sites. Although the exact processes used to produce the surplus thorium materials are not known, for the purpose of this profile it is assumed the production processes were comparable to those used at the FCP. This material, as well as thorium materials produced at the FCP, were stored for potential thorium recovery until 1992 when DOE declared the material waste.

FCP Thorium Metal Production

Thorium operations at the FCP began in 1954 with metal production in Plant 9 using calcium metal to reduce thorium tetrafluoride in a thermite reaction:

$$ThF_4 + 2\,Ca \rightarrow Th + 2CaF_2$$

Thorium metal product was shipped to Savannah River and other sites until this initial program was curtailed in 1956.

Thorium metal production was resumed in 1970, using Pilot Plant facilities to produce thorium derbies via a modified reduction process that used zinc fluoride (ZnF_2).

$$ThF_4 + ZnF_2 + 3Ca \rightarrow ThZn + 3CaF_2$$

The thorium-zinc alloy derbies were dezinced in vacuum induction furnaces by placing the derbies in graphite pots and vaporizing the zinc (see Figure 1). Thorium metal derbies were shipped to the Oak Ridge site.

Assorted scrap materials were generated from the metal production and fabrication steps from onsite and offsite operations. These include ingot crops, partially oxidized metal, miscellaneous solid pieces, metal spills, extrusion ends, clad metal, derbies, and metal samples.

Thorium metal derbies and thorium scrap metal are included in this profile and characterized by MEF 40206.

Solvent Extraction Purification

In 1965, a solvent-solvent extraction, purification process was developed and was fully implemented in the Pilot Plant during the following year. The development flowsheet consisted of a two-stage extraction process that utilized di-amylamyl phosphonate (DAAP) as the first stage extractant to separate both thorium and uranium from metallic impurities. This was followed by the use of di-sec-butylphenyl phosphonate (DSBPP) in the second stage to separate thorium and uranium. Eventual process improvements led to eliminating the need for the second stage solvent system, as shown in Figure 2.

Raffinate treatment was part of the purification process. Naturally occurring Radium-228 that was present in thorium feed materials was not extracted by the DAAP solvent and was discharged in the aqueous raffinate waste stream. Soluble radium was precipitated by treating raffinate with barium sulfate, which was later replaced by barium carbonate because of its greater solubility in water. Treated raffinate was then filtered to remove the radium sump cake that was drummed for burial in Pit 4. Filtered raffinate was pumped to the General Sump for lime neutralization before disposal to Pit 5.

Approximately, 540 tons of thorium (as thorium nitrate) were purified by the DAAP solvent extraction process to support all programs until purification operations were completed in 1972. The purification process was an integral part of producing thorium dioxide, initially by the sol-gel process for Hanford and later oxalate precipitation for Bettis. Additionally, thorium nitrate served as feedstock for production of thorium tetrafluoride used in the production of thorium metal.

Thorium Dioxide Production Via Sol-Gel Process

The FCP processed thorium nitrate to thorium hydroxide in the Pilot Plant starting in 1967. In the thoria gel process, thorium nitrate feed liquor was mixed with an aqueous ammonia solution to produce a thorium hydroxide precipitate:

$$Th(NO_3)_4(sol'n) + 4NH_4OH(sol'n) \dashrightarrow Th(OH)_4 + 4NH_4NO_3(sol'n)$$

After the precipitation was completed, the slurry was pumped through a plate and frame filter press where the thorium hydroxide was removed from the mother liquor, and subsequently dried in a tray dryer (see Figure 3).

Following conversion, the thorium hydroxide was sent to General Electric-Evendale for oxidation to thorium dioxide and the fabrication of thorium dioxide wafers . The wafers were fabricated to serve as spacers between thorium dioxide vibratory compaction powder and weld closures. About 300 tons of thorium dioxide for Hanford was produced at the FCP until the conclusion of this campaign in 1969.

Thorium Dioxide Production Via Oxalate Process

Conversion operations were resumed in 1970 and continued until 1976 to support the Bettis Light Water Breeder Reactor. During the campaign approximately 400 tons of thorium oxalate were produced from thorium nitrate received from a French source. Thorium dioxide production via oxalate precipitation began with the reaction of thorium nitrate solution with oxalic acid to produce a thorium oxalate precipitate:

$$Th(NO_3)_4(sol'n) + 2H_2C_2O_4(sol'n) \rightarrow Th(C_2O_4)_2\ 6H_2O(s) + 4HNO_3(sol'n)$$

The slurry was pumped to a plate and frame filter press where the thorium oxalate was removed from the mother liquor. Before it was removed from the filter press, the thorium oxalate filter cake was washed with deionized water and blown with compressed air to remove free liquid (see Figure 4). The oxalate was sent to General Electric-Evendale for firing to thorium dioxide. The thorium dioxide produced at Evendale was returned to the FCP for shipment to Bettis (see Figure 4).

