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Engineering Evaluation of Neutralization and Precipitation Processes Applicable to Sludge Treatment Project

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Abstract: This report presents an engineering evaluation of the neutralization process applicable to treatment of K Basin sludge. The neutralized dissolver solution slurry will be transferred to the TWRS waste tanks for storage. The results of this evaluation show that the neutralized dissolver solution meets TWRS acceptance criteria and batch mixer tanks are recommended for the neutralization process.

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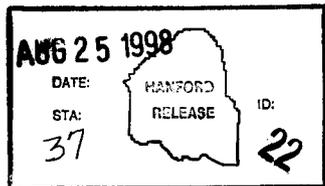


Table of Contents

1.0 INTRODUCTION 1

2.0 SUMMARY 1

3.0 CONSTRAINTS AND ASSUMPTIONS 1

 3.1 Constraints 1

 3.1.1 Regulatory 2

 3.1.2 Tank Farm Waste Acceptance Criteria 2

 3.1.3 Nuclear and Chemical Safety Requirements 4

 3.2 Assumptions 4

 3.2.1 Planned Process Flowsheet 5

4.0 REVIEW OF NEUTRALIZATION AND PRECIPITATION EXPERIENCE 6

 4.1 Hanford Site Experience 6

 4.1.1 Neutralization Methods 6

 4.1.2 Particle Size of Neutralized Hanford Site Waste 7

 4.1.3 Neutralization of Uranyl Nitrate Solution 12

 4.2 Other DOE Site Experience 13

 4.3 Laboratory Tests for K Basin Sludge 14

 4.4 Other World Wide Experience 16

5.0 DESCRIPTION OF NEUTRALIZATION PROCESS TECHNOLOGIES 17

 5.1 Continuous Stirred Tanks 17

 5.2 Static Mixers 17

 5.3 Batch Mixer Tanks 20

 5.4 Distributors 20

6.0 RECOMMENDATIONS 22

 6.1 Process 22

 6.1.1 Neutralization Method 22

 6.1.2 Temperature 22

 6.2 Technology 23

7.0 OPEN ISSUES 23

8.0 REFERENCES 25

APPENDIX A 27

TABLES

3-1 Tank Farm Waste Acceptance Criteria	3
3-2 Key Radionuclides and Other Constituents in Feed Stream to Neutralization	6
4-1 Hanford Production Facility Waste Neutralization Methods	7
4-2 Purex Neutralization Tank Agitators	9
4-3 Particle Sizes in Neutralized and Simulated Zirflex Cladding Waste at Purex	9
4-4 Particle Size in Direct Strike Neutralized and Simulated Redox Waste Cladding Waste	10
4-5 Size of Residual Particles in Supernate from Settling Tests of Simulated Direct Neutralized Current Acid Waste	11
4-6 Particle Sizes Analysis of Simulated Neutralized Current Acid Waste Ripening	11
4-7 Particle Sizes in Simulated Reverse Neutralized Plutonium Finishing Plant Waste	12
4-8 Particle Sizes in Simulated Direct Neutralized Savannah River Site Waste	14
4-7 Particle Size Distributions of Precipitates from Direct Strike Alkaline Treatment of Simulated Dissolver Solutions at 0.01 M Excess NaOH	16

FIGURES

5-1 Continuous Stirred Tank	18
5-2A Two Port and Three Port Vortex Mixers	19
5-2B A Single Vortex Cell Mixing Device	19
5-3 Batch Mixer Tank	21

LIST OF TERMS

CAW	Current Acid Waste
DOE	Department of Energy
DST	Double-Shell Tank
ERDF	Environmental Restoration Disposal Facility
EDTA	Ethylenediaminetetraacetate
HAW	High Activity Waste
HM	Heavy Metal
LAW	Low Activity Waste
NCAW	Neutralized Current Acid Waste
PUREX	Plutonium Uranium Extraction
PFM	Plutonium Finishing Plant
REDOX	Reduction Oxidation
TWRS	Tank Waste Remediation Waste System
TRU	Transuranic
WHC	Westinghouse Hanford Company
ZAW	Zirflex Acid Waste

1.0 INTRODUCTION

Engineering evaluations have been performed to determine likely unit operations and methods required to support the removal, storage, treatment and disposal of solids/sludges present in the K Basins at the Hanford Site. This evaluation was initiated to select a neutralization process for dissolver product solution resulting from nitric acid treatment of about 50 m³ of Hanford Site K Basins sludge. Neutralization is required to meet Tank Waste Remediation Waste System (TWRS) acceptance criteria for storage of the waste in the double shell tanks. After neutralization, the supernate and precipitate will be transferred to the high level waste storage tanks in 200E Area. Non transuranic (TRU) solids residue will be transferred to the Environmental Restoration Disposal Facility (ERDF).

This report presents an overview of neutralization and precipitation methods previously used and tested. This report also recommends a neutralization process to be used as part of the K Basins Sludge Treatment Project and identifies additional operations requiring further evaluation.

2.0 SUMMARY

A batch mixer tank is recommended for the neutralization/precipitation system. This equipment system is simple and has been used at the Hanford Site for neutralization of several waste types for 50 years using a direct strike (addition of NaOH solution to tank of acid solution) or reverse strike (addition of acid solution to tank of NaOH solution) neutralization of acid waste. The reverse strike neutralization method is recommended for good coprecipitation of Pu and Fe and elimination of the gelatinous Al(OH)₃ at pH 4 to 5 by maintaining high alkaline conditions during the entire neutralization/precipitation process. Depending on the size of the tank, agitator speed and mixing characteristics of the alkaline slurry, a distributor may be used for addition of the dissolver product solution to the NaOH in the tank. The distributor would prevent temporary and localized unmixed solution.

Work needs to continue on resolution of uncertainties associated with cost, flexibility, schedule, environmental impact, operation, maintenance and safety of the proposed pretreatment process.

3.0 CONSTRAINTS AND ASSUMPTIONS

This section will describe the constraints and assumptions that define the framework for neutralization of the dissolver solution.

3.1 Constraints

Constraints are requirements that are imposed on the system by outside agencies and are beyond control of design, construction and operating requirements.

3.1.1 Regulatory

The key constraints that will drive the K Basin Sludge Pretreatment process are the Code of Federal Regulations, the Washington Administrative Code, and Department of Energy (DOE) Orders. In addition there are guidelines and specifications that establish engineering requirements deemed necessary for safe design, construction and operation of the system. It is beyond the scope of this evaluation to identify constraints for the neutralization step and transfer of neutralized waste to the tank farms.

3.1.2 Tank Farm Waste Acceptance Criteria

The TWRS neutralization-specific waste acceptance criteria/requirements for the double-shell tanks are given in Table 3.1 (Carothers, et al. 1997, Mulkey 1997). Additional criteria from various sources are also included (e.g. Fe/Pu).

Table 3-1 Tank Farm Waste Acceptance Criteria

Parameter	Specification Limit
1.0 M \leq [NO₃], Temperature \leq 100 ° C	
[OH ⁻] ⁽¹⁾	0.010 M \leq [OH ⁻] \leq 5.0 M
[NO ₂ ⁻]	0.011 M \leq [NO ₂ ⁻] \leq 0.5 M
[NO ₃ ⁻]/([OH ⁻] + [NO ₂ ⁻])	<2.5
1.0 M < [NO₃]\leq 3.0 M, Temperature \leq 100 ° C	
[OH ⁻]	0.1 ([NO ₃ ⁻] \leq [OH ⁻] < 10 M
[OH ⁻] + [NO ₂ ⁻]	\geq 0.4([NO ₃ ⁻])
[NO₃]$>$3.0 M, Temperature \leq 100 ° C	
[OH ⁻]	0.3 M \leq [OH ⁻] < 10 M
[OH ⁻] + [NO ₂ ⁻]	\geq 1.2 M
[NO ₃ ⁻]	\leq 5.5 M
Other	
²³⁵ U	<0.84 wt % of total U
Transuranics	<100 nCi/g TRU supernate ⁽²⁾
Fe/Pu	353 g mole/g mole
Particle size, fissile and poison material	< 50 μ m ⁽³⁾
Particle size, non fissile material	<177 μ m
Specific gravity (comingled)	<1.41
Solids volume	To prevent flammable gas retention, waste tank liquid SpG x total solids depth (in.) <148. 379 m ³ (100,000 gal) of solids can be added to TK-AW-105 before exceeding this requirement.

1) For solutions below 75°C the [OH⁻] maximum limit is 8.0 M.

2) If supernate exceeds TRU limit, DOE waiver may be required.

3) Primary particle size, agglomeration to larger sizes acceptable.

