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K BASIN SLUDGE TREATMENT PROCESS DESCRIPTION

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Abstract: This document describes a process for chemically treating the sludge from the KE and KW Basins at Hanford so that the uranium, transuranic materials, and fission products can be sent to a double shell waste tank. The undissolved solids from the treatment process will be stabilized in grout for disposal at the Environmental Restoration Disposal Facility (ERDF). Appendices to this document include detailed flowsheet data for the sludge treatment process.

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K BASIN SLUDGE TREATMENT PROCESS DESCRIPTION

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LIST OF TERMS

BACT	best available control technology
BARCT	best available radioactive control technology
DOE	Washington Department of Health
Ecology	Washington State Department of Ecology
EDTA	ethylenediaminetetraacetic acid
ERDF	Environmental Restoration Disposal Facility
HEPA	high-efficiency particulate air
KE	K East
KW	K West
PCB	polychlorinated biphenyl
TOC	total organic carbon
TRU	transuranic
TSCA	<i>Toxic Substances Control Act of 1976</i>
TWRS	Tank Waste Remediation System
WIPP	Waste Isolation Pilot Plant

K BASIN SLUDGE TREATMENT PROCESS DESCRIPTION

1.0 INTRODUCTION

The K East (KE) and K West (KW) fuel storage basins at the 100 K Area of the Hanford Site contain sludge on the floor, in pits, and inside fuel storage canisters. The major sources of the sludge are corrosion of the fuel elements and steel structures in the basin, sand intrusion from outside the buildings, and degradation of the structural concrete that forms the basins. The decision has been made to dispose of this sludge separate from the fuel elements stored in the basins. The sludge will be treated so that it meets Tank Waste Remediation System (TWRS) acceptance criteria and can be sent to one of the double-shell waste tanks. The U.S. Department of Energy, Richland Operations Office accepted a recommendation by Fluor Daniel Hanford, Inc., to chemically treat the sludge. Sludge treatment will be done by dissolving the fuel constituents in nitric acid, separating the insoluble material, adding neutron absorbers for criticality safety, and reacting the solution with caustic to co-precipitate the uranium and plutonium. A truck will transport the resulting slurry to an underground storage tank (most likely tank 241-AW-105). The undissolved solids will be treated to reduce the transuranic (TRU) and ¹³⁷Cs content, stabilized in grout, and transferred to the Environmental Restoration Disposal Facility (ERDF) for disposal.

This document describes a process for dissolving the sludge to produce waste streams that meet the TWRS acceptance criteria for disposal to an underground waste tank and the ERDF acceptance criteria for disposal of solid waste. The process described is based on a series of engineering studies and laboratory tests outlined in the testing strategy document (Flament 1998).

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2.0 SLUDGE VOLUME AND COMPOSITION

The current best estimate is that there will be a total of 50.6 m³ of as-settled sludge that must be processed (nominal value, Pearce et al. 1998). The sludge will be transferred from the storage basins as a slurry of 12 wt% solids in water. Based on this, the total volume of the feed to the sludge treatment process will be 260 m³, including the water used to suspend and transfer the sludge.

There will be five distinct feed streams to the sludge treatment process--two from the KE Basin and three from the KW Basin. The five sludge feed streams are defined as follows:

- KE1--This stream consists of sludge retrieved from the various KE Basin pits and floor areas. This stream will also include KE Basin canister and fuel wash sludge particles less than or equal to 250 μ m in diameter.
- KE2--This process stream consists of sludge less than 6.35 mm and greater than 250 μ m in diameter collected from the KE Basin canister removal and fuel wash activities.
- KW1--This stream consists of the sludge retrieved from the various KW Basin pit and floor areas.
- KW2--This stream consists of sludge less than or equal to 6.35 mm and greater than 500 μ m in diameter collected from the KW Basin canister removal and fuel wash activities.
- KW3--This stream consists of canister sludge less than or equal to 500 μ m in diameter collected from the KW Basin Interim Water Treatment System knockout pot filter system.

Tables 2-1 and 2-2 show the volume and major chemical components of the five sludge feed streams.

The composition of the floor and pit sludges, which contains more iron oxides and sand than uranium, is much different than the canister sludges which are composed of mostly uranium oxides and uranium metal. The sludge treatment equipment will be designed to process all of the sludge streams, but some of the operating parameters will be adjusted as necessary to handle the different sludge stream compositions. The volume of chemical additions and the amount of undissolved solids will be much different for floor and pit sludges than for canister sludge.

Because the sludge will be transferred to the treatment process as five distinct streams with differing compositions, the sludge treatment process and equipment must be designed to handle each stream, rather than a composite stream, by itself.

Table 2-1 Nominal Inventory for KE Basin Process Feed Streams.

		Stream KE1		Stream KE2	
	Units	Stream KE1 Composition in total kg		Stream KE2 Composition in total kg	
As-settled Sludge Solid Content (g dry solids/cm ³ as-settled sludge)	g/cm ³	0.564		1.055	
As-settled Sludge Density	g/cm ³	1.403		2.359	
Volume of Sludge	m ³	41.459		2.369	
As-settled Sludge Chemical Composition					
U	g/cm ³	0.001108	48.340	0.637703	1,510.603
UO ₂	g/cm ³	0.038209	1,625.658	0.384611	811.785
U ₂ O ₇	g/cm ³	0.028711	1,190.347	0.202670	480.798
UO ₄ •4H ₂ O	g/cm ³	0.000990	41.051	-	-
Al(OH) ₃	g/cm ³	0.001920	79.593	0.038188	80.483
Al(OH) ₃	g/cm ³	0.008358	263.589	0.143847	340.749
Al ₂ O ₃	g/cm ³	0.041851	1,729.804	-	-
FeO(OH)	g/cm ³	0.182012	7,590.548	0.091262	216.182
BaO ₂	g/cm ³	0.154810	6,409.937	0.069935	165.064
CaO	g/cm ³	0.006824	282.917	0.001348	3.193
CO ₂	g/cm ³	0.001906	307.140	0.008278	14.873
Si	g/cm ³	0.000853	27.163	0.001941	4.895
Sum of Other Compounds	g/cm ³	0.037589	1,561.739	0.014023	33.218
Miscellaneous solids					
PCB	g/cm ³	0.000108	4.465	0.000201	0.064
RIER	g/cm ³	0.029389	1,218.882	0.014397	34.103
Zephin	g/cm ³	0.017818	738.740	-	-
Zircaloy 2	g/cm ³	-	-	0.043569	103.207
Graph	g/cm ³	-	-	-	-
Dry solid - radioisotope content					
²³⁹ Pu and ²⁴⁰ Pu	g/cm ³	0.000105	8.084	0.004319	10.225
²³⁹ Pu and ²⁴⁰ Pu	μCi/g	18.78	-	127.47	-
²⁴¹ Am	μCi/g	24.29	-	147.94	-
¹³⁷ Cs	μCi/g	302.78	-	1,374.21	-
⁹⁰ Sr	μCi/g	384.48	-	1,541.42	-
Uranium composition					
U	kg	-	2614.86	-	2,819.16
²³⁵ U	mass%	0.0000	-	0.0004	-
²³⁸ U	mass%	0.0084	-	0.0081	-
²³⁴ U	mass%	0.0361	-	0.0709	-
²³⁵ U	mass%	0.0658	-	0.0718	-
²³⁸ U	mass%	99.29	-	99.24	-

Table 2-2. Nominal Inventory for KW Basin Process Feed Streams.

		Stream KW1		Stream KW2		Stream KW3	
	Units		Stream KW1 Composition in total kg		Stream KW2 Composition in total kg		Stream KW3 Composition in total kg
As-settled Sludge Solid Content (g dry solids/cm ³ as-settled sludge)	g/cm ³	0.382		0.242		1.015	
As-settled Sludge Density	g/cm ³	1.202		0.540		2.562	
Volume of Sludge	m ³	4.67		0.199		1.876	
As-settled Sludge Chemical Composition							
U	g/cm ³	0.000187	0.871995	7.374575	1,464.425	0.035401	66.495
UO ₂	g/cm ³	0.010487	48.975796	-	-	0.835274	1,969.000
U ₂ O ₇	g/cm ³	0.010685	48.944738	-	-	0.368587	862.363
UO ₂ + H ₂ O	g/cm ³	0	0	-	-	0.004785	9.805
UH ₄	g/cm ³	0	0	-	-	0.082877	185.675
AMOH ₂	g/cm ³	0	0	-	-	0.215868	406.464
Al ₂ O ₃	g/cm ³	0.020981	97.880113	-	-	-	-
PuO ₂ (OH)	g/cm ³	0.085070	323.867767	-	-	0.179110	336.445
BiO ₂	g/cm ³	0.255239	1191.867215	-	-	0.059759	108.361
CaO	g/cm ³	0.004117	18.225854	-	-	0.000565	1.053
CO ₂	g/cm ³	0.001190	5.567143	-	-	0.001657	2.924
C	g/cm ³	0.000194	0.908042	-	-	0.001570	2.949
Sum of Other Compounds	g/cm ³	0.008626	44.855227	0.042141	8.358	0.124142	237.064
Miscellaneous solids							
PCB	g/cm ³	0	0	-	-	0.000008	0.016
OMER	g/cm ³	0	0	-	-	-	-
Zincite	g/cm ³	0	0	-	-	-	-
Zincblende 2	g/cm ³	0	0	0.518736	103.207	-	-
ZnSfide	g/cm ³	0	0	0.270611	55.524	-	-
Dry solid - radionuclide content							
²³⁸ Pu and ²³⁹ Pu	g/cm ³	0.000058	0.318071	0.026116	5.186	0.004831	9.282
²³⁸ Pu and ²³⁹ Pu	μCi/g	11.67		162.41		145.38	
²⁴¹ Am	μCi/g	10.97		124.25		114.87	
²⁴¹ Ce	μCi/g	96.62		4,581.41		1,537.75	
²⁴¹ Ge	μCi/g	82.54		3,603.71		2,260.13	
Uranium composition							
U	kg		87.24		1,464.42		2,207.77
²³⁸ U	mass%	-	-	-	-	-	-
²³⁵ U	mass%	0.0086		0.00890		0.00584	
²³⁴ U	mass%	0.0794		0.78000		0.78626	
²³⁶ U	mass%	0.0728		0.09600		0.06250	
²³⁸ U	mass%	99.2424		99.11000		99.14212	

Tables 2-1 and 2-2 show that there are basically three very different types of sludges. The first is the KE Basin floor and pit sludges (stream KE1), which contain more insoluble material than uranium. The second type of sludge includes the canister and wash sludges from the KE and KW Basins (streams KE2, KW2, and KW3), which contain a high percentage of uranium and little iron or insoluble material. The third type of sludge is the KW Basin floor and pit sludge (stream KW1), which is mostly insoluble material.

As would be expected, the canister sludges, which contain much more uranium than the floor and pit sludges, also contain much more plutonium and long-lived fission products.

3.0 SLUDGE TREATMENT REQUIREMENTS

The dissolved sludge stream to be transferred to an underground waste tank and the undissolved solids to be sent to ERDF for disposal must meet the acceptance criteria for transfers to those facilities. In addition, the offgas released from the sludge treatment facility must comply with the regulatory requirements of the state of Washington. Polychlorinated biphenyls (PCB) have been found in KE Basin sludge samples at concentrations greater than 50 ppm, so sludge treatment also must comply with the *Toxic Substances Control Act of 1976* (TSCA). The following sections describe sludge treatment requirements.

3.1 REQUIREMENTS FOR TREATED SLUDGE TRANSFER TO TANK 241-AW-105

The TWRS requirements for the treated sludge are specified in the *K Basin Sludge Pretreatment Requirements Summary* (Carothers et al. 1997). Table 3-1 summarizes the requirements. Samples are required for each shipment so that tank farm personnel can evaluate the waste batch against approved waste stream profile sheets for K Basin treated sludge. Before acceptance, the sludge is required to go through the TWRS waste acceptance criteria process.