Thorium dioxide from onsite operations, previously discussed, and received from offsite are addressed by this profile and characterized in MEFs 40218, 40220, 40221, 40222, and 40223.

Thorium Tetrafluoride

Thorium tetrafluoride (ThF_4) was a high-purity intermediate compound needed for the production of thorium metal. In the early production of thorium metal, thorium oxide was produced in Plant 9 by a wet way process and converted to ThF_4 in Plant 4. Later, operations were conducted in the Pilot Plant via a 2-stage, wet-way precipitation process, as follows:

$$\text{Pure } Th(NO_3)_4 + 4\ HF_{(aq)} \rightarrow ThF_4 \cdot (x)H_2O + 4\ HNO_3$$

After recovery of the hydrated salt by filtration, the material was dried at 177° C in air to a moisture content of 1 or 2 percent. The ThF_4 was then thoroughly dehydrated in batch tray retorts by heating in the range of 425° to 540° C under flows of nitrogen and anhydrous HF to prevent oxidation or pyrohydrolysis (see Figure 5).

Much of the thorium tetrafluoride in this profile was generated by this process. Additional thorium tetrafluoride was received from off-site sources for storage. This material is characterized by MEF 40215.

Storage of Scrap Thorium Dioxide in Plant 8 Bins and Silo

This thorium material was shipped to the FCP in the mid-1970s and placed into two storage bins and a silo located at Plant 8. The bins and silo were previously used for storage of uranium compounds. Prior to placing the thorium material in each for storage, the uranium compounds were removed leaving a small build up of uranium material on the inner surfaces. Due to structural safety concerns with the silo and radiation exposure concerns with the storage location, a removal and decontamination project was conducted in 1989. The residues were removed from the bins and the silo, overpacked into one hundred forty-four drums (lot codes 800-T100-0001 thru 0003), and stored in Building 60. Due to the residual uranium remaining in the bins and silo from prior use, the thorium waste from these storage areas contains uranium contamination ranging from 0.326% U to 38.77% U (MC&A Survey 89-2, Table V). These materials are included in the profile and characterized in MEF 40223.

Additional Thorium Materials

As potential feedstock for thorium programs, the FCP received several shipments of thorium material from offsite sources. Thorium hydroxide slurry was received from the Middlesex Storage Facility in Brunswick New Jersey. It was filtered and subsequently dried in a calciner at Plant 8. After drying, the thorium hydroxide filter cake was containerized and placed into storage. Additionally, thorium ore concentrates from the General Atomic Storage Facility in Youngsville North Carolina were received by the FCP and placed into storage. These materials are included in the profile. MEF 40219 characterizes thorium hydroxide and MEF 40228 characterizes the thorium ore concentrates.

Additionally, to support the previously described thorium process operations in the Pilot Plant and thorium process operations at various offsite facilities, dust collectors were employed to reduce thorium airborne contamination. Dust collector waste is included in this profile. MEF 40224 characterizes dust collector residues and dust collector bags.

Radiological/Chemical Composition:

Thorium extraction operations at the FCP ceased in 1972, so Th-232 decay products have had the opportunity for appreciable in-growth. The longest-lived radionuclide in the Th-232 decay chain is Ra-228 with a half-life of 5.75 years. Consequently, since the last chemical separation, sufficient time has elapsed for the thorium decay chain members to achieve approximately 97% of their equilibrium values. It may be assumed for most purposes, that activities of the Th-232 and its decay products are equal.