Parameters and control limits for criticality safety in double shell tanks (DST) are documented in WHC, 1995. K Basin sludge has a higher fissile material content than the waste in DSTs, therefore, a criticality feasibility analysis has been completed to define requirements necessary to assure criticality safety (Vail and Daling, 1997). The study concluded that the key control parameters are pH, particle size, uranium 235 enrichment levels, and neutron absorbers. The study concludes that criticality issues for K Basin sludge are resolved by pretreatment of the sludge to ensure particle sizes less than 50 micron, addition of chemicals to ensure the waste is alkaline, and addition of either depleted uranium for isotopic dilution of the ^{235}U or addition of absorbers such as iron for Pu poison. Subcriticality, in non-criticality safe geometries is ensured by maintaining fissile material concentrations below minimum for which criticality is possible (e.g. batch size) or by a subcritical mass ratio of neutron absorbers to fissile material.

3.1.3 Nuclear and Chemical Safety Requirements

The following safety concerns have been identified for the adjustment and neutralization process:

Criticality - The operations in this process must provide an adequate margin of subcriticality to ensure criticality safety. Criticality control in the dissolution step is based on limits for the mass of fissile material in a batch of sludge. Therefore, criticality control for later processing steps, including the adjustment process, is established by the controls used to limit the batch mass in the dissolver provided multiple batching and fissile material buildup in equipment is prevented. The adjustment and neutralization process also includes addition of neutron absorber material (either depleted uranium and/or iron) for criticality control of the solution for transfer to the tank farms.

Confinement - Confinement of radioactive or other hazardous materials involved in the process requires containing the spread of this material to within identified and controlled boundaries preventing, if possible, or helping to minimize the spread to occupied areas, minimizing the releases in facility effluents during normal operations and anticipated occurrences and limiting the releases resulting from design basis accidents.

Reaction Control - Heat is generated during the neutralization process. The rate of heat generation must be controlled to ensure process control and prevent excessive temperatures or pressures to challenge to the containment boundary.

Flammable Gas - The concentration of hydrogen gas must be maintained below the flammable limit. Hydrogen gas can be generated as a result of radiolysis of the water.

3.2 Assumptions

Assumptions were made for areas where limited information is available and the required analysis has not been completed. The main assumptions used in this evaluation are described below.

3.2.1 Planned Process Flowsheet

The planned flowsheet for processing K Basin sludges includes resins separations, sludge dissolution, solid separation, and neutralization/precipitation as discussed in the system description (Westra 1998). The block diagram and stream data for the whole flowsheet are documented in Westra 1998. The data important to the neutralization process are given in Table 3-2 for nominal sludge from the K East and K West Basins. The detailed composition of the streams are provided in Appendix A.

After separation of ion exchange resins, the sludge will be processed in a dissolver where uranium, iron and other compounds will be dissolved in nitric acid. Resins and insolubles will be leached out with an acidic solution to remove residual amounts of TRU and washed to reduce adherent films of TRU containing water. Insolubles such as silica and graphitic materials will exist in solution as an undissolved species. These insoluble residues will be solidified/stabilized (e.g., grout) and sent to ERDF. The dissolver product and the different leaching solution used to treat the solid residue is treated with NaOH solution where metal ions are precipitated in accordance with tank farm criteria. The resulting slurry will be transferred to a DST in 200 East Area.

The solution in the neutralization feed tank will be agitated and sampled. The samples will be analyzed for Pu^{239,240}, Am²⁴¹, uranium isotopic, Cs¹³⁷, Sr⁹⁰, H⁺, Fe, Al, Ca, PCBs and other components as required by the TWRS acceptance criteria. The results of the analysis and volume of solution in the tank will be used to determine how much depleted uranium and iron will be added as neutron absorbers, NaOH for neutralization and NaNO₂ for corrosion control to achieve tank waste acceptance. Both absorbers will be added since laboratory studies have shown that after co-precipitation of Pu, Am and U under simulated waste tank conditions, Pu can selectively dissolve if it is exposed to carbonate bearing solution and Am can dissolve if exposed to the solution containing the sodium salt of ethylenediaminetetraacetate (EDTA) during waste retrieval operations.

Table 3-2 Key Radionuclides and Other Constituents in Feed Stream to Neutralization

Constituent	Batch Case ⁽¹⁾	
	KE 1	KW 2
Al, M	0.056	0.0050
Fe, M	0.14	0.85
HNO ₃ , M	4.3	3.4
U, M	0.018	0.13
Pu mCi/l	0.7	5.2
Am mCi/l	0.89	4.3
Cs ¹³⁷ mCi/l	11.3	168

1) Nominal case is starting batch size of 160 kg sludge solids.

4.0 REVIEW OF NEUTRALIZATION AND PRECIPITATION EXPERIENCE

Information on production facility waste neutralization was compiled from technical manuals, laboratory tests on simulated waste and discussions with cognizant engineers and scientists. The neutralization information is summarized in the below sections for Hanford and offsite facilities.

4.1 Hanford Site Experience

4.1.1 Neutralization Methods

Table 4-1 identifies the waste neutralization methods used at the Hanford Site production facilities. A direct strike (sodium hydroxide addition to acid waste) or reverse strike (acid waste addition to sodium hydroxide) neutralization method was used depending on the waste type. Reverse strike neutralization was used at the Redox facility and the Plutonium Finishing Plant (PFP) because of the high concentration of aluminum nitrate salting agent in the waste and at the Purex facility for the zirflex cladding waste.

Zirconium clad fuel was processed at the Redox facility shortly before the facility was shut down. Process flowsheet information (Boldt 1966) and conversations with R. A. Watrous and A. L. Boldt on Redox operations did not identify the method used for neutralization of the zirflex cladding waste. It is assumed that the direct strike neutralization method used in laboratory waste neutralization tests (Schull and Herting, 1986) was the actual neutralization method used in the Redox process for zirflex cladding waste.

Table 4-1 Hanford Production Facility Waste Neutralization Methods

Chemical Process	Direct Strike	Reverse Strike
Bismuth Phosphate	x	
Reduction Oxidation (REDOX)	zirflex cladding waste	metal solution waste
Uranium Recovery	x	
Plutonium-Uranium Extraction (PUREX)	CAW/ZAW stream ⁽¹⁾	zirflex cladding waste
Waste Fractionization	x	
Plutonium Reclamation/Conversion (PPF)	changed to reverse due to $Al(OH)_3$ problem	x

1) CAW is acronym for current acid waste. ZAW is acronym for zirflex acid waste - current acid waste from processing zirconium clad fuel elements.

The reverse strike neutralization for high aluminum nitrate - nitric acid metal waste was used because at pH of 4 or 5 the gelatinous precipitate $Al(OH)_3$ or $Al_2O_3 \cdot 3H_2O$ becomes so heavy that agitation is difficult. As more caustic is added, the mass becomes less viscous and at pH 6 or 7, the precipitation is complete. The freshly precipitated hydroxide is readily soluble in excess NaOH as sodium aluminate. Dissolution of $Al(OH)_3$ is slower or incomplete if a) the direct strike caustic is added too slowly with insufficient agitation, b) the precipitate is allowed to age for any extended time period (several hours) before dissolution in excess NaOH, or c) if the temperature is allowed to go to $> 50^\circ C$ during neutralization (GE 1951). Conversation with J. S. Buckingham (40 years process chemistry support experience at Hanford laboratories) stated that $Al(OH)_3$ solids from direct neutralization of 1-2 M Al solution will stop an agitator.

4.1.2 Particle Size of Neutralized Hanford Site Waste

A search was performed on Hanford neutralized waste to obtain particle size information on precipitates. Particle size information was obtained for several simulated wastes from the production facilities. These wastes included neutralized cladding waste, neutralized metal waste and neutralized high aluminum salt waste. Additional information was located on particle size of

retrieved waste from the single shell tanks for the strontium removal program in the 1970s. The particle size information for retrieved tank waste was not used in this study.

Conversation with D. L. Herting (~20 years process support experience at Hanford Site laboratories) identified that particle size tests were performed with simulated fuel element cladding waste and waste transfer line constriction is often the result of accumulation of needle type crystals. Particle size of non fissile material added to the waste tanks is limited to $< 177 \mu\text{m}$ by specification. Conversations with R. E. Vandercook (~ 40 years chemical engineering experience at Hanford Site production facilities) and with J. S. Buckingham (~ 40 years process chemistry support experience at Hanford Site laboratories) resulted in neither of them remembering any specific studies on particle size of solids from neutralization of the waste at the production facilities. Conversation revealed there was little interest in particle size of solids in the neutralized waste during the early production periods and results from available particle size analyzers were not reliable at the time.

Reverse strike neutralization of zirflex cladding waste at Purex was used to minimize the ammonia evolution rate to the off gas system, form slurriable solids $\text{ZrO}_2 \cdot 2\text{H}_2\text{O}$ solids and increase the pH of the waste to meet tank waste acceptance criteria. The reverse strike coating waste-caustic reaction generated up to 50 vol % solids and required agitation for solids suspension in order to transfer the slurry to the waste tanks (RHO 1983). The transfer was followed by a 1900 liter water flush. Recent laboratory tests showed that direct strike neutralization of zirflex cladding waste generated about 40 vol % solids and reverse strike neutralization generated about 60 vol % solids (Schull and Herting 1986).