Table 3-1. Requirements for Treated Sludge Transfer to Tank 241-AW-105 (2 sheets)

Requirements	How met
Criticality <ul style="list-style-type: none"> pH > 8 U^{235} content < 0.84 wt% and iron/plutonium mass ratio > 353 Precipitate particle size < 50 μm 	Treatment process will add NaOH, depleted uranium, and iron to meet requirements. Caustic precipitation will form crystals < 50 μm .
Particle size < 177 μm To prevent flammable gas retention, waste tank liquid specific gravity $\times$ total solids depth (in) < 148. A total of 379 m ³ of solids can be added to tank 241-AW-105 before exceeding this requirement.	Filter upstream from neutralization tank. Treatment process will generate < 379 m ³ of precipitated solids.
No separable organic layer, exotherms/endotherms < 1.0	Samples indicate no separable organic or net exotherms.
For $[\text{NO}_2] \leq 1.0 \text{ M}$ then $0.010 \text{ M} \leq [\text{OH}] \leq 5.0 \text{ M}$ $0.011 \text{ M} \leq [\text{NO}_2] \leq 5.5 \text{ M}$ For $1.0 \text{ M} < [\text{NO}_2] \leq 3.0 \text{ M}$ then $0.1 ([\text{NO}_2]) \leq [\text{OH}] < 10 \text{ M}$. $[\text{OH}] + [\text{NO}_2] \geq 0.4 ([\text{NO}_2])$ For $[\text{NO}_2] > 3.0 \text{ M}$ then $0.3 \text{ M} \leq [\text{OH}] < 10 \text{ M}$ $[\text{OH}] + [\text{NO}_2] \geq 1.2 \text{ M}$, $[\text{NO}_2] \leq 5.5 \text{ M}$	Treatment process will add NaOH and NaNO_2 to meet requirements.
No TSCA*-regulated substances (PCB concentration in the liquid must be ≤ 0.5 ppb, PCB concentration in solids must contain < 2 ppm/congener)	Treatment process will reduce PCB concentration below TSCA* treatment standards.
Eliminate pyrophoric materials	Treatment process will remove or oxidize pyrophoric materials.

Table 3-1 Requirements for Treated Sludge Transfer to Tank 241-AW-105 (2 sheets)

Requirements	How met
Supernate transuranic <100 nCi/g	Treatment process will produce non-transuranic supernate
Waste tank heat generation rate <70,000 Btu/h	¹³⁷ Cs and ⁹⁰ Sr in sludge will add <10,000 Btu/h to the 1,203 Btu/h already in tank (Carothers et al 1997 ^a)
TOC <10 g/L if sent to noncomplexant tank	Treatment process will remove organic ion-exchange resin

^aToxic Substances Control Act of 1976, 15 USC 2601, et seq

^bCarothers, K G, K D Fowler, and J P Slaughter, 1997, *K Basin Sludge Pretreatment Requirements Summary*, HNF-SD-TWR-OCD-001, prepared by Lockheed Martin Hanford Corporation for Fluor Daniel Hanford, Inc., Richland, Washington

PCB = polychlorinated biphenyl

TOC = total organic carbon

3.2 REQUIREMENTS FOR UNDISSOLVED SOLIDS DISPOSAL TO ENVIRONMENTAL RESTORATION DISPOSAL FACILITY

The requirements for waste disposal at ERDF are specified in the *Environmental Restoration Disposal Facility Waste Acceptance Criteria* (BHI 1998). The requirements from that document that are applicable to disposal of the undissolved solids from K Basin sludge processing are as follows:

- Before disposal at ERDF, waste containing free liquids must be treated so that free liquids are no longer present
- Pyrophoric material contained in waste will be treated, prepared, and packaged to be nonflammable before being transported to ERDF for disposal
- Solid acid waste that exhibits the characteristic of low pH under the corrosivity tests of WAC 173-303 will not be accepted for disposal.
- Transuranic waste (waste containing greater than 100 nCi/g of TRU) will not be accepted for disposal at ERDF
- Ion-exchange resins must be thoroughly drained and stable before they are transported for disposal and shall not react with their surroundings to create excessive heat or corrosive-reactive products. Ion-exchange resins may be subject to restrictions associated with organic carbonaceous compounds
- Non-liquid PCBs in the form of contaminated soil, rags, or other debris may be disposed of at ERDF (this includes non-liquid waste with PCB concentrations greater than 500 ppm)

The requirements for no free liquid and packaging of pyrophoric material will be met by grouting the solids before transfer to ERDF. The requirements for pH and non-TRU will be met by leaching and washing the solids before grouting. Table 3-2 lists the limits for radioactive constituents.

Table 3-2 Environmental Restoration
Disposal Facility Waste Acceptance Criteria
Radionuclide Concentration Limits

Constituent	Limit (Ci/m ³)*
Americium-241	5.0E-02
Americium-243	5.7E-02
Carbon-14	5.3E+00
Carbon-14	5.3E+01
Cesium-137	3.2E+01
Europium-152	2.1E+07
Neptunium-237	1.5E-03
Plutonium-238	1.5E+00
Plutonium-239	2.9E-02
Plutonium-240	2.9E-02
Plutonium-241	6.2E+00
Plutonium-242	1.1E-01
Radium-228	2.2E-04
Strontium-90	7.0E+03
Technetium-99	1.3E+00
Thorium-228 + daughters	1.2E-04
Thorium-232	6.0E-03
Uranium-233/234	7.4E-02
Uranium-235	2.7E-03
Uranium-238 + daughters	1.2E-02
Zirconium-93	1.4E+02

*Radioactive waste Class C limits also apply (30 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," Code of Federal Regulations, as amended.)

3.3 REQUIREMENTS FOR OFFGAS RELEASE

New sources of toxic air pollutants, which include NO_x, are regulated by WAC 173-460. The small-quantity emission limits for NO_x are 7727 kg/yr and 0.91 kg/h. If the NO_x releases will exceed these limits, a dispersion modeling analysis can be done to determine the concentration at the Hanford Site boundary. The concentration at the Site boundary must be less

than the Acceptable Source Impact Level from WAC 173-460, which for NO_x is $100 \mu\text{g}/\text{m}^3$ averaged over 24 hours

The use of best available control technology (BACT) to control toxic air emissions is also required by WAC 173-460. The use of absorption columns for NO_x removal is common industrial practice. Absorption columns for NO_x removal from the sludge treatment facility will be proposed to state regulators as toxics-best available control technology. The offgas section of this document provides details on how the absorption columns will reduce the NO_x concentration to less than the release limit.

Radioactive airborne emissions are regulated by WAC 246-247, which requires the use of best available radioactive control technology (BARCT). Radioactive air emissions from all combined operations at the Hanford Site cannot exceed 10 mrem/yr effective dose equivalent to an offsite individual. High-efficiency particulate air (HEPA) filters are commonly identified as BARCT for radioactive particulates. The HEPA filters will be installed in the offgas system of the sludge treatment facility.

The PCB concentration in the offgas released from the sludge treatment facility is limited to $10 \mu\text{g}/\text{m}^3$ by U.S. Environmental Protection Agency regulations. A granulated activated carbon bed will be installed in the offgas system to reduce the PCB concentration below this limit.

The sludge treatment process described in this document will meet the above requirements for offgas emissions.

4.0 BATCH SIZE

The K Basin sludge will be transferred from the basins to the sludge processing facility in batches and will also be processed in batches. Many factors must be considered when selecting a batch size for the sludge treatment process. These factors include hazards classification, shielding requirements, criticality concerns, and processing rate. Another question that must be addressed is whether the batch size should be the same for the different sludge streams because the composition of floor/pit sludge is quite different from the composition of canister/wash sludge.

Several factors favor a smaller batch size for canister/wash sludge than for floor/pit sludge. The concentrations of uranium, plutonium, and ^{137}Cs are 4.5 to 5 times higher in canister/wash sludge than in the floor/pit sludge. Therefore, the source term for safety evaluations, the radiation dose rate, and the amount of absorber that must be added for tank farm criticality requirements will be much higher on a per liter basis for canister/wash sludge than for floor/pit sludge. This must be weighed against the simplicity of a common batch size for all sludge types.

The conclusion was reached that a common batch size should be used for all the sludge streams. The batch size that will be used for transfer and processing of the K Basin sludge is 160 kg of solids (dry basis) suspended in water at a concentration of 12 wt% solids. This will make a batch volume of approximately 1215 L. With a batch size of 160 kg of dry solids, it will take 214 batches to process all the sludge based on the sludge volumes reported in the design feed document for sludge (Pearce et al. 1998). Assuming a one batch/day processing rate and 60% operating efficiency, 214 batches can be processed in a 1-year period. This fits in with the commitment to complete sludge processing within a 1-year period following removal of the fuel from the KE and KW Basins.

A batch size of 160 kg of dry sludge will allow mass limits to be used for criticality control. One-third of a minimum critical mass of 1.25% enriched uranium is 204 kg, which is a factor of 1.27 times the 160 kg batch size. Even if the conservative assumption is used that a 160 kg batch is composed of 100% uranium, there will be a 44 kg margin between the batch size and an operating limit of 204 kg of uranium. Section 5.3.10 discusses mass limits for criticality control.

Because the neutralized waste will be hauled to the waste tank by truck using a shielded container, it is desirable to keep the batch size from getting too large. Using a sludge batch size of 160 kg, the volume of a batch of neutralized waste will range from about 6500 L to about 11,100 L depending on the sludge stream being processed. The neutralized waste batches of 6500 L can most likely be hauled in one truck load, but it is assumed that at the upper end of the range two truck loads per batch will be required.

An evaluation of the sludge inventory in the sludge processing facility will be done to determine the hazards category. Based on the 160 kg batch size, it is anticipated that it will be a hazards Category 2 facility.

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5.0 SLUDGE TREATMENT PROCESS DESCRIPTION

Figure 5-1 presents a flow diagram of the sludge treatment process. The sludge will be transferred from the basins to the treatment system in a shielded transport container. The sludge will be pumped from the transport container into the lag storage tank where it will be held until it can be moved on through the process. Sludge treatment will be done by dissolving the fuel constituents in nitric acid, separating the insoluble material, adding neutron absorbers for criticality safety, and reacting the solution with caustic to co-precipitate the uranium and plutonium. The resulting slurry will be transported to an underground storage tank (most likely tank 241-AW-105) in a shielded transport container.

Sludge treatment will include the following steps:

- Sludge transfer from transport container to lag storage vessel
- Resin bead separation
- Acid addition to the dissolver
- Sludge transfer from sludge buffer tank to dissolver
- Sludge dissolution
- Solution transfer from dissolver
- Solids/liquid separation
- Absorber addition (after sampling)
- Neutralization/precipitation
- Slurry transfer to tank farm

The portion of the sludge that is not dissolved will go through the following steps:

- Solids/liquid separation
- Solids washing
- Chemical treatment of solids for ^{137}Cs and TRU removal
- Solids/liquid separation
- Solids washing
- Stabilization in grout

The resin beads that are separated upstream from the dissolver will go through the following steps:

- Chemical leaching for ^{137}Cs and TRU removal
- Solids/liquid separation
- Solids washing
- Stabilization in grout along with undissolved solids from the dissolver

Figure 5-1 Flow Diagram of Sludge Treatment (2 sheets)

Figure 5-1 Flow Diagram of Sludge Treatment (2 sheets)

The dissolver offgas system will consist of the following

- Condenser
- NO_x absorber
- Mist eliminator
- Heater
- HEPA filters
- Activated carbon cartridge
- Sampling/monitoring system
- Release from stack

The following sections describe each major step in the sludge treatment process along with limited information on stream compositions, stream volumes, and operating efficiencies of different unit operations. Appendixes A through G contain detailed material balance data for each of the five sludge streams, for solids grouting, and for the total of all streams. The data include summary material balance figures for each sludge stream and detailed stream data sheets for each sludge stream. The data are presented on a batch basis and a total stream basis.

5.1 LAG STORAGE

The sludge will be transported from the KE and KW Basins to the sludge treatment system as a slurry of 12 wt% solids in water. The sludge will be transferred from the transport container to a lag storage vessel. The lag storage vessel will serve as holding tank for the sludge until it can be transferred to the resin removal equipment and then on to the dissolver. The lag storage vessel will be equipped with an agitator to keep the sludge particles suspended.

More than one lag storage vessel may be needed to provide more processing flexibility. This would allow sludge to be transferred into one vessel while it is being transferred out of another. Increasing the amount of lag storage will decrease the coordination needed between sludge retrieval and sludge treatment. Problems with sludge retrieval and transport from the 100 K Basins will have less impact on the sludge processing facility if there are several lag storage tanks. The flexibility gained by additional lag storage tanks must be weighed against the increased cost of installing the tanks. This will be evaluated in a future time/cost study that will determine how much additional cost should be spent on equipment to reduce the cycle time and thus the total time to process all the K Basin sludge.

An air bleed will be used to dilute and sweep away hydrogen produced by the uranium-oxidation reaction. Hydrogen generation has been observed in several samples of sludge from KE Basin canisters (Makinas 1997). Movement or agitation of the sludge apparently disturbs the oxide layer on fuel fragments and exposes additional uranium metal to water which reacts as follows:

Some uranium hydride may also be present and will oxidize in water to form H_2 by the following reaction

Gas samples were collected from the two sludge samples, which showed the highest gas generation rates. Analysis of the samples by mass spectrometry confirmed the presence of H_2 .