Although the specific sources varied, much of the thorium processed or stored at the FCP was derived indirectly from thorium ores. As a part of the refining process, the thorium

was separated from its decay products and other elements such as uranium. Specifications for products from the thorium processing at the FCP required that uranium content be less than 3 ppm. For material derived from ore, the uranium would be naturally-occurring uranium present in the ore that was not completely removed during the refining operations. Some material received was greater than that concentration so it was often subjected to a solvent extraction process that removed the excess uranium from the as-received thorium. Wastes at the FCP that consist of unused product that was returned for storage can be assumed to have concentrations below 3 ppm. Documentation of the exact concentrations of the uranium in the as-received material is unavailable for all materials, but initial processing can be expected to have limited the concentration to less than 100 ppm. While the majority of the waste in this profile falls below a concentration of 100 ppm uranium, an upper limit of 50% natural uranium will be used for all thorium wastes associated with this profile. This value is the result of the uranium contaminated thorium waste from Plant 8 bins and silo. Additionally, analytical results indicate that some of the thorium wastes contain higher than expected concentrations of Pu-238 and Pu-239. Due to the fact the thorium inventory covered by this profile does not contain irradiated thorium, it is surmised that some thorium materials were contaminated with transuranics after production.

Thorium metal waste covered by this profile includes clad thorium metal, derbies, ingot crops, partially oxidized metal, miscellaneous solid pieces, and metal spills. Although the content of the metal is 100% thorium, some metal waste includes partially oxidized metal and related production wastes such as sample mounts, graphite and ceramic crucibles, miscellaneous lab equipment, etc. As a result, the thorium content of some metal waste is less than 100%.

Additionally, the metal waste included in this profile has a low surface area to volume ratio and consequently is not considered potentially pyrophoric material or material that requires special caution (reference WM:PKGG-T-0026). It does, however, have the potential for generating hydrogen gas if confined in moist air for an extended period of time (reference WM:PKGG-T-0026). The hydrogen gas generation rate is affected by the amount of available metal surface area, the presence of moisture, and temperature. Consequently, it is difficult to estimate the amount of hydrogen gas that can be produced within a container and the potential to exceed Lower Flammability Level (LFL) for hydrogen. Nonetheless, procedure WM:PKGG-T-0026 requires that all containers of material that have the potential to generate flammable gases are vented. The presence of a vent allows the container headspace to respire with the external atmosphere, mitigating the potential to generate an atmosphere within the container that is above the LFL for hydrogen. Data on container headspace sampling has demonstrated that the presence of a vent prevents the generation of a flammable atmosphere in the container headspace. EW-1016, which is the controlling document for the FCP Waste Management Work Authorization Program, requires, in part, special packaging requirements be addressed in project specific work authorization packages. Per EW-1016 and related work authorization packages, all containers with hydrogen generating material will be vented and the vents visually inspected for physical damage prior to shipment to the NTS.

Thorium compounds covered by this profile include thorium dioxide, thorium hydroxide, and thorium tetrafluoride. The following table presents the approximate percent thorium concentrations in the pure thorium compounds. Thorium dioxide is theoretically 87.9 wt% thorium. Some of the thorium dioxide is clad in zirconium, aluminum, or stainless steel. Therefore, the actual thorium content of the waste will vary.

Compound	% Thorium
Thorium dioxide	87.9
Thorium hydroxide	77.3
Thorium tetrafluoride	75.3

Thorium process residues included in this profile are dust collector bags, and dust collector residues. Thorium dust collector waste is a fine particulate waste as defined by NTSWAC. To comply with subsection 3.1.6 of the NTSWAC, this waste will be shipped to NTS in secure packaging consisting of metal drums overpacked into metal boxes.

Project related trash and inert filler material (vermiculite, sand, etc.) is included in the waste package to reduce void space and increase structural stability of the waste form, as practical. The added volume is not included in the estimate of the waste volume used in calculating volume activity concentrations. This yields a conservative value for the volume activity concentrations.

The wastes included in this profile do not meet the listing descriptions for F, K, U, or P listed waste. Based on knowledge of thorium processing operations, no F, K, U, or P listed wastes were mixed with the thorium wastes, nor were the thorium wastes derived from F, K, U, or P listed wastes.

No waste included in this profile meets the regulatory criteria for the characteristic of ignitability, corrosivity, or reactivity. Based on process knowledge, no RCRA toxicity characteristic organics are known to be associated with these wastes. Furthermore, the wastes covered by this profile, with the exception of thorium metal waste, were subjected to confirmatory sampling for RCRA toxicity characteristic metals. The results of the sampling indicate the waste does not exhibit any toxicity characteristics for metals.