Information on the Purex neutralization tank agitators is listed in Table 4-2. Both tanks are 19,000 l capacity. Specific information on Redox neutralization tank size and agitators could not be located. A 7.5 horse power or 5 horse power agitator was probably used with gear reducers and shaft speeds of 97 rpm and 121 rpm respectively. The 7.5 and 5.0 horsepower units have paddle-wheel propellers of 838 mm and 610 mm diameter respectively. Each propeller has 10 blades at a pitch of 15 degrees (GE 1951).

Table 4-2 Purex Neutralization Tank Agitators⁽¹⁾

Function and Tank Number	Motor		Shaft			Impeller	
	Speed RPM	Horsepower	Length mm	Diameter mm	Speed RPM	Number	Diameter mm
Coating Waste (E5)	300	10	2590	51	300	1	355
Current Acid Waste (F16)	600	15	2590	51	600	2	229

1) Source of information is RHO 1983.

The neutralized waste particle size information is listed in Tables 4-3 to 4-7 for several Hanford Site waste types. Particle size was $\leq 10 \mu\text{m}$ except for a few laboratory tests that combined simulated Redox aluminum waste and zirconium cladding waste. The large particles were generally cubic, square, and flat type and/or a needle type crystal. Small particles were symmetrical with a plane of symmetry (equant).

Table 4-3 Particle Sizes in Neutralized and Simulated Zirconium Cladding Waste at Purex⁽¹⁾

Method	pH	Particle Description μm		
		Equant	Cubic, Square, Flat	Needle
Direct Strike ⁽²⁾	10.6, 11.0	<2-10	-	-
Reverse Strike ⁽²⁾	10.7, 10.8	<2-5	-	-
Direct Strike (10 % excess NaOH) ⁽³⁾	11.6, 12.4	<2-10	-	-
Reverse Strike (10 % excess NaOH) ⁽³⁾	12.2, 12.1	<2-5	-	-

1) Waste composition before neutralization is 0.43 M $(\text{NH}_4)_2\text{ZrF}_6$, 0.43 NH_4F , 0.04 NaNO_3

2) NaOH added to meet earlier tank farm waste acceptance criteria.

3) Excess NaOH added to meet current tank farm waste acceptance criteria for pH > 12.

Table 4-4 Particle Size in Direct Strike Neutralized and Simulated Redox Waste Cladding Waste⁽¹⁾

Waste ⁽²⁾	pH	Particle Description μm		
		Equant	Cubic, Square, Flat	Needle
Redox Cladding Waste	9.4, 9.5	2-3	<2	-
Redox Cladding Waste & 3 vol % Neutralized Redox Al Waste	9.4, 9.5	32	<2	58-62
Redox Cladding Waste & 6 vol % Neutralized Redox Al Waste	9.4, 9.5	-	<2, 13-16, 25-28	9-13
Redox Cladding Waste with excess NaOH to meet pH >12	11.7, 11.8	2-3	2-3	-
Redox Cladding Waste, 3 vol % Neutralized Redox Al Waste & excess NaOH to meet pH >12	11.8, 11.8	3-4	2-3	-
Redox Cladding Waste, 6 vol % Neutralized Redox Al Waste & excess NaOH to meet pH >12	12.0, 12.4	-	9, 53	-

1) Source of information is Schull and Herting 1986.

2) Composition of cladding waste before neutralization is 0.69 M $(\text{NH}_4)_2\text{ZrF}_6$, 0.77 M NH_4F , 0.07 M NH_4NO_3 . Composition of neutralized Redox Al waste is 0.56 M $\text{NaAl}(\text{OH})_4$, 0.49 M NaOH , 0.46 M NaNO_2 , 3.31 M NaNO_3 .

Table 4-5 Size of Residual Particles in Supernate from Settling Tests of Simulated Direct Neutralized Current Acid Waste⁽¹⁾

Settling Time hr	Particle Size of Supernate μm		
	Median	Geometric Mean	Arithmetic Mean
0.5	1.53-1.89	1.45-1.88	1.49-1.97
2.0	1.27	1.28	1.31
4.0	1.33	1.32	1.34
9.0	1.33	1.32	1.35
Aged NCAW ⁽³⁾			
0.2	1.50-1.53	1.52-1.57	1.59-1.65
2.0	1.36	1.41	1.47
4.0	1.43	1.42	1.49
4.0 ⁽²⁾	0.37	0.40	0.43

1) Source of information is Gerboth 1986. Composition of unneutralized and denitrated current acid waste is 0.95 M HNO_3 , 0.68 M Al, 0.14 M F, 0.032 g/l U, and 0.0004 g/l Pu. Waste neutralized to pH >12.

2) Elzone analyzer was adjusted to measure smaller size particles.

3) Waste boiled under reflux conditions for 3 weeks at pH > 12.

Table 4-6 Particle Sizes Analysis of Simulated Neutralized Current Acid Waste Ripening⁽¹⁾

Sample Time Days	Median μm	Geometric Mean μm	Arithmetic Mean μm
0	1.46	1.45	1.51
5	1.43	1.43	1.49
12	1.53	1.55	1.62
15	1.53	1.54	1.61

1) Source of information is Peters and Cleavenger 1985. Waste neutralized to pH > 12.

4-7 Particle Sizes in Simulated Reverse Neutralized Plutonium Finishing Plant Waste⁽¹⁾

Chemical	PFP 1	PFP 4	PFP 6	PFP 15
Al M	0.2	0.2	0.2	0.2
Fe M	0	0.02	0	0.02
U M	0	0	0.017	0.017
NaF M	0.01	0.01	0.01	0.01
HNO ₃ M	2.24	2.24	2.24	2.24
NaOH M (final)	2	2	2	2
NaNO ₂ M ⁽²⁾	0.05	0.05	0.05	0.05
Nominal Particle Size (Geo) um	0.38	2.10	1.52	1.78
Nominal Particle Size (Arith) um	0.39	2.18	1.60	1.90
% Settled Solids	No Solids	10.9	5.0	9.0
% Centrifuged Solids	No Solids	2.9	1.1	1.4

1) Source of information is Gallagher 1986.

2 Chemical added after neutralization.

4.1.3 Neutralization of Uranyl Nitrate Solution

Laboratory neutralization and settling tests were performed with vigorously mixed uranyl nitrate solutions of 5, 10, 20, 40, 70, and 100 g/l to evaluate the settling behavior of the resulting slurries for transfer from Purex to the waste tanks (Ryan 1993). It was concluded that immediately after neutralization, slurries produced from solutions containing ≥ 40 g U/l had a rapid settling fraction that could not be completely poured from the stirring beaker. After 3 to 5 weeks of slurry aging with agitation, the slurries produced with 5 to 40 g U/l settled very rapidly.

At 70 and 100 g U/l, the settling rates are rapid immediately after precipitation. Aging of the slurry on shaker mixer had the opposite effect for these more concentrated slurries and significantly decreased the settling rates.

These laboratory test results and observations raise concern that plugging of the transfer line may result from neutralization of solution containing ≥ 40 g U/l particularly if tank stirring and transfer line flow were stopped.

4.2 Other DOE Site Experience

Recent coprecipitation results were obtained from Savannah River Site laboratory tests of direct neutralized acid solutions that simulate Purex high activity waste, Purex low activity waste, heavy metal (HM) high activity waste (HAW), and HM low activity waste (LAW) solutions from F-Canyon and H-Canyon operations. The simulated waste contained varying amounts of iron, aluminum, manganese, nickel and uranyl nitrate salts dissolved in 2.0 M nitric acid. Plutonium and uranium were added to the required concentrations. Three additional solutions containing uranium only, plutonium only, and uranium-plutonium were prepared as blanks. Concentrated sodium hydroxide solution was added to portions of the acidic waste and blanks to provide a final liquid phase hydroxide concentration of 1.2 M. This hydroxide concentration is the target concentration for transfer of the high level waste to the waste storage tanks (Hobbs 1995). Table 4-8 lists the waste feed compositions, particle sizes of the precipitate and concentration of plutonium and uranium in the neutralized waste solution and blanks. There was no discernible relationships between time and plutonium and uranium concentrations for any of neutralized waste solution and blanks over a 59 day period.

A portion of the precipitated solids from each waste type was analyzed and included identification of crystalline phase by X-ray diffraction and particle size and morphology by scanning electron microscopic analysis. Plutonium was effectively removed from the simulated Purex and heavy metal waste solutions upon the addition of sodium hydroxide solution by coprecipitation with iron and uranium but not with aluminum. Uranium was observed to be saturated in all alkaline salt solutions except in the heavy metal low activity waste simulant where there was sufficiently high molar ratio of iron to uranium that coprecipitation occurs.