5.2 RESIN SEPARATION

Laboratory tests have shown that when the mixed bed Purolite LX resin is exposed to simulated dissolver conditions, it does not dissolve or lose much of its functionality (Breck et al. 1998, Poole et al. 1998a). If the resin is exposed to acidic dissolver conditions, it will become nitrated and the ^{237}Cs on the anion resin will be displaced by plutonium and americium. This will create two problems downstream from the dissolver: (1) the nitrated resin loaded with plutonium will become very reactive if dried, and (2) the plutonium and americium on the resin beads will make the TRU content in the undissolved solids so high that the plutonium will have to be leached from the resin to make the undissolved solids acceptable for disposal at ERDF. To alleviate these problems, the sludge will go through a resin separation step before dissolution.

The physical properties of the resin beads are different than the physical properties of the sludge particles in several ways. Two of the differences in physical properties (particle size and density) can be used to separate the resin from the sludge.

The diameter of the resin beads ranges from 200 to 1200 μm , which is larger than the particle size of most of the sludge particles. The particle size of KE Basin floor and weasel pit sludge varies from 0.1 μm to greater than 700 μm with the average particle size around 10 μm . About 10% of the sludge consists of particles greater than 700 μm . This includes particles of grafoil and uranium fragments up to 6 mm in diameter.

The density of the resin beads is less than the density of the main sludge components. The densities of Purolite resin beads are 1070 and 1240 kg/m^3 for the anion and cation beads, respectively. The densities of SiO_2 and Al_2O_3 are 2640 and 3970 kg/m^3 , respectively. The iron oxide, uranium oxide, and uranium metal in the sludge have even higher densities.

Based on the above differences in physical properties, an engineering study (Duncan and Flament 1998) recommended using a screen followed by an elutriation column to separate the resin beads from the other sludge components.

The sludge will be transferred from the lag storage vessel through a screen to the sludge buffer tank. The screen will separate most particles larger than 300 μm from the rest of the sludge and will direct the larger particles including the resin beads to the elutriation column. The screen upstream will be back flushed with water periodically to prevent plugging. The flush solution will be routed to the elutriation column.

The resin beads and other large particles will enter the elutriation column around the midpoint. The resin beads will be elutriated from the other large particles by pumping water upward through the column at a velocity of about 4 cm/s. Because the resin beads have a lower density than most of the other sludge constituents, they will rise to the top of the column and exit with part of the water. The water and elutriated resin will drain to the resin buffer tank. Any paint chips and grafoil too large to pass through the screen upstream from the column inlet probably will be removed along with the resin beads because they are easily suspended.

Approximately 50% of the zeolite entering the elutriation column will be elutriated along with the resin beads. The other 50% will remain with the sludge stream that leaves the bottom of the column. Most of the water leaving the top of the column will be recirculated to the bottom of the column to elutriate more resin beads.

The heavier sludge particles and a small amount of the resin beads will settle to the bottom of the elutriation column and drain from there to the sludge buffer tank.

Periodically, the resin beads will be transferred from the resin buffer tank to the leach tank where they will be treated to remove ^{137}Cs and TRU.

Elutriation of resin beads by the technique described above has been demonstrated in the laboratory (Squier 1998). A resin separation efficiency of 95% was achieved. However, 0.2 wt% of the sludge was entrained along with the resin beads in the elutriation column.

5.3 SLUDGE DISSOLUTION

Analysis of sludge samples from the basins has identified numerous oxides of uranium, but only one sample contained uranium hydride. Fragments of uranium metal are believed to be present in the sludge although it was not identified in any samples. Oxide coatings on the uranium metal may be preventing its detection by X-ray diffraction. The high density of some canister sludge samples is consistent with the presence of uranium metal. The sludge that comes from the fuel element washing machine is assumed to contain 50 wt% uranium metal as well as 5 wt% UO_2 .

5.3.1 Uranium Dissolution

The uranium oxide, uranium hydride, and uranium metal will dissolve in nitric acid to form uranyl nitrate, water, and nitrogen oxides. Because the uranium oxide, hydride, and metal in the sludge have a high surface area, most of it will dissolve rapidly at boiling temperature even at a nitric acid concentration less than 4 M. Uranium metal fragments with a diameter up to 6 mm may be present and will take the longest to dissolve. Several different reactions will be involved in the dissolution of the different forms of uranium and a discussion of them is beyond the scope of this document. Only an overall reaction that is representative of the uranium dissolution stoichiometry including reflux from the condenser will be presented.

The nitric acid consumed during dissolution of the various uranium oxides, uranium hydride, and fragments of uranium metal depends on how far the HNO_3 is reduced during

dissolution and how much NO_x is absorbed in the condenser and absorber and returned to the dissolver. Until the process is further defined, the following overall equations will be used to represent the uranium dissolution in the dissolver:

The first two equations were used for the Plutonium-Uranium Extraction flowsheet (Allen 1985) and account for HNO_3 reflux from a downdraft condenser.

Hot cell tests with sludge samples show that greater than 99% of the uranium, plutonium, americium, and fission products (mostly ^{137}Cs and ^{90}Sr) in the floor sludge will dissolve in 6 M HNO_3 (Carlson et al. 1998a, Carlson et al. 1998b). The remaining uranium, plutonium, americium, and fission products will remain tied up with the undissolved portion of the sludge. The traces of plutonium and americium that remain tied up in the undissolved solids will make it difficult to make the solids non-TRU (greater than 100 nCi/g) without further processing downstream. The undissolved solids also will contain traces of ^{137}Cs and ^{90}Sr . The residual ^{137}Cs may also exceed ERDF acceptance criteria without further processing. Leaching of the undissolved solids to reduce the TRU and ^{137}Cs content will be discussed in a later section.

Table 5-1 shows the percentage of uranium and other sludge components expected to dissolve in 6 M HNO_3 based on laboratory tests.

5.3.2 Iron Dissolution

Ferric oxyhydroxide present in the sludge will react with nitric acid according to the following equation:

Hot cell dissolution tests of sludge samples indicate that greater than 99% of the FeOOH is dissolved after boiling for 24 hours in 6 M HNO_3 (Carlson et al. 1998a, Carlson et al. 1998b).

Table 5-1 Dissolution Process Parameters

	Dissolution factor	Vaporization factor	Plating factor	Undissolved	Absorbed by resins after dissolution
Al(OH) ₃	99.00%			1.00%	
Al ₂ O ₃	95.00%			5.00%	
FeOOH	99.00%			1.00%	
C	0.00%			100.00%	
CaO	90.00%			10.00%	
CO ₂	0.00%	100.00%			
SiO ₂	0.00%			100.00%	
Miscellaneous	99.00%			1.00%	
Zircaloy	0.00%			100.00%	
Grafoil	0.00%			100.00%	
Na ₂ U ₂ O ₇	0.00%			100.00%	
U	99.95%			0.05%	
U ₃ O ₇	99.95%			0.05%	
UH ₃	99.95%			0.05%	
UO ₂	99.95%			0.05%	
UO ₄ -4H ₂ O	99.95%			0.05%	
PCB	Dissolution rate in order to get 12 ppb concentration in dissolution solution.	20.00% of remaining PCB	50.00% of of remaining PCB	30.00% of of remaining PCB	
Zeolite				100.00%	
OIER				100.00%	
Pu (Solid)	99.70% (minus what is absorbed by resins)			0.30%	According to equilibrium law $K_d=32$ (with $K_d=\text{Pu concentration of wet resin}/\text{Pu concentration in liq}$)
Am (Solid)	99.90% (minus what is absorbed by resins)			0.10%	According to equilibrium law $K_d=1.9$ (with $K_d=\text{Am concentration of wet resin}/\text{Am concentration in liq}$)
Cs (Solid)	99.70%			0.30%	
Sr (Solid)	99.95%				
Pu (Resin)					100.00%
Am (Resin)					100.00%
Cs (Resin)	90.00%				10.00%

5.3.3 Aluminum Dissolution

Aluminum hydroxide ($\text{Al}(\text{OH})_3$) was found only in KW Basin canister sludge samples. The canister sludge samples averaged less than 1 wt% aluminum, while the KE Basin floor sludge contained 4 wt% aluminum. Most of the aluminum in the floor sludge is in the form of alumina compounds, while the aluminum in the canister sludge is $\text{Al}(\text{OH})_3$. The $\text{Al}(\text{OH})_3$ and alumina will dissolve as follows:

Hot cell tests with sludge samples indicate that 90% to 95% of the $\text{Al}(\text{OH})_3$ and Al_2O_3 is dissolved after boiling for 24 hours in 6 M HNO_3 (Carlson et al. 1998a, Carlson et al. 1998b).

5.3.4 Silica Precipitation

Silica (SiO_2) was identified as a component in floor and canister sludges and several aluminum silicate compounds ($\text{NaAlSi}_3\text{O}_8$, $\text{CaAl}_2\text{Si}_2\text{O}_8 \cdot 4\text{H}_2\text{O}$) were found in KE Basin floor sludge samples.

A gelatinous precipitate that was observed during some sludge dissolution tests has not been identified, but is believed to be a silicon compound formed by the precipitation of some of the SiO_2 that dissolved. Hot cell dissolution tests of sludge samples indicate that there is very limited dissolution of SiO_2 in boiling 6 M HNO_3 , so essentially all of the SiO_2 will leave the dissolver with the undissolved solids.

The SiO_2 present in the sludge from sand intrusion and spalling of the basin concrete will constitute most of the undissolved solids.

The sand also contains aluminum and silicates in the form of clays and these are partially soluble in nitric acid. A gelatinous precipitate has been observed in hot cell dissolution tests of K Basin canister sludge in 10 M HNO_3 at 60 and 95 °C (Bredt et al. 1998). The amount of precipitate formed increases with temperature and acid concentration. A similar precipitate formed when Hanford Site blow sand from the 100 K Area was exposed to 10 M HNO_3 . A silica precipitate also formed when samples of concrete from the 100 K Basins were boiled in HNO_3 (Beck 1998).

The main concern with gel formation is that it may prevent efficient separation and washing of the undissolved solids downstream from the dissolver. Efficient separation and washing of the solids are a critical part of making the solids non-TRU and reducing the PCB concentration in the dissolved sludge to less than 0.5 ppb. These criteria must be met to send the solids to ERDF for disposal and to transfer the dissolved sludge to tank 241-AW-105.

Manipulating process conditions to ensure that the silica precipitates in a form that can be filtered rather than forming a gel is the key to processing materials that contain soluble silicates.

One way to help form a filterable precipitate is to use a strong acid at or near its boiling point (Terry 1983)

Laboratory studies were done to determine the cause of gel formation and what could be done to prevent gel formation or minimize its impact on sludge processing (Beck 1998). The tests showed that when concrete similar to that used in the K Basins was exposed to hot nitric acid, gel formed at all nitric acid concentrations between 1 and 10 M. However, the gel that formed when using low acid concentrations (1 to 4 M) caused filtration problems, while the gel that formed using high acid concentrations (8 to 10 M) could be filtered. Other materials that were tested for gel formation (Hanford Site sand and diatomaceous earth) failed to form gel under simulated dissolver conditions.

5.3.5 Zeolite Dissolution

The Zeolon 900H zeolite and the metallic zirconium fragments will remain with the undissolved solids. Laboratory tests by the Pacific Northwest National Laboratory indicate that 92% to 95% of the ^{137}Cs will be removed from the Zeolon 900H ion-exchange material when digested in HNO_3 (Poole et al. 1998b). The Zeolon 900H lost some of the aluminum and iron present in the material but the basic mordenite structure remained intact. Calculations indicate that at the above removal rate, the residual ^{137}Cs on the zeolite will not by itself cause the undissolved solids to exceed the ERDF acceptance criteria.

5.3.6 Polychlorinated Biphenyl Distribution

Laboratory tests were performed to determine the fate of the PCBs during nitric acid dissolution (Mong et al. 1998). The laboratory tests used a discrete mixture of chlorinated biphenyls (dichloro, tetrachloro, hexachloro, and octachloro) so decomposition of the PCB could be detected by a change in the ratio. The results of the tests indicate that the PCBs will not decompose in boiling nitric acid. This was expected because PCBs are very stable compounds. Because PCBs are hydrophobic, most of the PCBs that are not carried into the offgas will be adsorbed on the residual undissolved solids or on equipment. The expected distribution of the PCBs during sludge processing was calculated using only the tetrachloro and hexachloro compounds because they are most representative of the Aroclor 1254 PCB found in the basin sludge. The laboratory tests found that 20% of the tetrachloro and hexachloro biphenyls were volatilized into the offgas, 50% plated out on the laboratory glassware used to conduct the test, and 30% were adsorbed on the solids. The above PCB distribution was used for flowsheet calculations.