With regard to thorium metal, as discussed in the Solvent Extraction and Thorium Tetrafluoride sections of this PKN, thorium nitrate and thorium tetrafluoride were intermediates in the production of thorium metal. Manufacturing specifications for thorium nitrate (FMPC-149 and 11-BE-420-17) list maximum concentrations for RCRA metals on a thorium basis (maximum thorium in thorium nitrate is 45%). Derived TCLP concentrations for listed RCRA metals are: arsenic - 0.11ppm, cadmium – 0.023 ppm, chromium – 2.7ppm, lead – 1.13ppm, and silver - 0.11ppm. In addition, sampling on thorium tetrafluoride (SAPs Th-06 and 96-1344) report the highest TCLP concentrations for RCRA metals as: arsenic - <0.01ppm, barium - 1.36ppm, cadmium - 0.593ppm, chromium - 0.13ppm, lead - 0.6764ppm, mercury – non-detect (contract required detection limit was

0.02ppm), selenium - <0.0131ppm, and silver - <0.01ppm. Based upon the concentrations of RCRA metals in the intermediates for thorium metal, RCRA toxicity characteristic metals are not expected in thorium metal at concentrations that cause thorium metal to exhibit a RCRA toxicity characteristic.

As described previously, thorium, processing operations did not include the use of PCBs. The thorium waste represented under this profile does not include wastes that are classified as asbestos-containing materials or as medical-infectious waste.