Slurries containing high iron concentration did not settle to as high a solids concentration as the blanks and high aluminum containing slurries. The precipitated solid phases were generally irregularly shaped. Individual crystallites ranged from about 1 to 50 μm in diameter except for the uranium blank which ranged from about 5 to 100 μm (Hobbs 1995).

Conversation with D. T. Hobbs of Savannah River Technology Center, Westinghouse Savannah River Company indicated there was no other particle size information available on neutralized waste from the production facilities.

Table 4-8 Particle Sizes in Simulated Direct Neutralized Savannah River Site Waste⁽¹⁾

Chemical	Purex HAW	Purex LAW	HM-HAW	HM-LAW	U Only	Pu Only	Pu/U Only
Al M	0.048	0	1.20	0	0	0	0
Fe M	0.11	0.53	0.02	0.15	0	0	0
Mn M	0	0.025	0	0	0	0	0
Ni M	0.057	0	0	0	0	0	0
U g/l	9.9	0.91	0.0029	0.0015	9.9	0	9.9
Pu g/l	0.0017	0.0022	0.0195	0	0	0.0017	0.0017
HNO ₃ M	2.0	2.0	2.0	2.0	2.0	2.0	2.0
NaOH M	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Pu mg/l ⁽²⁾	6.8±1.8 E-04	1.1±0.56 E-03	3.5±1.4 E-01	Not Available	Not Avail.	2.0±1.6 E-01	8.4± 4.8 E-04
U mg/l ⁽²⁾	4.1±1.4	4.7±2.0	2.4±0.13	0.70±0.31	4.5±1.3	0.041±0.023	6.5±1.8
Aggregate Particle Size um	None	None	Not Available	Not Available	1,000-10,000	10-80	50-300
Crystallite Particle Size um	1-40, 5-50	1-40, 5-50	1-40	Not Available	5 -100	Not Available	1-20
% Settled Solids	35	84	26	40	16	Not Available	19

1) Source of information is Hobbes 1995

2) Average concentrations in alkaline solution over a 59 day period.

4.3 Laboratory Tests for K Basin Sludge

Information was compiled from a recent Russian Institute of Physical Chemistry laboratory study on alkaline treatment of acid dissolver solution for simulated Hanford Site K Basins sludge (PNNL 1998). Sedimentation rates of precipitates formed by alkaline treatment of the simulated dissolver solution showed no regular dependence of the conditions of precipitation (temperature of 40 & 80 ° C, excess NaOH of 0.01, 0.1 and 1.0 M or direction of neutralization). An intense stirring speed was used to mix the NaOH and acid solutions.

Composition, particle size and precipitate fraction information are listed in Table 4-7. The particle size of the primary crystallites were measure at <10 nm using a small angle X-ray scattering method. The product precipitate was coagulated for 24 hr at 40 °C, separated from mother solution by 10 minutes centrifugation, and washed 3 times with 5-fold volumes of water before sampling and analysis.

Based on these studies, the alkaline treatment of the acidic dissolver solution should be performed by precipitation and digestion at 40°C with 0.01 M NaOH excess (pH 12) during direct strike addition of NaOH to the dissolver solution. These conditions yielded the lowest uranium concentration in the supernate, require the least excess NaOH, and provide the highest apparent partitioning of plutonium. The resulting solutions are non-TRU for both Pu and Am.

Contact of the product precipitates having no Fe(III) in the solid phase with carbonate-bearing solution can produce TRU level plutonium and americium concentrations in solution. Alkaline solutions containing EDTA also can leach americium to near TRU levels from iron free solids. This contact represent attempts to simulate the reaction that can occur during the tank waste retrieval operations.

Table 4-7 Particle Size Distributions of Precipitates from Direct Strike Alkaline Treatment of Simulated Dissolver Solutions at 0.01 M Excess NaOH.⁽¹⁾

Element Concentration			Maxima Crystal Size nm		% Settled Solids ⁽²⁾	
U M	Fe M	Al M	First	Second	Measured	Calculated ⁽³⁾
0.157	0	0	-	3.4-3.6	45.5, 50.3	42.4
0.141	0.068	0	1.3	3.0-3.2	37.0, 57.0	47.3
0.079	0.336	0	1.7	2.2	70.0, 75.0	66.7
0.016	0.603	0	1.7	-	82.0, 88.0	85.7
0.126	0	0.278	-	2.8-3.2	40.5, 56.0	52.6
0.079	0	0.696	3.0-3.1	3.7-4.0	60.5, 65.5	68
0.031	0	1.11	1.8-1.9	2.6-2.8	86.0, 86.0	74.4
0.016	0.537	0.141	1.5	1.9	85.5, 86.0	86.3
0.016	0.068	1.11	1.9	-	92.0, 93.0	87.9
0.025	0.224	0.463	1.9	-	67.5, 68.5	68

1) Source of information is PNNL 1998

2) Based on initial acid dissolver solution volume before neutralization with 16 M NaOH (~5 volume% dilution)

3) Volume fraction of precipitate= $2.7 [U] + 1.35 [Fe] + 0.67 [Al]$

4.4 Other World Wide Experience

Information could not be located for this section to be included at this time.

5.0 DESCRIPTION OF NEUTRALIZATION PROCESS TECHNOLOGIES

The neutralization systems are continuous stirred tanks, static mixers, and batch tanks.

5.1 Continuous Stirred Tanks

A schematic of a stirred tank precipitation process is presented in Figure 5-1. This process collects dissolver product solution, washes, and leachate from the main process in a blending tank. The blending tank is operated as batch and sampled as needed. The collected dissolver solution is transferred to the continuous stirred tank for neutralization with NaOH. The stirred tanks have pH control, agitator for mixing the solution, and possible cooling coils for heat removal. The neutralized solution and precipitate are collected in a holding tank, adjusted for nitrite ion content and sampled. Solution meeting tank farm waste acceptance criteria of Table 3-1 is transferred to the waste tanks.

The continuous stirred tank has the capability to perform either a direct or reverse strike neutralization. The disadvantages of the continuous stirred tank are potential need for multiple mixer chambers to achieve the target pH, the equipment may not have capability to thoroughly mix a gelatinous precipitate with fresh NaOH solution or move settled solids to the receiver tank, and the equipment may not achieve the level of pH control in one step flow neutralization process.

5.2 Static Mixers

The mixer is shown in Figure 5-2. The system is very similar to the schematic in Figure 5-1 but is mixed by tangential fluid flow. In principle, the unit operates by the introduction of reagent and streams tangentially to a diode chamber. Differences in the inlet velocity promote rapid momentum at the outer perimeter of the diode chamber. The partially mixed stream then migrates towards the central exit port increasing the tangential velocity component by conservation of angular momentum. The narrow streamlines are such that eddy diffusion reduces remaining concentration gradients to acceptable levels prior to exiting the unit. The static unit described above is available from AEA Technologies and has been used at the Enhanced Actinide Remote Plant at Stellafield by British Nuclear Fuel Limited. There are other static mixers available but they contain an internal structure including vanes and other hardware that promote the vorticity.

The static mixers are completely passive and need no mechanical energy input within the unit (e.g. rotating shafts, seals, and impeller blades). The static mixer appears to be capable of either direct or reverse strike neutralization. The disadvantages of the static mixer may be inability to handle gelatinous precipitate, thoroughly mix a viscous alkaline slurry and/or provide the required level of pH control.