The solution leaving the dissolver may contain up to 12 ppb PCBs (solubility limit in water). Later sections of this document will discuss steps that will be taken to reduce the PCB concentration in the offgas and downstream from the dissolver. The total amount of PCBs in the sludge is estimated to be about 4.5 kg (Pearce et al. 1998). The total amount of PCBs that is expected to plate out on process equipment is 50% of this or 2.25 kg. The PCBs plated out on the equipment will be disposed of following the campaign during decontamination and deactivation of the facility.

5.3.7 Dissolution Process

This section describes the current process envisioned for dissolving the sludge based on operating experience dissolving uranium oxide fines and discusses the results of ongoing laboratory experiments.

The finely divided uranium oxide in the floor/pit and settler tank sludges will react very rapidly in boiling nitric acid even at low concentrations. An engineering study of sludge dissolution (Westra and Flament 1998) concluded that the best way to control the reaction rate when dissolving this sludge is to first make up an acid solution in the dissolver and then slowly add the sludge continuously over a period of 8 hours. This will limit the amount of finely divided uranium that is available to react at any given time. The floor/pit sludge with an average particle size of 10 μm will dissolve continuously as it is added to 2 to 6 M HNO_3 at 100 °C. Calculations show that a minimum acid concentration of 4.2 M is needed to continuously dissolve the 500 μm particles in the KW Basin settler tank sludge (Nevers and Flament 1998). If the reaction rate is controlled by the sludge feed rate to the dissolver, dilute acid is not needed for reaction control.

The 6 mm diameter particles of uranium metal that will be present in the canister/wash sludge will dissolve much slower than the finely divided uranium oxides in the floor/pit and settler tank sludge. The time required to completely dissolve the 6 mm particles in HNO_3 at 103 °C was calculated to be 71 hours in 3 M HNO_3 , 19 hours in 5 M HNO_3 , and 12 hours in 6 M HNO_3 (Westra and Flament 1998, Nevers and Flament 1998). Using an acid concentration of 6 M at close to boiling temperature for dissolving canister/wash sludge will result in a total dissolution time of approximately 20 hours (8 hours to continuously feed the sludge to the dissolver and another 12 hours to dissolve the 6 mm uranium particles in the last sludge fed to the dissolver).

Based on the above discussion, all of the sludge streams should be dissolved by continuously feeding the sludge into 6 M HNO_3 at 95 °C. It will take longer to dissolve the canister/wash sludge than the other sludge streams due to the larger particle size, but otherwise the process will be the same for all sludge streams.

The following paragraphs describe the process that will be used for dissolving the K Basin sludges.

A batch of 600 L of 6 M nitric acid solution will be made up in the dissolver. The acid will be agitated and heated to 95 °C. Then the sludge, with the resin beads removed, will be pumped into the dissolver continuously at a rate of 2.5 L/min (20 kg solids/h). Air will be bled into the dissolver vapor space to help oxidize NO to NO_2 , which will improve NO_2 absorption in the condenser and absorber. The dissolver temperature and vacuum, along with the NO_2 concentration in the offgas, will be monitored to ensure that the reaction is under control. The concentration of xenon and ^{85}Kr in the offgas will be monitored to track uranium metal dissolution. The acid concentration will be monitored using a conductivity probe. Additional acid will be added continuously to maintain the acid concentration at 6 M. At a feed rate of 2.5 L/min, it will take 8 hours to transfer the approximately 1215 L batch of sludge into the dissolver.

When dissolving floor/pt and settler tank sludge, the dissolver will be held at 95 °C for 2 hours after sludge addition is completed to ensure that all of the uranium is dissolved. The dissolver will be held at 95 °C for a total time of approximately 10 hours.

When dissolving canister/wash sludge, the dissolver will be held at 95 °C for 14 hours after the sludge addition is completed to dissolve the 6 mm particles of uranium metal that may be present in the sludge. The ⁸⁵Kr and xenon concentration in the offgas will be monitored along with the solution conductivity to determine the dissolution endpoint. When the ⁸⁵Kr and xenon concentration drops to zero and the solution conductivity levels off, it will be an indication that essentially all of the uranium metal has dissolved. The total time that the dissolver will be held at 95 °C for a batch of canister/wash sludge will be approximately 22 hours.

When sludge dissolution is complete, the dissolver will be cooled to 45 °C and the solution will be transferred out of the dissolver to a centrifuge for solids/liquid separation. The dissolver solution will be agitated during the transfer to keep the undissolved solids suspended so that they are transferred out of the dissolver along with the solution. Following transfer of the solution out of the dissolver, the dissolver will be rinsed with 380 L of water, which will then be transferred out through the centrifuge.

5.3.6 Dissolver Equipment Description

A dissolver vessel with a capacity of 3785 L and a diameter of 120 cm is recommended for dissolving the sludge as described in the previous section. With this configuration, the initial 6 M acid makeup in the dissolver will come to a depth of 51 cm. This is adequate to cover the blades of a mechanical agitator. The final solution volume in the dissolver will be approximately 2250 L, which will come to a solution depth of approximately 190 cm. This would leave a 134 cm headspace in a 120 cm diameter, 3785 L tank.

The dissolver will have a mechanical agitator and internal cooling coils. A steam or hot water jacket, or external electrical heaters, will most likely heat the dissolver. An elevated down tank will be connected to the dissolver so that water can be quickly added to quench the reaction if necessary. Quench water will only be added if the dissolver solution temperature and/or vacuum indicate the reaction rate is excessive.

The dissolver must be fabricated of a material that has good resistance to boiling 6 M HNO₃. An acceptable material of construction is 304 L stainless steel. Other materials may also be acceptable.

A critical component of the sludge dissolution system as described above is the sludge feed system. The feed system must be capable of feeding the sludge into the dissolver at a slow, controlled rate without allowing the suspended solids to settle out in the transfer lines. This may be done by recirculating the sludge from the sludge buffer tank through a small head tank located directly above the dissolver. The recirculation rate will be high enough to keep all the solids suspended. The sludge will then be fed from the head tank down a short vertical line into the dissolver.

5.3.9 Dissolver Instrumentation and Control

The following instrumentation will be used to monitor and control the dissolver. This list should be considered the minimum required.

- Solution conductivity to monitor the acid concentration
- Solution temperature
- Liquid level
- Specific gravity
- Dissolver vacuum control system
- Sludge addition flow rate and control system
- Acid addition flow rate and control system
- NO_x concentration in the offgas
- H_2 concentration in the offgas
- ^{85}Kr concentration in the offgas
- Xenon concentration in the offgas
- Gamma monitor to detect fissile material heel left in the bottom of the dissolver
- Cooling water flow rate
- Heater controls

The vacuum control system will consist of an automatic control loop that will adjust a flow control valve in the offgas system as necessary to control the dissolver vacuum at the set point.

The principal method used to ensure that the reaction remains under control is the slow, continuous sludge feed to the dissolver. This limits the amount of finely divided uranium that can be in the dissolver at any time because the small particles will dissolve very quickly in 6 M HNO_3 . The dissolver operating temperature will be 95 °C, which is close to the optimum temperature for dissolving uranium. Any increase in temperature will cause little, if any, increase in reaction rate.

The following paragraph describes the dissolver reaction control scheme as envisioned at this time:

The dissolver temperature and vacuum, as well as the NO_x concentration in the offgas, will be closely monitored to ensure that the reaction remains under control. If the temperature increases to 100 °C, sludge addition and HNO_3 addition will be stopped and the cooling water flow will be increased. The sludge addition control system will be interlocked to the temperature instrument to automatically stop sludge addition at 105 °C, if it has not been done manually. If the temperature and NO_x concentration continue to increase after the sludge feed is stopped and the cooling water increased, water will be added from a drain tank to quench the reaction.

5.3.10 Dissolver Criticality Safety

A soluble nuclear poison and fissile material mass limits on the lag storage vessel and dissolver will be used to ensure criticality safety. The soluble nuclear poison will be added to the lag storage vessel before transferring a batch of sludge into the vessel.

For mass control, the amount of fissile material transferred into the lag storage vessel will be measured using either a fissile material detector, or a combination of load cells and level instrumentation. A fissile material detector is the preferred method, but if it is not feasible or cost effective to fabricate a fissile material detector, the combination of load cells and level instrument will be used.

The minimum critical masses for 1.0% and 1.25% enriched uranium with no burnup are 2000 and 612 kg, respectively (Kessler 1998). The KW Basin has stored 1.25% enriched fuel so the 612 kg minimum critical mass would apply to KW Basin sludge. Assuming that the lag storage vessel and dissolver mass limit is set at one-third of the minimum critical mass, the uranium mass limit would be 204 kg for sludge from the KW Basin. This is a factor of 1.27 times the total mass of dry sludge in a 160 kg dissolver batch.

The uncertainty associated with the fissile material in the dissolver heel will have to be included in the mass limit. The uncertainty will increase with each subsequent batch of sludge processed through the dissolver without verifying the size of the heel. A gamma monitor and periodic inspections will be used to ensure that there is not a heel buildup.

5.4 SOLIDS/LIQUID SEPARATION AND WASHING

The undissolved solids must be removed from the dissolver product stream to meet the waste tank acceptance criteria. The PCB concentration limits are the most restrictive limits in the acceptance criteria as far as solids separation is concerned. The concentration limit for PCBs is 0.5 ppb in the liquid and 2 ppm in solids. Because PCBs are hydrophobic, most of the PCBs will be associated with the solids. Therefore, a very good solids/liquid separation must be achieved to ensure that the PCB concentration in the stream sent to the waste tank will be below the limits.

The ERDF waste acceptance criteria require that the waste be non-TRU (less than 100 nCi/g of TRU) with the ^{137}Cs concentration less than 32 Ci/m³. To meet these criteria, the interstitial liquid containing TRU and ^{137}Cs dissolved in acid must be thoroughly washed from the solids. This will be done as part of the solids/liquid separation process.

Most of the undissolved solids will come from the dissolution of floor sludges (streams KE1 and KW1). Laboratory studies by Pacific Northwest National Laboratory (Carlson et al. 1998a) indicate that 7 to 16 wt% of the floor sludge will remain undissolved at the end of each sludge dissolution step. The undissolved solids will be about 91% SiO_2 with the rest being mostly Al_2O_3 , FeOOH , carbon, and miscellaneous material. The particle size of the undissolved solids will be in the 0.1 to 200 μm range with more than 96 vol% of the particles greater than 5 μm in diameter.

Technologies for separating the solids from the dissolver product and leachate streams were evaluated to determine whether a centrifuge, filters, settling, or a combination of these methods should be used (Duncan and Zimmer 1998). Separation of the solids by settling was eliminated as an option due to the extended time that would be required for the small particles in the undissolved solids to settle. After reviewing various filter and centrifuge designs, it was concluded that the best way to separate the solids was to use a sedimentation centrifuge followed by a polishing filter.

A Robatel DPC 900 centrifuge can be expected to achieve at least 95% solids removal efficiency in this application and was recommended for the first step in solids separation. This centrifuge has a proven record in nuclear service at the La Hague and Sellafield reprocessing plants.

The Robatel DPC 900 centrifuge is a solid bowl centrifuge equipped with a high-pressure spray to remove the solids from the sides of the bowl. A vertical shaft running through the center of the bowl rotates the bowl. As dissolver product or leachate is fed into the centrifuge bowl, the solids and the liquid are forced against the inside wall of the bowl by centrifugal force. The solids are retained below baffles on the sides of the bowl. The clarified liquid overflows the baffles and the top of the bowl and drains to the clarified liquid tank. This type of centrifuge can be used to wash the solids after they are separated from the liquid. The solids are cut from the side of the bowl by a high-pressure spray while the centrifuge is rotated at low speed. The spray also washes the solids by diluting the interstitial liquid. The centrifuge then returns to high speed to separate the solids from the wash solution. Up to 18 kg of solids (dry basis) can accumulate in the centrifuge bowl before it needs to be cleaned out.

A polishing filter will be required downstream of the centrifuge to remove the small (0.1 to 5 μm) particles that pass through the centrifuge. This will be less than 5% of the particles in the stream before centrifugation. A cartridge filter with polyethylene filter elements was recommended for the polishing filter. The 3 M cartridge filter evaluated for this application has a solids removal efficiency of 99%. The filter elements will be made of polyethylene so they will also serve as a PCB adsorber because PCBs are hydrophobic. In laboratory studies by Pacific Northwest National Laboratory, more than 90% of the PCBs in the liquid phase were removed by filtration through a polyvinylidene fluoride filter (Mong et al. 1998). The efficiency of the polyethylene filter in removing PCBs is expected to be similar to the efficiency of the polyvinylidene fluoride filter used in the laboratory test.

The combined solids removal efficiency of the centrifuge and polishing filter will be greater than 99.5%.

The solids separation and washing will be done as follows. The dissolver product with suspended solids will be transferred from the dissolver to the centrifuge. The clarified liquid will overflow the centrifuge bowl and drain to the clarified liquid tank. From there, it will be transferred through the cartridge filter to the adjustment tank.