Figure 1

SIMPLIFIED FLOW SHEET
FOR THORIUM METAL PRODUCTION
PILOT PLANT

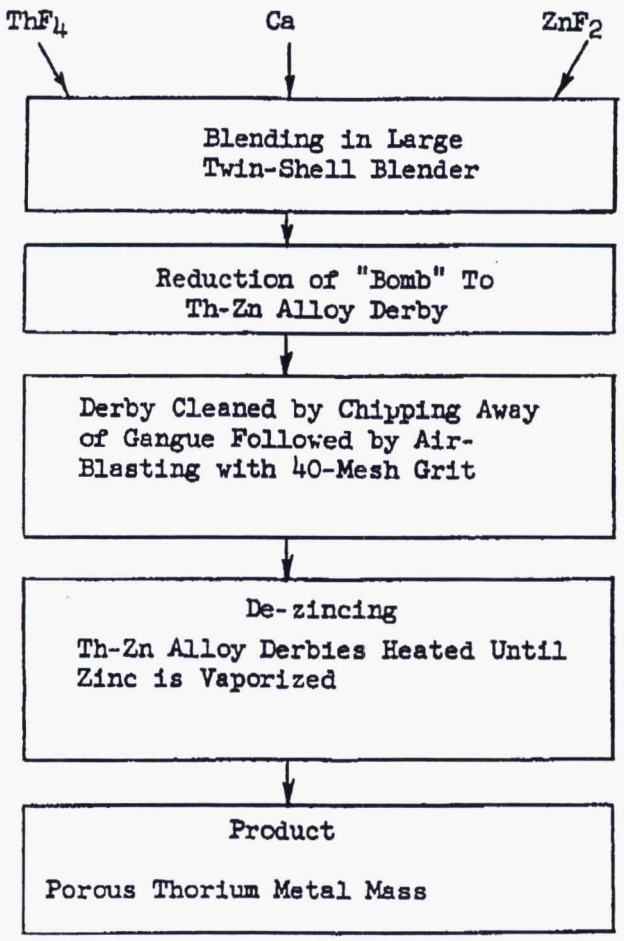


Figure 2

SIMPLIFIED FLOW SHEET FOR THORIUM NITRATE PRODUCTION
- PILOT PLANT