Figure 5-1 Continuous Stirred Tank

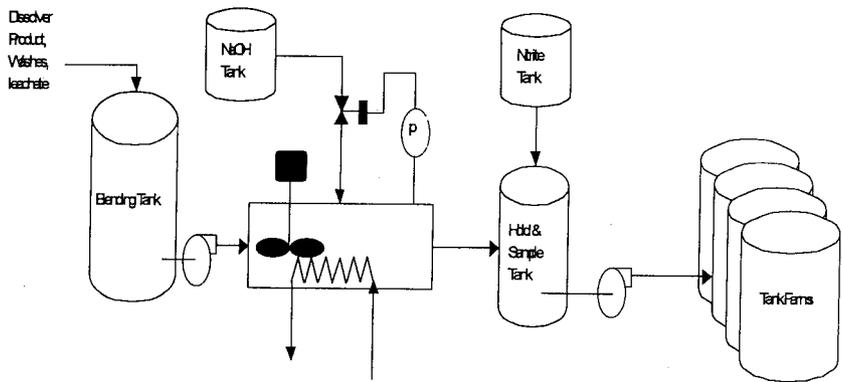


Figure 5-2A Two port and three port vortex mixers

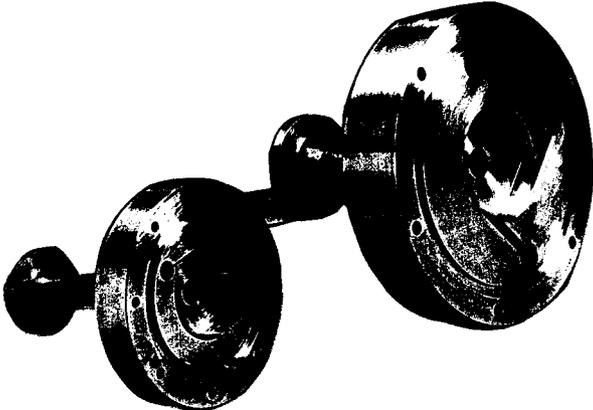


Figure 5-2B A single vortex cell mixing device

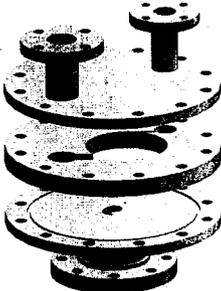
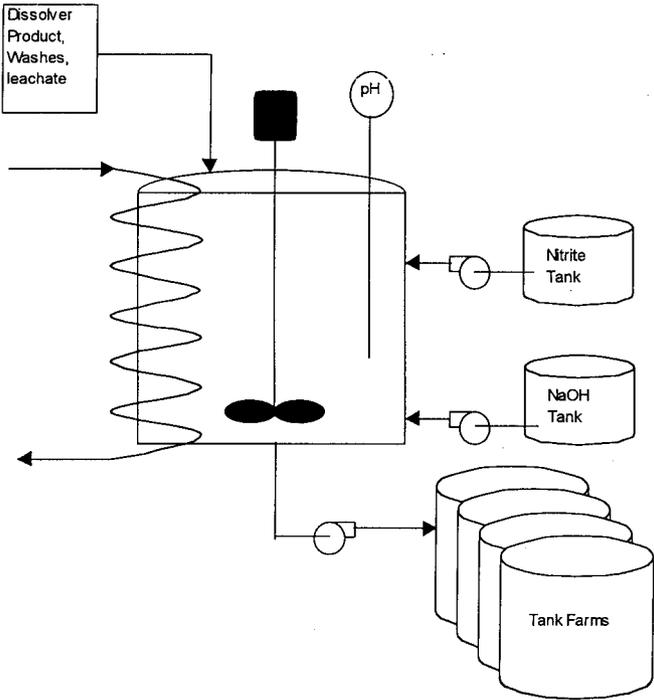


Figure 5-3 Batch Mixer Tank



6.0 RECOMMENDATIONS

The following recommendations are provided for the neutralization process and technology.

6.1 Process

6.1.1 Neutralization Method

The method of neutralization is an important parameter for maintaining operational flexibility and continuity of the proposed sludge pretreatment process. High aluminum waste has been shown to cause operational problems for Redox metal waste and Plutonium Finishing Plant waste. A gelatinous $\text{Al}(\text{OH})_3$ precipitate will form at pH 4 to 5 during direct strike neutralization with NaOH solution. Reverse strike neutralization has been shown to eliminate this solids problem by maintaining high alkalinity conditions in the neutralizer tank. The 1998 PNNL work on neutralization methods of dissolver solution and 1993 Ryan work on neutralization of uranyl nitrate used intense mixing of the solutions and do not properly represent dissolver solution neutralization conditions expected in large equipment systems (e. g. Purex waste neutralization tanks).

Information from the Effluent Treatment Facility at La Hague, France have shown that direct strike neutralization (slow addition of NaOH to acid) causes a faster precipitation rate of Pu than Fe. This effect causes a split between Pu and the neutron absorber iron and may impact maintaining subcriticality. If NaOH is added and mixed into the acid solution by reverse strike or direct but with special operating conditions that are easily observed in the laboratory, then segregation of Pu and Fe would not occur. In large batch systems that typically use slow speed agitators, segregation of Pu and Fe may be possible during direct strike neutralization. The neutralization/precipitation process equipment must be designed to coprecipitate iron and plutonium to the maximum extent practical.

Reverse strike neutralization of the nitric acid dissolver solution product into NaOH solution is recommended for good coprecipitation of Pu with Fe. Also, reverse strike neutralization eliminates the formation of gelatinous $\text{Al}(\text{OH})_3$ at pH 4 to 5 by maintaining high alkaline conditions during neutralization/precipitation.

6.1.2 Temperature

The laboratory results from alkaline treatment of sludge dissolver solution showed that a temperature of 40°C gave good partitioning of uranium, plutonium and americium and particle size distribution of precipitate (PNNL 1998). Process chemistry information from the Hanford Site Redox plant shows that dissolution of $\text{Al}(\text{OH})_3$ is slower or incomplete if the temperature is allowed to go to > 50°C during neutralization (GE 1951). Therefore a 40°C temperature is recommended for the neutralization process.

6.2 Technology

The batch mixer tank system is recommended for the initial neutralizer/precipitation system. This equipment system is the simplest of the three equipment systems and has been used at the Hanford Site for neutralization of several waste types for 50 years. Depending on the agitator speed and mixing characteristics of the alkaline slurry, a distributor may be used for addition of the dissolver product solution to the NaOH in the tank.

The waste neutralization technology is based on laboratory beaker tests that use a magnetic stir bar for intense mixing of the solution and operating facility large tanks that use slow speed agitators and solution distributors. The quality and particle size of the precipitate are dependent on several parameters. These parameters include concentration of constituents in the feed, rate of neutralizing solution addition, and mixing rate of the solutions in the tank.

It is recommended that larger scale neutralization tests be performed to evaluate effect of equipment variables on process chemistry and quality of the precipitate (including the ability to transfer solids to the waste tanks).

7.0 OPEN ISSUES

Several open issues have been identified that are important to the success of the K Basin sludge pretreatment. These include:

- Laboratory tests results from neutralization of uranyl nitrate have shown that at a feed concentration ≥ 40 g U/l there was a rapid settling fraction of solids that could not be poured from a just vigorously stirred test beaker. The rapid settling action causes a high risk of accumulation of solids in the neutralizer and transfer line. Numerous rinses would probably be required to remove residual precipitate from the neutralization tank and transfer line to the tank farm.

- Action item:
- 1) Perform further testing and evaluation for optimization of precipitation conditions in order to facilitate handling of the slurry.
 - 2) Perform a reduced scale test at representative conditions to optimize design of the agitator or distributor and behavior of the precipitate including the ability to transfer the precipitate to the waste tanks.
 - 3) Perform a check on the amount of precipitated solids from neutralization and determine if settled solids exceed TWRS limit of 379 m^3 (100,000 gal) for tank 241-AW-105.

- There was insufficient time to preform a check for applicable information on waste neutralization and particle size from the Oak Ridge National Laboratory and other world wide experience.

Action item: Perform a literature check for available information and establish conversations with cognizant personnel.

8.0 REFERENCES

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APPENDIX A
DETAILED COMPOSITION OF THE SLUDGE STREAMS

COMPOSITION OF THE SOLUTION BEFORE ADJUSTMENT (STREAM # ST-503)