The pressure drop across the filter will be monitored and the filter elements will be changed out when the pressure drop approaches the design limit, or when the flow rate through the filter decreases to the point that it is slowing down sludge processing. Calculations indicate that about 49 filter cartridges will be used to process all the sludge (Pearce 1998). Of these, 46

are expected to be non-TRU and will be sent to ERDF for disposal. One of the filter cartridges is expected to exceed the TRU threshold of 100 nCi/g, but have a PCB concentration below the treatment standard in the TSCA. This filter will be stored as TRU waste for disposal at the Waste Isolation Pilot Plant (WIPP). There is currently no disposal path for the two filter cartridges that are expected to be both TRU and TSCA regulated for PCBs. These will be stored until a disposal path is identified. The used filter cartridges that will be sent to ERDF will be grouted in 208 L drums. One drum will be needed for each filter cartridge.

The solids that are removed by the centrifuge will be washed once with dilute nitric acid or water before being transferred out of the centrifuge to the leaching tank where additional TRU and fission products will be leached from the solids. Section 5.7 describes the solids leaching process.

5.5 SOLUTION ADJUSTMENT

After the dissolver product solution has been transferred through the cartridge filter into the adjustment tank, depleted uranium and iron will be added to the solution as neutron absorbers. The addition of neutron absorbers is needed to meet TWRS requirements for criticality control in tank 241-AW-105. Depleted uranium and iron will be added as absorbers for the ^{235}U and ^{239}Pu , respectively. Both absorbers will be added because laboratory studies have shown that after co-precipitation of plutonium and uranium under simulated waste tank conditions, plutonium can selectively dissolve if it is exposed to carbonate or ethylenediaminetetraacetic acid (EDTA) (Kret et al. 1998). Carbonate and EDTA are both present in the Hanford Site waste tanks.

Depleted uranium is the best absorber for ^{235}U because ^{235}U and ^{238}U cannot be separated chemically. Iron has been used for many years as an absorber in plutonium-bearing waste sent from the Plutonium Finishing Plant to underground waste tanks. Other metals could be used as well as iron for a plutonium absorber, but iron is already present in the waste tanks and its use as a plutonium absorber is addressed in the TWRS authorization basis. Iron dissolved from KE Basin floor sludge will supply most of the iron that is required for a plutonium absorber when processing that sludge stream.

Before addition of the absorbers, the solution in the adjustment tank will be agitated for at least 0.5 hours and then sampled. The samples will be analyzed for $^{239/240}\text{Pu}$, uranium isotopic, ^{137}Cs , ^{90}Sr , H^+ , iron, aluminum, calcium, total organic carbon, PCBs, and other things as required by TWRS acceptance criteria. The results of the $^{239/240}\text{Pu}$, uranium isotopic, and iron analyses, along with the volume in the tank, will be used to determine how much depleted uranium and iron will need to be added as absorbers. The results of the $^{239/240}\text{Pu}$ and uranium isotopic analyses also will be used for fissile material accountability. Approximately 2 days may be needed for the laboratory to complete the $^{239/240}\text{Pu}$ analysis depending on the analytical technique used. The facility will install two or three adjustment tanks, if required, to prevent analytical turnaround time from delaying processing.

Depleted uranium (0.3 wt% ^{235}U) will be added as necessary to lower the enrichment to less than 0.84 wt% ^{235}U as required by TWRS (Carothers et al. 1997). Characterization samples

of the basin sludge have shown that the average uranium enrichment is below 0.84 wt% ²³⁵U (Pearce et al. 1998), but individual samples had uranium enrichments as high as 1.25 wt% ²³⁵U.

Iron will be added as necessary to obtain an iron to plutonium weight ratio of 353:1. Characterization samples have shown that the average iron to plutonium weight ratio in the KE Basin floor sludge is 740:1 (Pearce et al. 1998). However, the sludge will not be processed as a homogeneous mixture so iron will need to be added to some batches.

The depleted uranium will be added as a concentrated uranyl nitrate solution and the iron will be added as ferric nitrate solution. The absorber solutions will be made up in the uranyl nitrate makeup tank and ferric nitrate makeup tanks, respectively. It is doubtful that depleted uranyl nitrate solution is available, so it is assumed that depleted UO₂ powder will be dissolved in nitric acid to make up the uranyl nitrate solution. The solution in the adjustment tank will be at a temperature of approximately 40 °C when the absorbers are added. The solution will be agitated during absorber addition and for at least 0.5 hours afterwards before the solution is ready for transfer to the neutralization tank for the neutralization/precipitation step.

Table 5-2 presents the process parameters for the solution adjustment tank.

Table 5-2. Adjustment Tank Parameters.

Pu poisoning	
Requirement on Fe/Pu ratio	353
Fe(NO ₃) ₃ concentration	2.0 M
U235 dilution	
Requirement on U enrichment	< 0.840%
Maximum U enrichment in KE	0.947%
Ratio of concerned sludge in KE	16.50%
Maximum U enrichment in KW	0.947%
Ratio of concerned sludge in KW	16.50%
UO ₂ (NO ₃) ₂ concentration	1.0 M
U enrichment in UO ₂ (NO ₃) ₂	0.30%
NaNO₂ adjustment after neutralization	
NaNO ₂ final concentration	According to TWRS requirements on [NO ₂ -] or [OH-] +[NO ₂ -]
NaNO ₂ additives initial concentration	40%
Water adjustment after neutralization	
Solids concentration of slurry sent to TWRS	40 g/l

5.6 NEUTRALIZATION/PRECIPITATION

The acidic dissolver product solution will be reacted with 19 M sodium hydroxide at 40 °C to neutralize the solution and co-precipitate the uranium, plutonium, and iron. The aluminum, americium, and strontium in the solution will also precipitate. A small amount of aluminum may redissolve at a pH greater than 10, but it is assumed that this will be a negligible amount. The cesium will remain in solution.

The amount of NaOH needed to neutralize the solution will be calculated from the amount of uranium and iron absorber added and the uranium, iron, aluminum, and H^+ analyses from the sample taken in the adjustment tank.

Uranyl nitrate reacts with NaOH to form sodium diuranate (nominally $Na_2U_2O_7$ but actually a mixture of salts). The following equation represents the reaction:

The following equation shows the reaction of plutonium nitrate with NaOH:

Ferric nitrate and aluminum nitrate react with NaOH according to the following reactions:

Nitric acid will be neutralized by NaOH as follows:

Unreacted oxalic acid from the solids treatment steps will be neutralized as follows:

It is assumed that all of the above reactions will go to completion so 3 moles of NaOH will be needed for every mole of uranium, iron, and aluminum in solution. One mole of NaOH will be needed to neutralize each mole of acid. Additional NaOH as well as $NaNO_3$ will be needed to meet TWRS waste tank requirements. These requirements vary depending on the nitrate concentration. The nitrate concentration in the neutralization tank will vary from less than 1 M to greater than 3 M depending on the sludge stream, so the TWRS requirements for NaOH and $NaNO_3$ also will vary. The neutralization tank will be equipped with cooling coils to remove the heat generated by the neutralization reactions.

The Institute of Physical Chemistry in Moscow, Russia conducted laboratory studies (Krot et al. 1998) to determine optimum precipitation conditions for dissolved sludge. One of the areas studied was the order of mixing to determine if the acidic dissolver solution should be neutralized by direct strike (NaOH added to acid solution) or reverse strike (acid solution added to NaOH). During caustic precipitation, the order of mixing can affect the particle size of the precipitate. The crystal size of the precipitate must be less than 50 μm to meet TWRS acceptance criteria.

The Institute of Physical Chemistry study indicated that both methods of mixing the reactants (direct strike and reverse strike) resulted in a precipitate with a crystal size much less than the 50 μm criterion. The study did not find any clear advantage for either of the orders of mixing. An engineering study of the neutralization process recommended that reverse strike neutralization be used (Klem 1998). The recommendation to use reverse strike for the caustic precipitation was based on the fact that direct strike precipitation of waste streams containing uranium and aluminum has caused line plugging problems at the Hanford Site in the past. Reverse strike neutralization of these same streams produced a slurry that could be transferred without plugging transfer lines. However, the aluminum concentration in the waste streams that caused line plugging problems after direct strike neutralization was considerably higher than it will be in the sludge waste stream.

Because reverse strike neutralization has been selected, the NaOH will be added to the neutralization tank first, and then the acidic sludge stream will be pumped in from the adjustment tank. Following neutralization, NaNO_2 will be added.

Dilution water will also need to be added at this time when processing some of the sludge streams to ensure that after precipitation the slurry will be dilute enough that it can be transferred without plugging lines. The current design for the sludge unloading station at tank 241-AW-105 requires pumping the sludge through 15 m of 3.8 m diameter line with a slope of 2.1 cm/m. Laboratory studies by Pacific Northwest National Laboratory have indicated that caustic precipitation of uranium at concentrations greater than 40 g/L will produce a slurry that probably cannot be transferred without risking line pluggage (Ryan 1992). Dilution water will be added as needed to reduce the total solids concentration to less than 40 g/L.

The Institute of Physical Chemistry study also analyzed the plutonium and americium concentration in the supernate after precipitation, and investigated the effects of varying the aluminum, iron, and uranium concentrations. Varying the composition of the solution had little effect on precipitation. The combined plutonium and americium concentration in the supernate after solids precipitation was found to be less than 100 nCi/g, which makes the supernate non-TRU.

Laboratory studies of PCB distribution during neutralization showed that 95% of the PCBs in the liquid ended up with the precipitated solids following neutralization (Mong et al. 1998). Material balance calculations indicate that the maximum PCB concentration in the neutralized waste will be 0.01 ppb in the liquid and 0.66 ppm in the precipitated solids. These concentrations are below the limits of 0.3 ppb in the liquid and 2 ppm in the solids.

The total volume of neutralized waste to be sent to tank 241-AW-105 is approximately 1620 m³. Table 5-3 shows the total volume generated by each sludge stream and the average composition.

Table 5-3. Sludge Treatment Summary

	KE1	KE2	KW1	KW2	KW3	Supernate insoluble solids
Total sol'n to TWRS	965.6 m ³	217.4 m ³	92.6 m ³	107.2 m ³	204.5 L m ³	33.2 m ³
Percent of total	59.6%	13.4%	5.7%	6.6%	12.6%	2.0%
Solid conc before H ₂ O adjustment	14 g/L	52 g/L	4.8 g/L	58 g/L	54 g/L	0.01 g/L
Solid conc after H ₂ O adjustment	14 g/L	40 g/L	4.8 g/L	40 g/L	40 g/L	0.01 g/L
PCB in liquid	0.01 ppb	0.01 ppb	0.00 ppb	0.00 ppb	0.01 ppb	0.00 ppb
PCB in solids	0.664 ppm	0.005 ppm	0.000 ppm	0.000 ppm	0.008 ppm	0.001 ppm

PCB = polychlorinated biphenyl

TWRS = Tank Waste Remediation System

5.7 LEACHING OF DISSOLVER RESIDUE FOR TRANSURANIC AND CESIUM REMOVAL

Laboratory studies of K Basin sludge dissolution found that the TRU and ¹³⁷Cs concentration in the undissolved solids exceed the ERDF acceptance criteria. An 8 wt% oxalic solution has been shown to be effective for dissolving iron-bearing sludge at the Savannah River Plant (Bradley and Hill 1977). An engineering study was performed to determine the best chemical reagents to use for leaching the TRU and cesium from the solids (Bechtold 1998). The engineering study recommended several chemical combinations that should be tested in addition to oxalic acid.

The Pacific Northwest National Laboratory conducted laboratory leaching studies to test the recommended leach chemicals using the residue to form K Basin sludge dissolution tests. The leach tests showed that the best solution for leaching TRU and cesium from the dissolver residue was 4.8 M nitric acid and 0.24 M hydrofluoric acid at 90 °C for 4 hours (Delegard et al. 1998). Table 5-4 shows the dissolution factors obtained in the laboratory leaching tests.

Table 5-4. Solid Leaching Process Parameters.