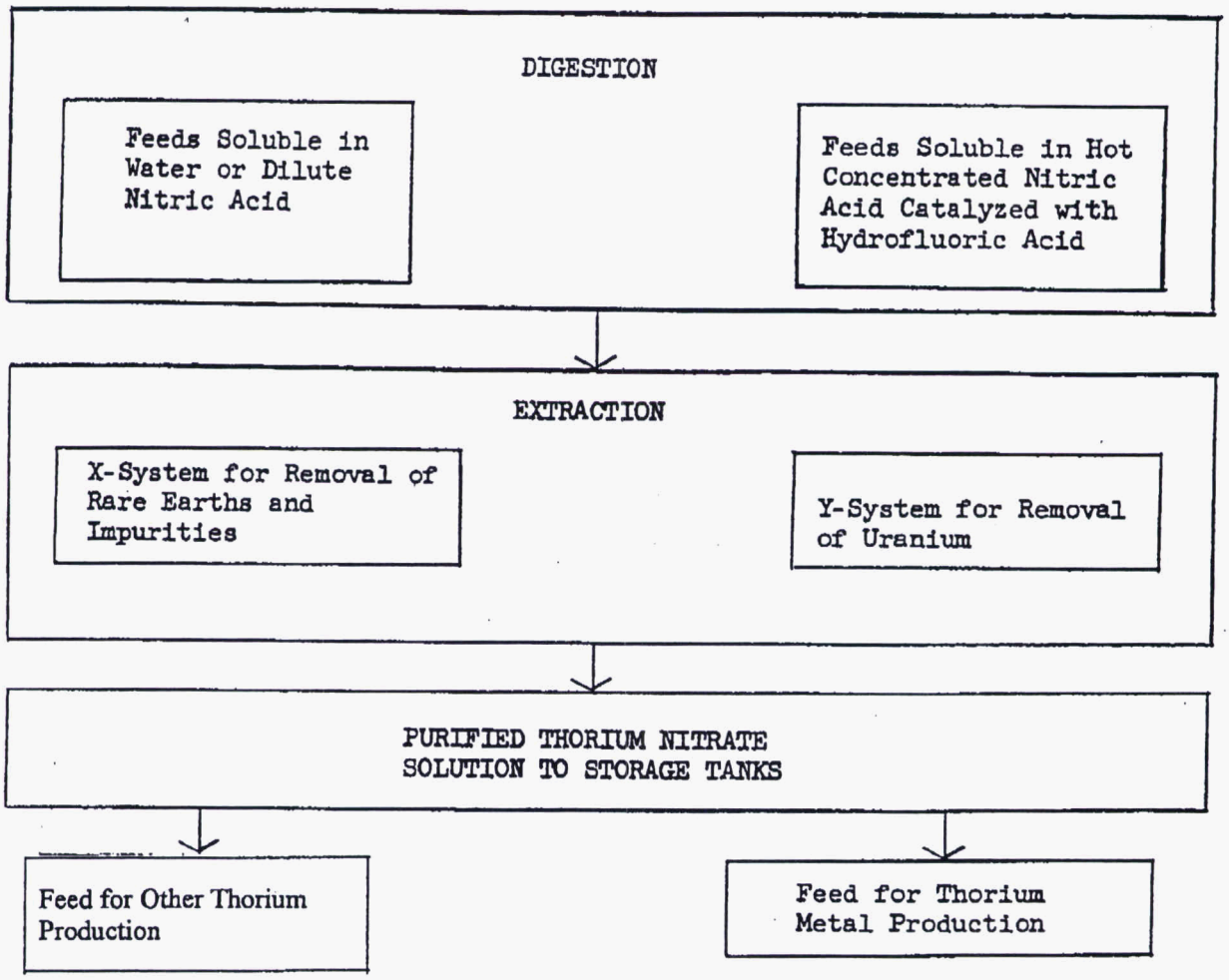


Figure 3

SIMPLIFIED FLOW SHEET FOR THORIA GEL PRODUCTION
PILOT PLANT

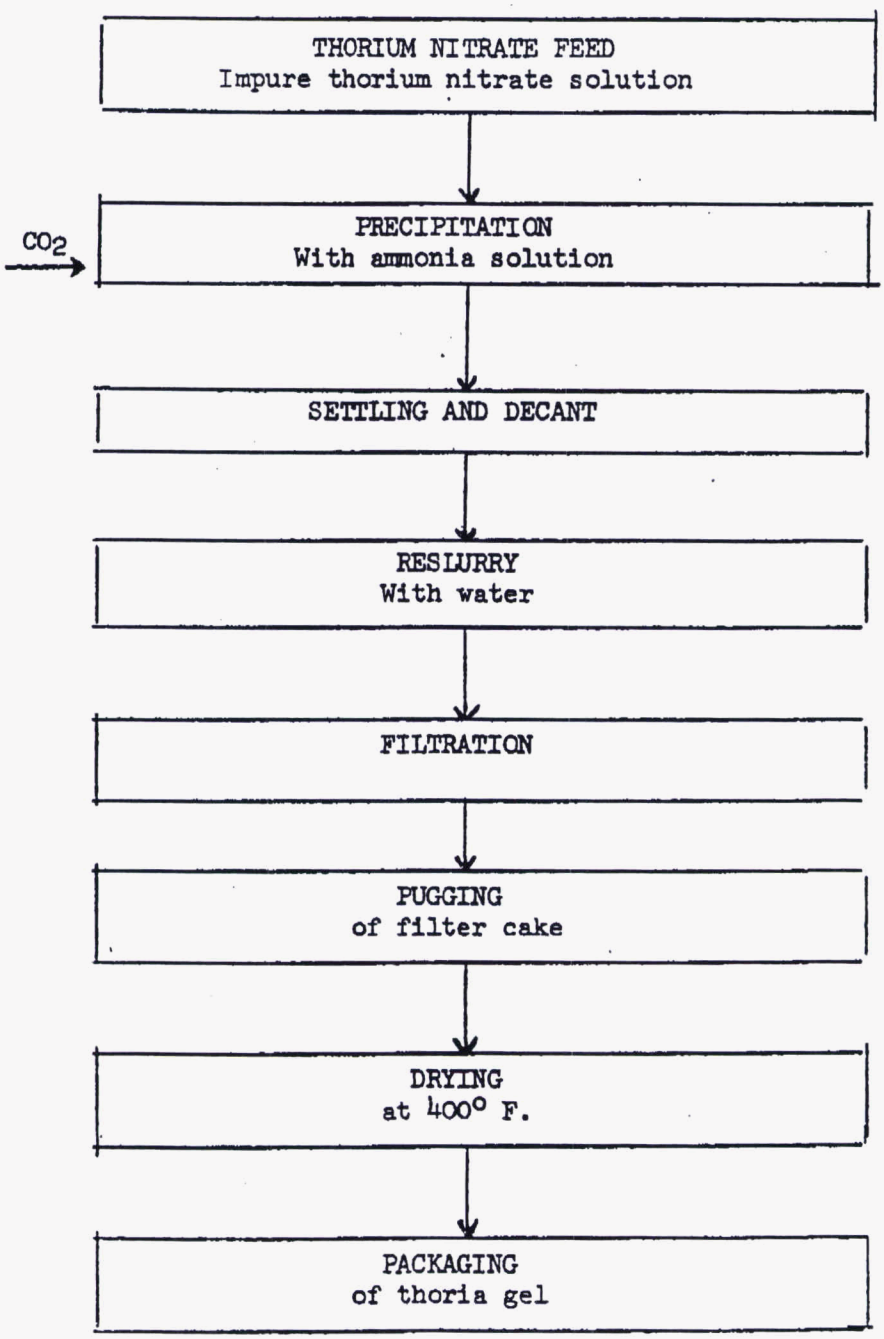


Figure 4