# OF BATCHES	COMPOSITION OF A DAILY BATCH FOR					COMPOSITION OF SOLUTION FROM SOLID RESIDUES GROUTING	COMPOSITION OF TOTAL STREAMS
	KE1 146.1	KE2 24.4	KW1 11.2	KW2 10.2	KW3 22.4		
Volume	4.341 m3	3.193 m3	5.622 m3	3.255 m3	2.986 m3	33.1 m3	908.4 m3
Density	1.171	1.197	1.149	1.193	1.204	1.002	1.169
Total Mass	5,084,405 kg	3,872,252 kg	6,480,697 kg	3,883,487 kg	3,595,374 kg	33,161.9 kg	1,061,926.0 kg
LIQUID							
Volume	4.341 m3	3.193 m3	5.622 m3	3.255 m3	2.986 m3	33.1 m3	908.4 m3
Density	1.171	1.197	1.149	1.193	1.204	1.002	1.170
Total Mass Liquid + Gaz	5,084,068 kg	3,822,171 kg	6,480,058 kg	3,883,398 kg	3,595,242 kg	33,161.9 kg	1,061,866.2 kg
H2O	3,644,081 kg	2,573,333 kg	4,866,861 kg	2,642,356 kg	2,378,651 kg	33,130.0 kg	763,152.5 kg
HNO3	1,193,699 kg	993,604 kg	1,452,018 kg	1,000,957 kg	853,553 kg	31.2 kg	246,553.8 kg
H2C2O4	1.498 kg	0.250 kg	0.050 kg	0.459 kg	0.050 kg	0.2 kg	231.6 kg
HF	4.395 kg	1.049 kg	9.788 kg	1.149 kg	0.520 kg	0.5 kg	801.0 kg
NaOH							
Al(NO3)3	51.740 kg	37.692 kg	34.843 kg		48.879 kg	0.0 kg	9,966.6 kg
AlF3							
Fe(NO3)3	146.730 kg	23.836 kg	78.238 kg		40.426 kg	0.1 kg	23,804.2 kg
CaO	1.742 kg	0.118 kg	1.551 kg		0.074 kg	0.0 kg	276.3 kg
NaNO2							
NaNO3							
Miscellaneous	10.575 kg	1.346 kg	3.988 kg	0.812 kg	10.294 kg	0.0 kg	1,861.9 kg
UO2(NO3)2	29.607 kg	190.949 kg	12.939 kg	237.564 kg	162.931 kg	0.0 kg	15,218.2 kg
Pu	3.004 Ci	20.380 Ci	1.850 Ci	24.371 Ci	23.248 Ci	0.0 Ci	1,727.8 Ci
Am	3.885 Ci	23.656 Ci	1.754 Ci	19.869 Ci	18.370 Ci	0.0 Ci	1,780.3 Ci
Cs	49.010 Ci	219.530 Ci	15.423 Ci	779.393 Ci	261.506 Ci	0.1 Ci	26,526.6 Ci
Sr	45.491 Ci	246.547 Ci	10.016 Ci	607.904 Ci	361.515 Ci	0.0 Ci	27,100.9 Ci
FCB	0.002 g	0.002 g			0.002 g	0.002 g	0.344 g
SOLIDS + RESINS							
Volume	0.000 m3	0.000 m3	0.000 m3	0.000 m3	0.000 m3		0.0 m3
Density	2.022	3.582	2.211	4.737	2.326		2.136
Total Mass Solids + Resins	0.338 kg	0.074 kg	0.621 kg	0.090 kg	0.033 kg		59.8 kg
Wt% solids	0.01 wt%	0.00 wt%	0.01 wt%	0.00 wt%	0.00 wt%	0.00 wt%	0.01 wt%
Al(NO3)3	0.000 kg	0.001 kg			0.001 kg		0.1 kg
Al(OH)3	0.003 kg		0.003 kg				0.5 kg
Al2O3							
Fe(NO3)3					0.001 kg		
Fe(OH)3	0.003 kg	0.001 kg	0.002 kg		0.001 kg		0.5 kg
C	0.001 kg	0.001 kg	0.000 kg		0.001 kg		0.2 kg
CaO	0.001 kg	0.000 kg	0.001 kg		0.000 kg		0.2 kg
Na2C2O4							
CO2							
H2O							
SiO2	0.253 kg	0.039 kg	0.615 kg		0.029 kg		45.4 kg
Grout							
Miscellaneous	0.001 kg	0.000 kg	0.000 kg	0.000 kg	0.001 kg		0.1 kg
Zirconium		0.024 kg		0.058 kg			1.2 kg
Grafit				0.031 kg			0.3 kg
HNO3							
H2C2O4							
Na2U2O7							
U	0.000 kg	0.000 kg	0.000 kg	0.001 kg	0.000 kg		0.0 kg
U3O7	0.000 kg	0.000 kg	0.000 kg		0.000 kg		0.0 kg
UH3	0.000 kg	0.000 kg			0.000 kg		0.0 kg
UO2	0.000 kg	0.000 kg	0.000 kg		0.000 kg		0.0 kg
UO2(NO3)2					0.000 kg		0.0 kg
UO4.4H2O	0.000 kg				0.000 kg		0.0 kg
Pu	0.000 Ci	0.000 Ci	0.000 Ci	0.000 Ci	0.000 Ci		0.0 Ci
Am	0.000 Ci	0.000 Ci	0.000 Ci	0.000 Ci	0.000 Ci		0.0 Ci
Cs	0.001 Ci	0.005 Ci	0.000 Ci	0.017 Ci	0.006 Ci		0.6 Ci
Sr	0.000 Ci	0.001 Ci	0.000 Ci	0.002 Ci	0.001 Ci		0.1 Ci
FCB	0.061 g	0.060 g			0.001 g		8.937 g
RESINS							
Zeolite	0.029 kg						4.2 kg
oIFER	0.047 kg	0.008 kg					7.1 kg
Pu	0.000 Ci	0.000 Ci					0.019 Ci
Am	0.000 Ci	0.000 Ci	0.000 Ci				0.003 Ci
Cs	0.003 Ci	0.001 Ci					0.452 Ci
TOTAL ACTIVITIES							
Total U	17.884 kg	115.345 kg	7.816 kg	143.584 kg	98.420 kg	0.0 kg	9,192.7 kg
Total Pu	3.851 Ci	20.380 Ci	1.953 Ci	24.371 Ci	23.248 Ci	0.0 Ci	1,727.9 Ci
Total Am	3.885 Ci	23.658 Ci	1.754 Ci	19.870 Ci	18.370 Ci	0.0 Ci	1,780.3 Ci
TRU	6.889 Ci	44.038 Ci	3.603 Ci	44.241 Ci	41.619 Ci	0.0 Ci	3,508.2 Ci
Total Cs	49.014 Ci	219.536 Ci	15.423 Ci	779.410 Ci	261.512 Ci	0.1 Ci	26,526.6 Ci
Total Sr	45.491 Ci	246.547 Ci	10.016 Ci	607.907 Ci	361.517 Ci	0.0 Ci	27,100.7 Ci
Beta Gamma	94.504 Ci	486.081 Ci	25.439 Ci	1,387.317 Ci	623.029 Ci	0.2 Ci	53,627.3 Ci
CONCENTRATION							
PCB in liquid	0.35 ppb	0.48 ppb			0.51 ppb	0.00 ppb	0.32 ppb
PCB in solids	180.214 ppm	1.459 ppm			33.758 ppm		149.362 ppm
Solids	0.08 g/l	0.02 g/l	0.11 g/l	0.03 g/l	0.01 g/l		0.07 g/l
U	0.004 g/cm3	0.036 g/cm3	0.001 g/cm3	0.044 g/cm3	0.033 g/cm3	0.000 g/cm3	0.010 g/cm3
Pu total	0.692 Ci/m3	6.384 Ci/m3	0.329 Ci/m3	7.487 Ci/m3	7.787 Ci/m3	0.000 Ci/m3	1.902 Ci/m3
238 Pu	0.138 Ci/m3	1.277 Ci/m3	0.066 Ci/m3	1.497 Ci/m3	1.557 Ci/m3	0.000 Ci/m3	0.380 Ci/m3
239 Pu	0.277 Ci/m3	2.554 Ci/m3	0.132 Ci/m3	2.985 Ci/m3	3.115 Ci/m3	0.000 Ci/m3	0.761 Ci/m3
240 Pu	0.277 Ci/m3	2.554 Ci/m3	0.132 Ci/m3	2.985 Ci/m3	3.115 Ci/m3	0.000 Ci/m3	0.761 Ci/m3
Am	0.895 Ci/m3	7.410 Ci/m3	0.312 Ci/m3	6.104 Ci/m3	6.153 Ci/m3	0.000 Ci/m3	1.960 Ci/m3
TRU	1.587 Ci/m3	13.794 Ci/m3	0.641 Ci/m3	13.590 Ci/m3	13.940 Ci/m3	0.000 Ci/m3	3.862 Ci/m3
TRU	1.355 nCi/g	11.522 nCi/g	0.558 nCi/g	11.392 nCi/g	11.576 nCi/g	0 nCi/g	3.304 nCi/g
Beta Gamma	21.789 Ci/m3	145.992 Ci/m3	4.925 Ci/m3	426.169 Ci/m3	208.680 Ci/m3	0.005 Ci/m3	59.033 Ci/m3

COMPOSITION OF THE SOLUTION BEFORE NEUTRALIZATION (STREAM # ST-601)