Leaching solution	
Amount	20 cm ³ /g of residues
HNO ₃	4.80 M
HF	0.24 M
Dissolution factors on radioactive elements contained in the solids	
Pu	89.00%
Am	95.00%
Cs	68.00%
Sr	83.00%
Dissolution factors of solids	
Al(OH) ₃	0.00%
Al ₂ O ₃	0.00%
FeOOH	0.00%
C	0.00%
CaO	0.00%
CO ₂	0.00%
SiO ₂	0.00%
Miscellaneous	0.00%
Zircaloy	0.00%
Grafoil	0.00%
U	83.00%
U ₃ O ₇	83.00%
UH ₃	83.00%
UO ₂	83.00%
UO ₄ ·4H ₂ O	83.00%
PCB	0.00%
Zeolite	0.00%
OLER	0.00%
Decontamination factors on radioactive elements contained in Resins	
Pu	86.00%
Am	64.00%
Cs	54.00%

In the sludge treatment facility, the nitric acid and hydrofluoric acid will be transferred from separate makeup tanks into the leach tank to make up the leach solution. Following leaching, the leach solution and suspended solids will be sent to the centrifuge for solids/liquid separation and solids washing as described in Section 5.4. The solids will be washed three times with water before being removed from the centrifuge. The chemical composition and particle size distribution of the leached solids will be essentially the same as before leaching. That is, the solids will be mostly SiO_2 with small amounts of Al_2O_3 , $\text{Fe}(\text{OH})_3$, carbon, and miscellaneous material. The particle size of the leached solids will be in the 0.1 to 200 μm range with more than 96 vol% of the particles greater than 5 μm in diameter.

The washed solids will be transferred from the centrifuge to the solids reception tank for eventual grouting along with the leached resin beads. This will be done at the end of the processing campaign as described in Section 5.9.

The clarified leachate will drain from the centrifuge to the clarified liquid tank and then will be transferred through the cartridge filter to the adjustment tank. There it will be combined with the clarified dissolver product stream.

The sample analysis from the adjustment tank will be used to determine if the solution contains enough aluminum to complex the free fluoride from the leach solution. An aluminum to fluoride mole ratio of 1:3 is needed to complex free fluoride sufficiently to prevent corrosion of 300 Series stainless steel. Adequate aluminum will be present in the combined leach and dissolver product solution when processing most sludge streams. Aluminum nitrate will be added to the adjustment tank, if necessary, to complex the free fluoride.

5.8 LEACHING OF RESIN BEADS FOR TRANSURANIC AND CESIUM REMOVAL

The resin beads that are separated from the sludge stream in the elutriation column will exceed the ERDF acceptance criteria for TRU and ^{137}Cs . An engineering study was done to select chemical reagents that should be used for leach tests of resin beads from K Basin sludge samples (Dodd 1998). The engineering study recommended several reagents, which were then used in laboratory leach tests with resin beads from sludge samples.

The laboratory leach tests indicated that the best reagent for resin bead leaching was a solution of 0.1 M oxalic acid and 2 M nitric acid at 40 °C for 4 hours (Delegard and Rinehart 1998). Table 5-3 shows the decontamination factors obtained in the laboratory leaching tests.

The resin bead leaching will be done in the leach tank. The nitric acid and oxalic acid will be transferred from separate makeup tanks into the leach tank to make up the leach solution.

Following the resin bead leaching, the leach solution and suspended resin beads will be sent to the centrifuge for solids/liquid separation and resin washing as described in Section 5.4. The resin will be washed twice with water before being removed from the centrifuge.

Table S-5. Resin Leaching Process Parameters.

Leaching solution	
Amount	15 cm ³ /g of residue
HNO ₃	2.0 M
Oxalic acid	0.9%
Decontamination factors on radioactive elements contained in Resins	
Pu	86.00%
Am	64.00%
Cs	54.00%
Dissolution factors of solids coming together with the resin stream	
Al(OH) ₃	90.00%
Al ₂ O ₃	90.00%
FeOOH	90.00%
C	0.00%
CaO	80.00%
CO ₂	0.00%
SiO ₂	0.00%
Miscellaneous	90.00%
Zircaloy	0.00%
Grafoil	0.00%
U	92.50%
U ₃ O ₇	92.50%
UH ₃	92.50%
UO ₂	92.50%
UO ₄ ·4H ₂ O	92.50%
PCB	0.00%
Zeolite	0.00%
OTER	0.00%
Dissolution factors on radioactive elements contained in the solids coming together with the resin stream	
Pu	98.00%
Am	82.70%
Cs	53.30%
Sr	92.50%

The washed resin beads will be transferred from the centrifuge to the solids reception tank for eventual grouting along with the undissolved solids. This will be done at the end of the processing campaign as described in Section 5.9.

The leachate will drain from the centrifuge to the clarified liquid tank and will then be transferred through the cartridge filter to the adjustment tank. There it will be combined with the clarified dissolver product stream.

5.9 GROUTING OF RESIN BEADS AND UNDISSOLVED SOLIDS

After each batch of resin beads and undissolved solids from the dissolver are leached with appropriate reagents in the leach tank, they will be transferred as a slurry to the solids reception tank. This tank will be large enough to hold the resin beads and undissolved solids from the entire sludge processing campaign. Including the slurry water, this will come to a total volume of 51 m³. It will contain approximately 9700 kg of solids/resin on a dry basis. At the end of the campaign, the solids/resin mixture will be thoroughly agitated to homogenize the solids so that representative samples can be obtained. Samples of the solids/resin mixture will be analyzed to characterize the waste and ensure that the grouted waste will meet the ERDF waste acceptance criteria.

When solids characterization has been completed, the solids will be transferred as a slurry to Chem Nuclear L14-170 cask liners for grouting (Pearce 1998). Excess liquid will be decanted from the solids to obtain the appropriate solids/liquid ratio for grouting. The total liquid that will be decanted during the grouting process will be about 32 m³. This liquid will be routed through the filter for solids removal and then to the neutralization tank for transfer to the underground waste tank.

The grout containers will be equipped with an agitator and addition lines for waste, water, and grout mix. The grout formulation will be based on the composition of the solids. After the grout mix has been added and the mixture allowed to cure, the waste will be ready for transport to ERDF.

The final grout matrix will contain about 15% dry sludge solids. Each L14-170 liner will contain 4.8 m³ of grouted waste and seven will be required for a total grout volume of about 32 m³.

Flowsheet calculations show that the TRU concentration of the combined solids in the solids hold tank will be 36 nCi/g which is less than the ERDF limit of 100 nCi/g. The concentration of ¹³⁷Cs and other radionuclides will also be below the ERDF disposal limits.

5.10 OFFGAS TREATMENT

The dissolver offgas will be routed through a condenser before it is combined with the offgas from the other vessels. The combined offgas will be routed through the NO_x absorption system and high-efficiency mist eliminator, heated above its dew point, and then routed through

HEPA filters and before it is exhausted to the stack. The offgas will be sampled and monitored to verify that it complies with regulatory criteria.

The Washington State Department of Health (DOH) administers radioactive airborne emissions under WAC 246-247. The Washington State Department of Ecology (Ecology) administers nonradioactive air contaminants under WAC 173-400.

The determination of the control and monitoring systems required to comply with BACT and BARCT is dependent on process design and the specific pollutants emitted from the process. The DOH and Ecology must be consulted during the design phase to ensure that BACT and BARCT requirements are met. Therefore, the following discussion is a proposed strategy with the reasoning behind it.

5.10.1 Radioactive Gases

Radioisotopes of iodine, krypton, and xenon are present in nuclear fuel when it is discharged from the reactor and residual amounts may be present in the sludge in the KE and KW Basins. Residual amounts of these gases are expected to be found only in metallic uranium fuel pieces in the sludge. Most of the uranium in the sludge has reacted with water to form uranium oxide compounds. The gaseous fission products associated with this uranium have already been released as the uranium reacted with water. The sludge database document (Pearce et al. 1998) indicates that there will be a total of 3.09 MT of uranium metal in the sludge.

Because all of the fuel in the storage basins has been out of the reactor for at least 10 years and most of it has been out for more than 25 years, short-lived isotopes such as ^{131}I , ^{135}Xe , and ^{133}Xe have now decayed to insignificant levels. This is confirmed by the fission product decay tables calculated by the ORIGEN computer code (Schwarz 1997). Krypton-85 and ^{129}I have longer half-lives so they will still be present in metallic fuel pieces, although ^{129}I is only present at very low concentrations. By the time the sludge is processed, it will be 30 years since most of the fuel in the basins was discharged from the reactor.

Table 5-6 shows the curies/ton of ^{129}I and ^{85}Kr present in 12% ^{239}Pu Mark IV fuel 20 and 30 years after reactor discharge. The data were taken from the ORIGEN computer code printout. Table 5-7 shows the total estimated ^{129}I and ^{85}Kr present in the basin sludge based on 3.09 MT of uranium metal.

Table 5-6 Iodine-129 and Krypton-85 Content of 1 Metric Ton Uranium of N Reactor Fuel

	20 years after discharge	30 years after discharge
Iodine-129, Ci/MTU	2.648E-3	2.648E-3
Krypton-85, Ci/MTU	251	131

Table 5-7 Total Estimated Iodine-129 and Krypton-85 in K Basin Sludge

	20 years after discharge	30 years after discharge
Iodine-129, Ci	8.2 E-3	8.2 E-3
Krypton-85, Ci	775	404

Krypton removal and disposal techniques are limited because it is a chemically inert noble gas. Krypton has been removed from reprocessing plant offgas streams using a cryogenic process. However, once the ^{85}Kr is removed, it must be stored in gas cylinders, which may be a worse hazard than allowing it to be released from the stack. Therefore, it should be proposed to DOH that krypton removal equipment not be included in the sludge treatment design.

Technology for iodine removal from offgas is well developed. Control of ^{129}I in the offgas can be done by using a silver zeolite bed or similar iodine removal technology. However, because the total ^{129}I present in the sludge is less than 10 mCi (see Table 5-7), it should be proposed to DOH that iodine removal equipment also is not necessary for the sludge treatment system.

5.10.2 Radioactive Particulates

High-efficiency particulate air filters are commonly identified as BARCT for controlling radioactive particulates (RL 1997). Parallel HEPA filter units will be used so that one filter unit can remain in service while the other is taken off line to replace the filter element. A heater will be necessary upstream from the filters to ensure that the offgas temperature remains above the dewpoint. If moisture reaches the filters it will increase the pressure drop and allow radioactivity to leach through the filter media.

5.10.3 Nitrogen Oxides

Nitrogen oxides will be generated during dissolution of the sludge in nitric acid. The amount of NO_x generated and the mix between NO and NO_2 depends on the dissolver operating conditions and the type of sludge being processed. The state of Washington small-quantity emission limit for NO_x is 7727 kg/yr or 0.91 kg/h. If the NO_x release from the sludge processing facility exceeds these limits, a dispersion modeling analysis must be done to determine the concentration at the Site boundary. The NO_x concentration at the Site boundary must be less than $100 \mu\text{g}/\text{m}^3$. The sludge processing facility will be designed to reduce the NO_x to less than 7727 kg/yr or 0.91 kg/h.

The NO_x leaving the dissolver will be a mixture of NO , which is only slightly soluble in water, and NO_2 , which is very soluble in water. If air is present in the offgas, oxygen in the air will react with the NO to form NO_2 by the following reaction:

In an absorption column, the NO_2 will be absorbed in water and react to form HNO_2 as follows

To recover the NO formed by the last two reactions, it must be reoxidized to NO_2 and absorbed before it leaves the column. An air bleed can be used to help oxidize the NO to NO_2 to improve NO_x recovery efficiency.

Four NO_x absorber configurations were evaluated using a computer model that has been validated by operating data from the La Hague plant in France (Ponvert and Flament 1998). The evaluated configurations are as follows:

- Single column using water as the scrub solution and an air bleed to oxidize the NO to NO_2
- Two absorption columns using water as the scrub solution and an air bleed to oxidize the NO to NO_2
- Two absorption columns – the first using a water scrub and the second using a caustic scrub, air bleed to oxidize the NO to NO_2
- Two absorption columns using water as the scrub solution and oxygen-enriched air (40% O_2) to oxidize the NO to NO_2

All of the configurations evaluated used 0.21 m diameter packed columns with pall ring packing. The first three configurations used a packing height of 10 m, while the last configuration used a 6 m packing height because the use of oxygen-enriched air for oxidation made it more efficient. The study described the advantages and disadvantages of each configuration. All four of the configurations could reduce the NO_x concentration to less than 0.91 kg/h.

The NO_x concentrations in the Ponvert and Flament study were calculated using the conservative assumption that the sludge is composed of 50% UO_2 and 50% uranium metal with no other components. Because of this conservative assumption, the NO_x flow rate is higher in this study than in the flowsheets calculated in the Appendixes. The flowsheets in the Appendixes were calculated using nominal sludge compositions from the design basis feed document for sludge (Pearce et al. 1998).

An evaluation based on BACT is needed to finalize the NO_x control configuration. The DOH and Ecology must be consulted at this time to ensure that the BACT requirement is met.

There appears to be a considerable benefit in using enriched air to reduce the column height, so the fourth configuration was selected as the baseline for the sludge processing facility. The following paragraphs describe the NO_x recovery system.