PILOT PLANT - THORIUM OXALATE PROCESS

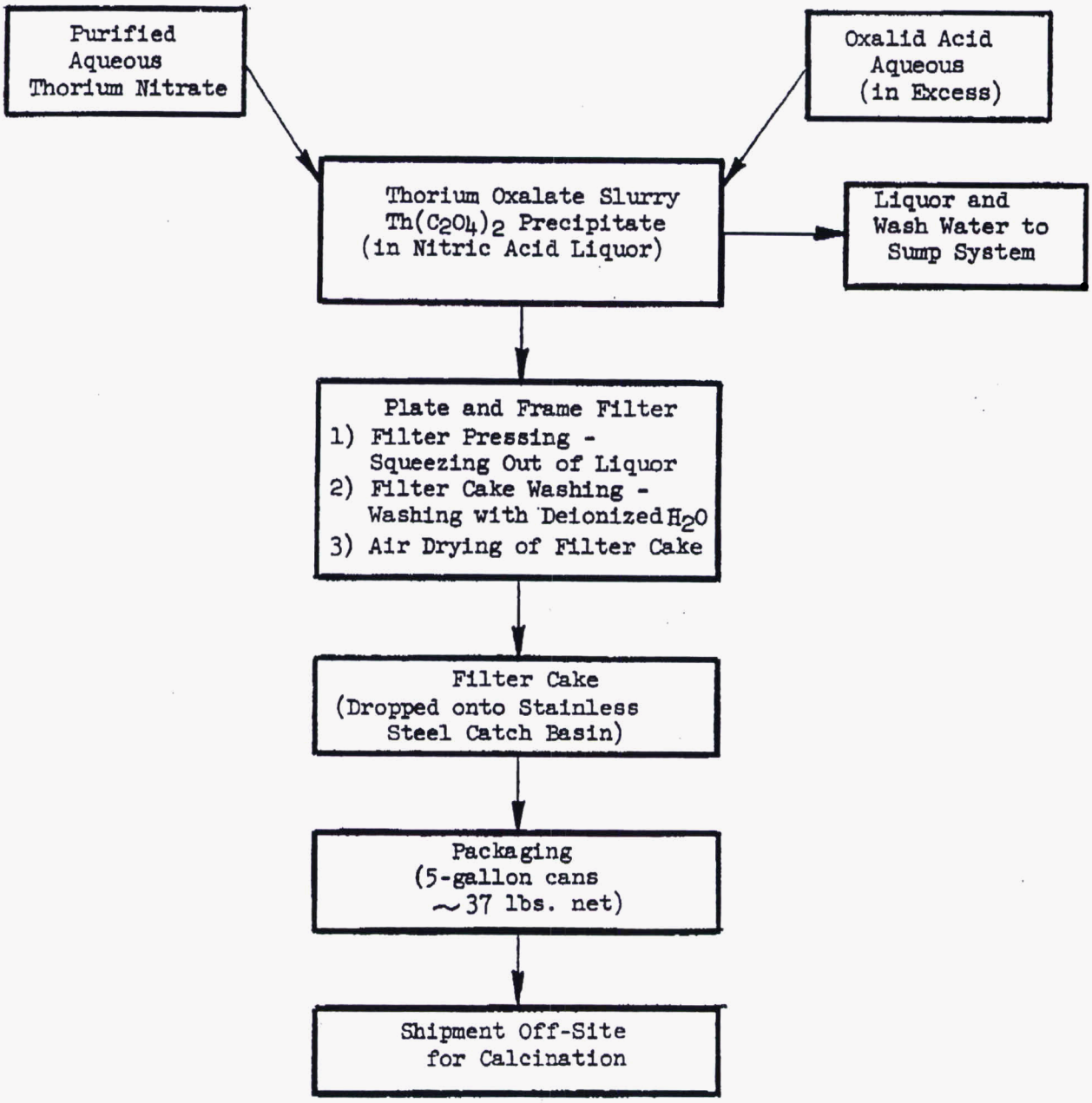
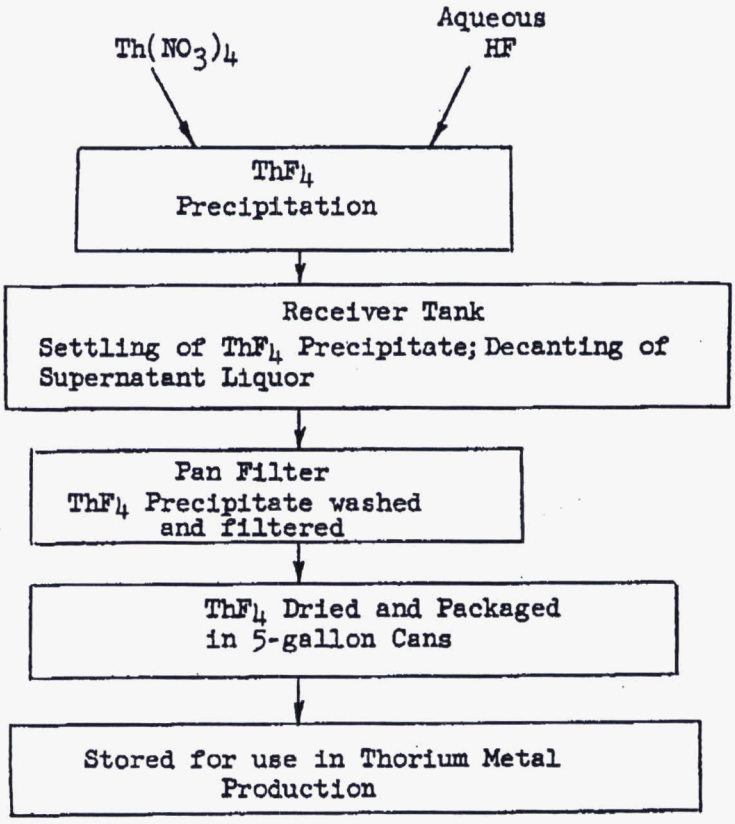


Figure 5

SIMPLIFIED FLOW SHEET
FOR THORIUM TETRAFLUORIDE PRODUCTION
- PILOT PLANT