# OF BATCHES	COMPOSITION OF A DAILY BATCH FOR					COMPOSITION OF SOLUTION FROM SOLID RESIDUES GROUTING	COMPOSITION OF TOTAL STREAMS
	KE1 146.1	KE2 24.4	KW1 11.2	KW2 10.2	KW3 22.4		
Volume	4.344 m3	4.292 m3	5.623 m3	4.648 m3	4.205 m3	33.1 m3	977.3 m3
Density	1.171	1.203	1.149	1.201	1.209	1.002	1.172
Total Mass	5,087,655 kg	5,163,395 kg	6,462,118 kg	5,582,130 kg	5,082,893 kg	33,168.5 kg	1,145,800.2 kg
LIQUID							
Volume	4.344 m3	4.292 m3	5.623 m3	4.648 m3	4.205 m3	33.1 m3	977.3 m3
Density	1.171	1.203	1.149	1.201	1.209	1.002	1.174
Total Mass Liquid + Gaz	5,087,655 kg	5,163,395 kg	6,461,496 kg	5,582,045 kg	5,082,893 kg	33,168.5 kg	1,145,800.4 kg
H2O	3,646,363 kg	3,427,382 kg	4,867,656 kg	3,724,709 kg	3,325,556 kg	33,134.4 kg	816,658.8 kg
HNO3	1,193,699 kg	993,604 kg	1,452,018 kg	1,000,957 kg	953,518 kg	31.2 kg	246,553.8 kg
H2C2O4	1.498 kg	0.250 kg	0.050 kg	0.459 kg	0.050 kg	0.2 kg	231.6 kg
HF	4.395 kg	1.049 kg	9.788 kg	1.149 kg	0.520 kg	0.5 kg	801.0 kg
NaOH							
Al(NO3)3	51.740 kg	37.692 kg	34.843 kg	5.000 kg	48.879 kg	2.0 kg	10,019.7 kg
AlF3							
Fe(NO3)3	146.730 kg	504.688 kg	78.238 kg	603.519 kg	575.712 kg	0.2 kg	53,721.5 kg
CaO	1.742 kg	0.118 kg	1.551 kg		0.074 kg	0.0 kg	276.3 kg
NaNO2							
NaNO3							
Miscellaneous	10.575 kg	1.346 kg	3.985 kg	0.812 kg	10.294 kg	0.0 kg	1,861.9 kg
UO2(NO3)2	30.575 kg	197.192 kg	13,362 kg	245.434 kg	168.257 kg	0.0 kg	15,715.7 kg
Pu	3.004 Ci	20.380 Ci	1.850 Ci	24.371 Ci	23.248 Ci	0.0 Ci	1,727.9 Ci
Am	3.885 Ci	23.658 Ci	1.754 Ci	19.869 Ci	18.370 Ci	0.0 Ci	1,780.3 Ci
Cs	49.010 Ci	219.530 Ci	15.423 Ci	779.393 Ci	261.506 Ci	0.1 Ci	26,525.2 Ci
Sr	45.491 Ci	246.546 Ci	10.016 Ci	607.904 Ci	361.518 Ci	0.0 Ci	27,100.6 Ci
PCB	0.002 g				0.002 g	0.000 g	0.344 g
SOLIDS + RESINS							
Volume	0.000 m3	0.000 m3	0.000 m3	0.000 m3	0.000 m3		0.0 m3
Density	2.022	3.582	2.211	4.737	2.326		2.136
Total Mass Solids + Resins	0.038 kg	0.074 kg	0.621 kg	0.090 kg	0.033 kg		59.9 kg
Wt% solids	0.01 wt%	0.06 wt%	0.01 wt%	0.00 wt%	0.00 wt%	0.00 wt%	0.01 wt%
Al(NO3)3							
Al(OH)3	0.000 kg	0.001 kg			0.001 kg		0.1 kg
Al2O3	0.003 kg		0.003 kg				0.5 kg
Fe(NO3)3							
FeOOH	0.003 kg	0.001 kg	0.002 kg		0.001 kg		0.5 kg
C	0.001 kg	0.001 kg	0.000 kg		0.001 kg		0.2 kg
CaO	0.001 kg	0.000 kg	0.001 kg		0.000 kg		0.2 kg
Na2C2O4							
CO2							
H2O							
SiO2	0.253 kg	0.039 kg	0.615 kg		0.029 kg		45.4 kg
Grout							
Miscellaneous	0.001 kg	0.000 kg	0.000 kg	0.000 kg	0.001 kg		0.1 kg
Zircaloy		0.024 kg			0.058 kg		1.3 kg
Grafoil					0.031 kg		0.3 kg
HNO3							
H2C2O4							
Na2U2O7							
U	0.000 kg	0.000 kg	0.000 kg	0.001 kg	0.000 kg		0.0 kg
U3O7	0.000 kg	0.000 kg	0.000 kg		0.000 kg		0.0 kg
UH3	0.000 kg	0.000 kg			0.000 kg		0.0 kg
UO2	0.000 kg	0.000 kg	0.000 kg		0.000 kg		0.0 kg
UO2(NO3)2							
UO4·4H2O	0.000 kg				0.000 kg		0.0 kg
Pu	0.000 Ci	0.000 Ci	0.000 Ci	0.000 Ci	0.000 Ci		0.0 Ci
Am	0.000 Ci	0.000 Ci	0.000 Ci	0.000 Ci	0.000 Ci		0.0 Ci
Cs	0.001 Ci	0.005 Ci	0.000 Ci	0.017 Ci	0.006 Ci		0.6 Ci
Sr	0.000 Ci	0.001 Ci	0.000 Ci	0.002 Ci	0.001 Ci		0.1 Ci
PCB	0.061 g	0.000 g			0.001 g		8.937 g
RESINS							
Zeolite	0.029 kg						4.2 kg
OJER	0.047 kg	0.008 kg					7.1 kg
Pu	0.000 Ci	0.000 Ci					0.019 Ci
Am	0.000 Ci	0.000 Ci	0.000 Ci				0.003 Ci
Cs	0.003 Ci	0.001 Ci					0.452 Ci
TOTAL ACTIVITIES							
Total U	18.469 kg	119.117 kg	8.071 kg	148.258 kg	101.638 kg	0.0 kg	9,493.3 kg
Total Pu	3.004 Ci	20.380 Ci	1.850 Ci	24.371 Ci	23.248 Ci	0.0 Ci	1,727.9 Ci
Total Am	3.885 Ci	23.658 Ci	1.754 Ci	19.870 Ci	18.370 Ci	0.0 Ci	1,780.3 Ci
TRU	6.889 Ci	44.038 Ci	3.603 Ci	44.241 Ci	41.619 Ci	0.0 Ci	3,508.2 Ci
Total Cs	49.014 Ci	219.535 Ci	15.423 Ci	779.410 Ci	261.512 Ci	0.1 Ci	26,526.6 Ci
Total Sr	45.491 Ci	246.547 Ci	10.016 Ci	607.907 Ci	361.517 Ci	0.0 Ci	27,100.7 Ci
Beta Gamma	94.504 Ci	465.891 Ci	25.439 Ci	1,387.317 Ci	673.029 Ci	0.2 Ci	53,673.3 Ci
CONCENTRATION							
PCB in liquid	0.35 ppb	0.35 ppb			0.36 ppb	0.00 ppb	0.30 ppb
PCB in solids	180.214 ppm	1.459 ppm			33.759 ppm		149.362 ppm
Solids	0.06 g/l	0.02 g/l	0.11 g/l	0.02 g/l	0.01 g/l		0.06 g/l
U	0.004 g/cm3	0.028 g/cm3	0.001 g/cm3	0.032 g/cm3	0.024 g/cm3	0.000 g/cm3	- 0.010 g/cm3
Pu total	0.692 Ci/m3	4.748 Ci/m3	0.329 Ci/m3	5.243 Ci/m3	5.528 Ci/m3	0.000 Ci/m3	1.768 Ci/m3
238 Pu	0.136 Ci/m3	0.650 Ci/m3	0.066 Ci/m3	1.049 Ci/m3	1.105 Ci/m3	0.000 Ci/m3	0.354 Ci/m3
239 Pu	0.217 Ci/m3	1.899 Ci/m3	0.132 Ci/m3	2.097 Ci/m3	2.211 Ci/m3	0.000 Ci/m3	0.707 Ci/m3
240 Pu	0.277 Ci/m3	1.899 Ci/m3	0.132 Ci/m3	2.097 Ci/m3	2.211 Ci/m3	0.000 Ci/m3	0.707 Ci/m3
Am	0.864 Ci/m3	5.512 Ci/m3	0.312 Ci/m3	4.274 Ci/m3	4.368 Ci/m3	0.000 Ci/m3	1.822 Ci/m3
TRU	1.586 Ci/m3	10.260 Ci/m3	0.641 Ci/m3	9.517 Ci/m3	9.896 Ci/m3	0.000 Ci/m3	3.590 Ci/m3
TRU	1.354 nCi/g	8.529 nCi/g	558 nCi/g	7.925 nCi/g	8.188 nCi/g	0 nCi/g	3.061 nCi/g
Beta Gamma	21.735 Ci/m3	108.585 Ci/m3	4.524 Ci/m3	299.446 Ci/m3	148.148 Ci/m3	0.005 Ci/m3	54.872 Ci/m3

COMPOSITION OF THE SLURRY AFTER NEUTRALIZATION AND WATER ADJUSTMENT (STREAM # ST-604)