The initial NO_x removal from the dissolver offgas will occur in the downdraft condenser. The remaining NO_x removal will be achieved by a NO_x absorption system consisting of two columns with water used as the scrub solution. Air enriched to 40% oxygen will be added upstream of the absorption columns to oxidize NO to NO₂.

Scrub solution draining from the bottom of the columns will be collected in a tank and recirculated to the top of the columns. The scrub solution will be cooled to improve NO_x absorption efficiency.

When the HNO₃ concentration in the scrub solution increases to 6 M, part of the scrub solution will be transferred to the dissolver during makeup of a batch of dissolver solution. Fresh water will be added to the top of the absorption column to replenish the volume of scrub solution. The absorption column will be designed to remove a minimum of 90% of the NO_x leaving the condenser. The configurations evaluated in the engineering study achieved greater than 95% NO_x removal.

The absorption of NO_x in water or dilute HNO₃ is a widely used commercial process. In the past, the DOH has accepted absorption columns as BACT for NO_x recovery at the Plutonium-Uranium Extraction and UO₂ plants at the Hanford Site.

5.10.4 Polychlorinated Biphenyls

Laboratory studies have been done of the PCB distribution in boiling nitric acid containing iron filings to simulate conditions in the sludge dissolver (Mong et al. 1998). The results of these studies showed that after 8 hours in boiling HNO₃, 30% of the PCBs were adsorbed on the solids, 50% plated out on the laboratory glassware used to conduct the test, and 20% was volatilized into the offgas system. The PCB distribution in the sludge processing facility may be somewhat different than it was in the laboratory test because the laboratory tests were done using much higher PCB concentrations than will be present in the sludge dissolver. This was done to get more accurate analytical results than could be obtained if the lower PCB concentrations that will be present in the sludge dissolver were used in the tests.

Because there is considerable uncertainty in extrapolating the results of the laboratory PCB tests to plant conditions, a granulated activated carbon bed should be installed in the offgas system to ensure that the PCB concentration in the offgas will be less than the 10 µg/m³ limit. Granulated activated carbon is an established technology for trapping PCBs in offgas systems (Ashworth 1998).

5.11 SLUDGE TREATMENT SUMMARY

The sludge processing facility described in this document will receive a total of 50.6 m³ of sludge. This sludge will be processed in 214 batches, which will generate about 1620 m³ of waste slurry that will be transferred to a double-shell waste tank. The waste will contain approximately 35,400 kg of solids (dry basis).

The process will also generate about 32 m³ of grouted waste that will be transported to ERDF for disposal. This will take seven grout containers each having a capacity of 4.8 m³. There will also be 49 waste drums generated for disposal of filter cartridges. Forty-six of the filter cartridges will be grouted in drums sent to ERDF, one will be TRU waste that will eventually be sent to WIPP, and two filter cartridges will be TRU waste containing PCBs at concentrations too high to go to either ERDF or WIPP. These two filter cartridges will be stored in drums until a disposal path is determined.

Table 5-8 shows a summary of sludge treatment parameters for the five sludge streams and the grouted waste.

	KE1	KE2	KW1	KW2	KW3	Residues Grouting	TOTAL
Initial Sludges							
Volume of as-sealed sludges	41.5 m ³	2.4 m ³	4.7 m ³	0.2 m ³	1.9 m ³		50.58 m ³
%	82.0%	4.7%	9.2%	0.4%	3.7%		
Total Solids	564 g/l	1650 g/l	382 g/l	8216 g/l	1910 g/l		
U	63 g/l	1190 g/l	19 g/l	7375 g/l	1175 g/l		
PCB in solid	191.5 ppm	0.6 ppm	0.0 ppm	0.0 ppm	4.2 ppm		
TRU	17,335 nCi/g	192,684 nCi/g	4,666 nCi/g	265,889 nCi/g	192,508 nCi/g		
OPER	29.4 kg/m ³	14.4 kg/m ³	0.0 kg/m ³	0.0 kg/m ³	0.0 kg/m ³		
Sludge treatment							
Number of batches	146.1	24.4	11.2	10.2	22.4		214.4
Dry solids per batch	160 kg	160 kg	160 kg	160 kg	160 kg		
Dissolution condition	6.0 M	6.0 M	6.0 M	6.0 M	6.0 M		
Conditioned wastes to ERDF							
Amount of dry residues to be grouted	8,115 kg	297 kg	1,134 kg	150 kg	119 kg	9,815 kg	9,815 kg
%	82.7%	3.0%	11.6%	1.5%	1.2%		
Total amount of grouted wastes produced						65,434 kg	65,434 kg
Number of 48 m ³ liners drums produced						6.7	6.7
TRU						31 nCi/g	31 nCi/g
Wastes to TWRS							
Total solution sent to TWRS	965.6 m ³	217.4 m ³	92.6 m ³	107.2 m ³	204.5 m ³	33.2 m ³	1610 m ³
%	59.6%	13.4%	5.7%	6.6%	12.6%	2.0%	
Ratio Final Vol / Inu Vol	5.4	7.5	6.8	8.9	7.6		7.6
Solid concentration before water adjustment	14 g/l	52 g/l	4.8 g/l	58 g/l	54 g/l	0.01 g/l	17 g/l
Solid concentration after water adjustment	14 g/l	40 g/l	4.8 g/l	40 g/l	40 g/l	0.01 g/l	22 g/l
PCB liq	0.01 ppb	0.01 ppb	0.00 ppb	0.00 ppb	0.01 ppb	0.00 ppb	0.01 ppb
PCB sol	0.664 ppm	0.005 ppm	0.000 ppm	0.000 ppm	0.008 ppm	0.001 ppm	0.262 ppm
Wastes							
Number	40.4	1.3	5.5	0.6	0.6		48.4
%	83.6%	2.6%	11.4%	1.2%	1.2%		
PCB sol	4,870 ppm	33,257 ppm	0.000 ppm	0.000 ppm	132,172 ppm		
TRU Activity	29 nCi/g	6,643 nCi/g	8 nCi/g	5,385 nCi/g	10,386 nCi/g		
Destination	ERDF	WIPP	ERDF	WIPP	WIPP		

Table 5-8 Sludge Treatment Summary.

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APPENDIX A
KEI STREAM

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SLUDGE TREATMENT MATERIAL BALANCE

STRONG HE'S
Removal Cases L7 SeC= 100 g/solids
P=0.0075 0.01

■ LUDIGME TREATMENT USING LUTALISA™

STREAMLINE WORK

Open End Game 1, 1 Match, 100 kg points.

Requirements

STREAM KE1	Requirements		Obtained results
EDS Analysis Data	TIME	Req	Obtained
PCB in liq	< 0.5 ppb		0.01 ppb
PCB in sol	< 2 ppm		0.664 ppm
Concentration	< 40 g/l		14.27 g/l
Na(NO3) concentration	Req on [OH-] 0.30 M		3.28 M
NaOH Concentration	Req on [OH-]+[NO2-] 1.20 M		0.30 M
NaOH + Na(NO2) Concentration	Req on [NO2-] none		1.20 M
Na(NO2) concentration			0.90 M
Volume generated m3			966 m3
Filter 1 Chemical analysis EDS on residues in liq	EDS Requirements	EDS Results	Obtained
PCB (ppm)	< 2 ppm		4.870 ppm
Li g/ml	< 0.028 g/ml		0.0001 g/ml
Pu(Total)	Ci/m3		0.040 Ci/m3
238 Pu	< 1.5 Ci/m3		0.008 Ci/m3
239 Pu	< 0.029 Ci/m3		0.016 Ci/m3
240 Pu	< 0.029 Ci/m3		0.016 Ci/m3
Am	< 0.05 Ci/m3		0.025 Ci/m3
TRU	< 100 nanoCi/g	> 100 nanoCi/g	29 nCi/g
Volume generated m3			8.1 m3
Number of 0.2 m3 drums			40.4

DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF-2735, Rev. 0

[illegible]

DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNP-2735, Rev 0

[illegible]

DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF-2735, Rev 0

[illegible]

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2735 Rev 0

STREAM KEY	ST-101	ST-102	ST-103	ST-104	ST-105	ST-106	ST-107	ST-108	ST-109	ST-110
Normal Case - TOTAL STREAM	ST-101 (kg/m³)	ST-102 (kg/m³)	ST-103 (kg/m³)	ST-104 (kg/m³)	ST-105 (kg/m³)	ST-106 (kg/m³)	ST-107 (kg/m³)	ST-108 (kg/m³)	ST-109 (kg/m³)	ST-110 (kg/m³)
Volume	170 000 m³	2 280 m³	171 279 m³	7 472 m³	171 279 m³	2 400 m³	107 007 m³	320 000 m³	307 000 m³	307 000 m³
Density	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³
Total Mass	169 983 372 kg	4 279 683 kg	169 983 371 kg	7 464 824 kg	169 983 371 kg	2 399 840 kg	106 986 486 kg	319 983 371 kg	306 983 371 kg	306 983 371 kg
Number of packages										
Volume	171 470 m³	2 280 m³	171 470 m³	6 280 m³	171 470 m³	2 400 m³	107 007 m³	320 000 m³	307 000 m³	307 000 m³
Density	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³
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Number of packages										
Volume	171 470 m³	2 280 m³	171 470 m³	6 280 m³	171 470 m³	2 400 m³	107 007 m³	320 000 m³	307 000 m³	307 000 m³
Density	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³
Total Mass	171 453 280 kg	4 279 683 kg	171 453 280 kg	6 273 824 kg	171 453 280 kg	2 399 840 kg	106 986 486 kg	319 983 371 kg	306 983 371 kg	306 983 371 kg
Number of packages										
Volume	171 470 m³	2 280 m³	171 470 m³	6 280 m³	171 470 m³	2 400 m³	107 007 m³	320 000 m³	307 000 m³	307 000 m³
Density	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³
Total Mass	171 453 280 kg	4 279 683 kg	171 453 280 kg	6 273 824 kg	171 453 280 kg	2 399 840 kg	106 986 486 kg	319 983 371 kg	306 983 371 kg	306 983 371 kg
Number of packages										
Volume	171 470 m³	2 280 m³	171 470 m³	6 280 m³	171 470 m³	2 400 m³	107 007 m³	320 000 m³	307 000 m³	307 000 m³
Density	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³
Total Mass	171 453 280 kg	4 279 683 kg	171 453 280 kg	6 273 824 kg	171 453 280 kg	2 399 840 kg	106 986 486 kg	319 983 371 kg	306 983 371 kg	306 983 371 kg
Number of packages										
Volume	171 470 m³	2 280 m³	171 470 m³	6 280 m³	171 470 m³	2 400 m³	107 007 m³	320 000 m³	307 000 m³	307 000 m³
Density	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³
Total Mass	171 453 280 kg	4 279 683 kg	171 453 280 kg	6 273 824 kg	171 453 280 kg	2 399 840 kg	106 986 486 kg	319 983 371 kg	306 983 371 kg	306 983 371 kg
Number of packages										
Volume	171 470 m³	2 280 m³	171 470 m³	6 280 m³	171 470 m³	2 400 m³	107 007 m³	320 000 m³	307 000 m³	307 000 m³
Density	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³	1 000 kg/m³
Total Mass	171 453 280 kg	4 279 683 kg	171 453 280 kg	6 273 824 kg	171 453 280 kg	2 399 840				