# OF BATCHES	COMPOSITION OF A DAILY BATCH FOR					COMPOSITION OF SOLUTION FROM SOLID RESIDUES GROUTING	COMPOSITION OF TOTAL STREAMS
	KE1	KE2	KW1	KW2	KW3		
	146.1	24.4	11.2	10.2	22.4		
Volume	6.607 m3	8.896 m3	8.304 m3	10.488 m3	8.123 m3	33.2 m3	1620.5 m3
Density	1.191	1.178	1.172	1.163	1.176	1.003	1.180
Total Mass	7,867,102 kg	10,478,476 kg	9,733,486 kg	12,196,437 kg	10,732,717 kg	33,284.2 kg	1,912,817.7 kg
LIQUID							
Volume	6.573 m3	8.766 m3	8.290 m3	10.336 m3	8.892 m3	33.2 m3	1607.7 m3
Density	1.182	1.155	1.169	1.139	1.153	1.003	1.168
Total Mass Liquid + Gaz	7,772,796 kg	10,121,526 kg	9,693,262 kg	11,776,138 kg	10,368,508 kg	33,293.7 kg	1,877,405.7 kg
H2O	5,424,238 kg	7,533,580 kg	6,977,677 kg	9,064,801 kg	7,744,789 kg	33,210.3 kg	1,354,059.2 kg
HNO3							
H2C2O4							
HF							
NaOH	79,200 kg	94,200 kg	98,300 kg	98,700 kg	95,200 kg	13.0 kg	18,128.1 kg
Al(NO3)3							
AlF3	6,153 kg	1,469 kg	13,704 kg	1,609 kg	0,727 kg	0.6 kg	1,121.4 kg
Fe(NO3)3							
CaO	1,742 kg	0,118 kg	1,551 kg		0,074 kg	0.0 kg	276.3 kg
NaN02	410,500 kg	487,900 kg	509,000 kg	511,500 kg	492,800 kg	25.0 kg	93,880.0 kg
NaN03	1,840,388 kg	2,002,914 kg	2,089,042 kg	2,098,718 kg	2,024,623 kg	44.7 kg	408,070.8 kg
Miscellaneous	10,575 kg	1,346 kg	3,988 kg	0,812 kg	10,294 kg	0.0 kg	1,861.9 kg
UO2(NO3)2							
Pu							
Am							
Cs							
Sr	49,010 Ci	219,530 Ci	15,423 Ci	779,393 Ci	261,506 Ci	0.1 Ci	26,525.6 Ci
PCB	0.000 g	0.000 g			0.000 g	0.000 g	0.017 g
SOLIDS + RESINS							
Volume	0.034 m3	0.129 m3	0.014 m3	0.152 m3	0.131 m3	0.0 m3	12.8 m3
Density	2.757	2.757	2.852	2.764	2.787	0.5 kg	2.777
Total Mass Solids + Resins	94,306 kg	356,950 kg	40,223 kg	420,299 kg	364,209 kg	0.5 kg	35,412.9 kg
Wt% solids	1.20 wt%	3.41 wt%	0.41 wt%	3.45 wt%	3.39 wt%	0.00 wt%	1.85 wt%
Al(NO3)3	13,233 kg	12,440 kg	0,034 kg	0,337 kg	17,225 kg	0.1 kg	2,629.0 kg
Al(OH)3	0,003 kg		0,003 kg				0.5 kg
Al2O3							
Fe(NO3)3							
FeOOH	53,908 kg	185,411 kg	28,744 kg	221,719 kg	211,504 kg	0.1 kg	19,736.5 kg
C	0,001 kg	0,001 kg	0,000 kg	0,000 kg	0,001 kg		0.2 kg
CaO	0,001 kg	0,000 kg	0,001 kg		0,000 kg		0.2 kg
Na2C2O4	2,230 kg	0,372 kg	0,074 kg	0,684 kg	0,074 kg	0.3 kg	344.8 kg
CO2							
H2O							
SiO2	0,253 kg	0,039 kg	0,615 kg		0,029 kg		45.4 kg
Grout							
Miscellaneous	0,001 kg	0,000 kg	0,000 kg	0,000 kg	0,001 kg		0.1 kg
Zirconol		0,024 kg		0,058 kg	0,031 kg		1.2 kg
HNO3							0.3 kg
H2C2O4							
NaN2O7	24,599 kg	156,655 kg	10,750 kg	197,469 kg	135,375 kg	0.0 kg	12,644.4 kg
U	0,000 kg	0,000 kg	0,000 kg	0,001 kg	0,000 kg		0.0 kg
U3O7	0,000 kg	0,000 kg	0,000 kg		0,000 kg		0.0 kg
UH3	0,000 kg	0,000 kg			0,000 kg		0.0 kg
UO2	0,000 kg	0,000 kg	0,000 kg		0,000 kg		0.0 kg
UO2(NO3)2							
UO4-4H2O	0,000 kg				0,000 kg		0.0 kg
Pu	3,004 Ci	20,380 Ci	1,850 Ci	24,371 Ci	23,248 Ci	0.0 Ci	1,727.9 Ci
Am	3,885 Ci	23,658 Ci	1,754 Ci	19,870 Ci	18,370 Ci	0.0 Ci	1,780.3 Ci
Cs	0,001 Ci	0,005 Ci	0,000 Ci	0,017 Ci	0,006 Ci		0.6 Ci
Sr	45,491 Ci	246,547 Ci	10,016 Ci	607,907 Ci	361,517 Ci	0.0 Ci	27,100.7 Ci
PCB	0.063 g	0.002 g		0.003 g	0.000 g	0.000 g	9.264 g
RESINS							
Zeolite	0,029 kg						4.2 kg
OIR	0,047 kg	0,008 kg					7.1 kg
Pu	0,000 Ci	0,000 Ci					0.019 Ci
Am	0,000 Ci	0,000 Ci	0,000 Ci				0.003 Ci
Cs	0,003 Ci	0,001 Ci					0.452 Ci
TOTAL ACTIVITIES							
Total U	18,469 kg	119,117 kg	8,071 kg	148,258 kg	101,638 kg	0.0 kg	9,493.3 kg
Total Pu	3,004 Ci	20,380 Ci	1,850 Ci	24,371 Ci	23,248 Ci	0.0 Ci	1,727.9 Ci
Total Am	3,885 Ci	23,658 Ci	1,754 Ci	19,870 Ci	18,370 Ci	0.0 Ci	1,780.3 Ci
TRU	6,889 Ci	44,138 Ci	3,603 Ci	44,241 Ci	41,619 Ci	0.0 Ci	3,508.2 Ci
Total Cs	46,014 Ci	219,536 Ci	15,423 Ci	779,410 Ci	261,512 Ci	0.1 Ci	26,526.6 Ci
Total Sr	45,491 Ci	246,547 Ci	10,016 Ci	607,907 Ci	361,517 Ci	0.0 Ci	27,100.7 Ci
Beta Gamma	94,504 Ci	466,881 Ci	25,439 Ci	1,387,317 Ci	623,029 Ci	0.2 Ci	53,873.3 Ci
CONCENTRATION							
PCB in liquid	0.01 ppb	0.01 ppb			0.01 ppb	0.00 ppb	0.01 ppb
PCB in solids	0.954 ppm	0.005 ppm			0.008 ppm	0.001 ppm	0.265 ppm
Solids	14.27 g/l		4.84 g/l	40.07 g/l	36.92 g/l	0.01 g/l	21.85 g/l
U	0.003 g/cm3	0.013 g/cm3	0.001 g/cm3	0.014 g/cm3	0.011 g/cm3	0.000 g/cm3	0.006 g/cm3
Pu total	0.455 Ci/m3	2.291 Ci/m3	0.223 Ci/m3	2.324 Ci/m3	2.548 Ci/m3	0.000 Ci/m3	1.068 Ci/m3
238 Pu	0.091 Ci/m3	0.458 Ci/m3	0.045 Ci/m3	0.465 Ci/m3	0.510 Ci/m3	0.000 Ci/m3	0.213 Ci/m3
239 Pu	0.182 Ci/m3	0.916 Ci/m3	0.089 Ci/m3	0.929 Ci/m3	1.019 Ci/m3	0.000 Ci/m3	0.427 Ci/m3
240 Pu	0.182 Ci/m3	0.916 Ci/m3	0.089 Ci/m3	0.929 Ci/m3	1.019 Ci/m3	0.000 Ci/m3	0.427 Ci/m3
Am	0.588 Ci/m3	2.659 Ci/m3	0.211 Ci/m3	2.896 Ci/m3	2.611 Ci/m3	0.000 Ci/m3	1.089 Ci/m3
TRU	1.043 Ci/m3	4.951 Ci/m3	0.434 Ci/m3	4.218 Ci/m3	4.562 Ci/m3	0.000 Ci/m3	2.165 Ci/m3
TRU	876 nCi/g	4,203 nCi/g	370 nCi/g	3,627 nCi/g	3,878 nCi/g	0 nCi/g	1,834 nCi/g
Beta Gamma	14,303 Ci/m3	52,394 Ci/m3	3,063 Ci/m3	132,277 Ci/m3	68,291 Ci/m3	0.005 Ci/m3	33,094 Ci/m3

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