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2735, Rev. 0

STREAM KEY	201901	201902	201903	201904	201905	201906	201907	201908	201909	201910	201911	201912	202001	202002	202003	202004	202005	202006	202007	202008	202009	202010	202011	202012	202101	202102	202103	202104	202105	202106	202107	202108	202109	202110	202111	202112	202201	202202	202203	202204	202205	202206	202207	202208	202209	202210	202211	202212	202301	202302	202303	202304	202305	202306	202307	202308	202309	202310	202311	202312	202401	202402	202403	202404	202405	202406	202407	202408	202409	202410	202411	202412	202501	202502	202503	202504	202505	202506	202507	202508	202509	202510	202511	202512	202601	202602	202603	202604	202605	202606	202607	202608	202609	202610	202611	202612	202701	202702	202703	202704	202705	202706	202707	202708	202709	202710	202711	202712	202801	202802	202803	202804	202805	202806	202807	202808	202809	202810	202811	202812	202901	202902	202903	202904	202905	202906	202907	202908	202909	202910	202911	202912	203001	203002	203003	203004	203005	203006	203007	203008	203009	203010	203011	203012	203101	203102	203103	203104	203105	203106	203107	203108	203109	203110	203111	203112	203201	203202	203203	203204	203205	203206	203207	203208	203209	203210	203211	203212	203301	203302	203303	203304	203305	203306	203307	203308	203309	203310	203311	203312	203401	203402	203403	203404	203405	203406	203407	203408	203409	203410	203411	203412	203501	203502	203503	203504	203505	203506	203507	203508	203509	203510	203511	203512	203601	203602	203603	203604	203605	203606	203607	203608	203609	203610	203611	203612	203701	203702	203703	203704	203705	203706	203707	203708	203709	203710	203711	203712	203801	203802	203803	203804	203805	203806	203807	203808	203809	203810	203811	203812	203901	203902	203903	203904	203905	203906	203907	203908	203909	203910	203911	203912	204001	204002	204003	204004	204005	204006	204007	204008	204009	204010	204011	204012	204101	204102	204103	204104	204105	204106	204107	204108	204109	204110	204111	204112	204201	204202	204203	204204	204205	204206	204207	204208	204209	204210	204211	204212	204301	204302	204303	204304	204305	204306	204307	204308	204309	204310	204311	204312	204401	204402	204403	204404	204405	204406	204407	204408	204409	204410	204411	204412	204501	204502	204503	204504	204505	204506	204507	204508	204509	204510	204511	204512	204601	204602	204603	204604	204605	204606	204607	204608	204609	204610	204611	204612	204701	204702	204703	204704	204705	204706	204707	204708	204709	204710	204711	204712	204801	204802	204803	204804	204805	204806	204807	204808	204809	204810	204811	204812	204901	204902	204903	204904	204905	204906	204907	204908	204909	204910	204911	204912	205001	205002	205003	205004	205005	205006	205007	205008	205009	205010	205011	205012	205101	205102	205103	205104	205105	205106	205107	205108	205109	205110	205111	205112	205201	205202	205203	205204	205205	205206	205207	205208	205209	205210	205211	205212	205301	205302	205303	205304	205305	205306	205307	205308	205309	205310	205311	205312	205401	205402	205403	205404	205405	205406	205407	205408	205409	205410	205411	205412	205501	205502	205503	205504	205505	205506	205507	205508	205509	205510	205511	205512	205601	205602	205603	205604	205605	205606	205607	205608	205609	205610	205611	205612	205701	205702	205703	205704	205705	205706	205707	205708	205709	205710	205711	205712	205801	205802	205803	205804	205805	205806	205807	205808	205809	205810	205811	205812	205901	205902	205903	205904	205905	205906	205907	205908	205909	205910	205911	205912	206001	206002	206003	206004	206005	206006	206007	206008	206009	206010	206011	206012	206101	206102	206103	206104	206105	206106	206107	206108	206109	206110	206111	206112	206201	206202	206203	206204	206205	206206	206207	206208	206209	206210	206211	206212	206301	206302	206303	206304	206305	206306	206307	206308	206309	206310	206311	206312	206401	206402	206403	206404	206405	206406	206407	206408	206409	206410	206411	206412	206501	206502	206503	206504	206505	206506	206507	206508	206509	206510	206511	206512	206601	206602	206603	206604	206605	206606	206607	206608	206609	206610	206611	206612	206701	206702	206703	206704	206705	206706	206707	206708	206709	206710	206711	206712	206801	206802	206803	206804	206805	206806	206807	206808	206809	206810	206811	206812	206901	206902	206903	206904	206905	206906	206907	206908	206909	206910	206911	206912	207001	207002	207003	207004	207005	207006	207007	207008	207009	207010	207011	207012	207101	207102	207103	207104	207105	207106	207107	207108	207109	207110	207111	207112	207201	207202	207203	207204	207205	207206	207207	207208	207209	207210	207211	207212	207301	207302	207303	207304	207305	207306	207307	207308	207309	207310	207311	207312	207401	207402	207403	207404	207405	207406	207407	207408	207409	207410	207411	207412	207501	207502	207503	207504	207505	207506	207507	207508	207509	207510	207511	207512	207601	207602	207603	207604	207605	207606	207607	207608	207609	207610	207611	207612	207701	207702	207703	207704	207705	207706	207707	207708	207709	207710	207711	207712	207801	207802	207803	207804	207805	207806	207807	207808	207809	207810	207811	207812	207901	207902	207903	207904	207905	207906	207907	207908	207909	207910	207911	207912	208001	208002	208003	208004	208005	208006	208007	208008	208009	208010	208011	208012	208101	208102	208103	208104	208105	208106	208107	208108	208109	208110	208111	208112	208201	208202	208203	208204	208205	208206	208207	208208	208209	208210	208211	208212	208301	208302	208303	208304	208305	208306	208307	208308	208309	208310	208311	208312	208401	208402	208403	208404	208405	208406	208407	208408	208409	208410	208411	208412	208501	208502	208503	208504	208505	208506	208507	208508	208509	208510	208511	208512	208601	208602	208603	208604	208605	208606	208607	208608	208609	208610	208611	208612	208701	208702	208703	208704	208705	208706	208707	208708	208709	208710	208711	208712	208801	208802	208803	208804	208805	208806	208807	208808	208809	208810	208811	208812	208901	208902	208903	208904	208905	208906	208907	208908	208909	208910	208911	208912	209001	209002	209003	209004	209005	209006	209007	209008	209009	209010	209011	209012	209101	209102	209103	209104	209105	209106	209107	209108	209109	209110	209111	209112	209201	209202	209203	209204	209205	209206	209207	209208	209209	209210	209211	209212	209301	209302	209303	209304	209305	209306	209307	209308	209309	209310	209311	209312	209401	209402	209403	209404	209405	209406	209407	209408	209409	209410	209411	209412	209501	209502	209503	209504	209505	209506	209507	209508	209509	209510	209511	209512	209601	209602	209603	209604	209605	209606	209607	209608	209609	209610	209611	209612	209701	209702	209703	209704	209705	209706	209707	209708	209709	209710	209711	209712	209801	209802	209803	209804	209805	209806	209807	209808	209809	209810	209811	209812	209901	209902	209903	209904	209905	209906	209907	209908	209909	209910	209911	209912	210001	210002	210003	210004	210005	210006	210007	210008	210009	210010	210011	210012
Stream Name	10 791 824 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg	1 000 000 000 kg																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2735 Rev 0

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APPENDIX B
KE2 STREAM

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SLUDGE TREATMENT MATERIAL BALANCE

31 P00400 R1.2
Normal Case
30 Batch 450 kg solids
per fortnight

SAVON TREATMENT CONCENTRATION

1

Requirements

STREAM K22	Requirements		Obtained results
EMMAE waste of Tests	TVMS Requirements		
PCB in liq	< 0.5 ppb		0.01 ppb
PCB in sol	< 2 ppm		0.005 ppm
Concentration	< 40 g/l		40.13 g/l
Na(NO3) concentration			2.65 M
NaOH Concentration	Req on [OH-] 0.26 M		0.26 M
NaOH + Na(NO2) Concentration	Req on [OH-]+[NO2-] 1.06 M		1.06 M
Na(NO2) concentration	Req on [NO2-] none		0.79 M
Volume generated m3			217 m3
Filter (circulated water for EMMAE or waste water to WWP)	EMMAE Requirements	Waste Requirements	
PCB (ppm)		< 2 ppm	53.267 ppm
U (g/ml)	< 0.028 g/ml		0.0147 g/ml
Pu(Total)	Cum3		6.871 Cum3
238 Pu	< 1.5 Cum3		1.374 Cum3
239 Pu	< 0.029 Cum3		2.748 Cum3
240 Pu	< 0.029 Cum3		2.748 Cum3
Am	< 0.06 Cum3		4.156 Cum3
TRU	< 100 nanoC/kg	> 100 nanoC/kg	6.643 nC/kg
Volume generated m3			0.3 m3
Number of 0.2 m3 drums			1.3

DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF.2735 Rev 0

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DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF-2715 Rev 04

[illegible]

DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF-2735, Rev 0

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DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF-2735, Rev 0

[illegible]

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2715, Rev 0

[illegible]

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HMF-2735, Rev. 0

[illegible]

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2735, Rev 0

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DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2735, Rev 0

STREAM K82 Normal Case	ST-701 GROWTH MEDIA	ST-702 FUEL OIL/HT WATER/COOL	ST-703 ELECTROLYTE WATER TEMPERATURE
TOTAL STREAM			
Volume Density Feed Mass			3.00E-01 1.000 2.45E-02E kg
Number of substances			
UNID			
Volume			3.00E-01
Density			1.000
Feed Mass (kg) = 0.0245			2.45E-02E kg
H2O			
H4O2			
H2O2O4			
H2			
H2O2H			
A H4O2O			
A F2			
F H4O2O2			
Cl2			
HgHCl2			
HgHClO2			
NaHClO2			
NaCl			
NaClO2			
NaClO4			
NaClO3			
NaClO			
NaClO2			
NaClO3			
NaClO4			
NaClO5			
NaClO6			
NaClO7			
NaClO8			
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NaClO110			
NaClO111			
NaClO112			
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NaClO114			
NaClO115			
NaClO116			
NaClO117			
NaClO118			

APPENDIX C
KW1 STREAM

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SLUDGE TREATMENT CHEMICAL FLOW SHEET

SEWAGE TREATMENT MATERIAL BALANCE

STREAM KW1
Normal Case C = 8000 kg solids
at 1000 kg/h

**ALL-ONE TREATMENT
CONCENTRATION**

Requirements

STREAM RW1	Requirements		Obtained results
PCB in liq	TPWR Requirements	TPWR Requirements	TPWR Requirements
PCB in soil	< 0.5 ppb		0.00 ppb
Concentration	< 2 ppm		0.000 ppm
Na(NO3) concentration	< 40 g/l		4.84 g/l
NaOH Concentration	Req on [OH-] 0.30 M		2.98 M
NaOH + Na(NO2) Concentration	Req on [OH-]+[NO2-] 1.18 M		0.30 M
Na(NO2) concentration	Req on [NO2-] none		1.18 M
Volume generated m3			0.89 M
			93 m3
PCB (ppm)	TPWR Requirements	TPWR Requirements	TPWR Requirements
U g/ml	< 0.028 g/ml	< 2 ppm	0.000 ppm
Pu(Total)	Cu/m3		0.000 g/ml
238 Pu	< 1.5 Cu/m3		0.010 Cu/m3
239 Pu	< 0.029 Cu/m3		0.002 Cu/m3
240 Pu	< 0.029 Cu/m3		0.004 Cu/m3
Am	< 0.05 Cu/m3		0.004 Cu/m3
TRU	< 100 nanoCu/g	> 100 nanoCu/g	0.008 Cu/m3
Volume generated m3			8 nCu/g
Number of 0.2 m3 drums			11 m3
			55

DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF-2735, Rev 0

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DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF-2735, Rev 0

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DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2735, Rev 0

[illegible]

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2735 Rev. 0

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DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNP-2735, Rev 0

STREAM NAME	ST-304	ST-305	ST-310	ST-311	ST-312	ST-313	ST-314	ST-315
Nominal Case - TOTAL STREAM	TOTAL SOLIDS (kg/dry wt)	TOTAL SOLIDS (kg/dry wt)	TOTAL SOLIDS (kg/dry wt)	TOTAL SOLIDS (kg/dry wt)	TOTAL SOLIDS (kg/dry wt)	TOTAL SOLIDS (kg/dry wt)	TOTAL SOLIDS (kg/dry wt)	TOTAL SOLIDS (kg/dry wt)
Volume	22,487 m ³	2,054 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³
Density	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³
Total Mass	25,642 kg	2,342 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg
Number of Packages	1	1	1	1	1	1	1	1
ST-304								
Volume	22,487 m ³	2,054 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³
Density	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³
Total Mass	25,642 kg	2,342 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg
Number of Packages	1	1	1	1	1	1	1	1
ST-305								
Volume	2,054 m ³	2,054 m ³	2,054 m ³	2,054 m ³	2,054 m ³	2,054 m ³	2,054 m ³	2,054 m ³
Density	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³
Total Mass	2,342 kg	2,342 kg	2,342 kg	2,342 kg	2,342 kg	2,342 kg	2,342 kg	2,342 kg
Number of Packages	1	1	1	1	1	1	1	1
ST-310								
Volume	22,104 m ³	2,054 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³
Density	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³
Total Mass	25,104 kg	2,342 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg
Number of Packages	1	1	1	1	1	1	1	1
ST-311								
Volume	22,104 m ³	2,054 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³
Density	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³
Total Mass	25,104 kg	2,342 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg
Number of Packages	1	1	1	1	1	1	1	1
ST-312								
Volume	22,104 m ³	2,054 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³
Density	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³
Total Mass	25,104 kg	2,342 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg
Number of Packages	1	1	1	1	1	1	1	1
ST-313								
Volume	22,104 m ³	2,054 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³
Density	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³
Total Mass	25,104 kg	2,342 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg
Number of Packages	1	1	1	1	1	1	1	1
ST-314								
Volume	22,104 m ³	2,054 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³
Density	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³
Total Mass	25,104 kg	2,342 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg
Number of Packages	1	1	1	1	1	1	1	1
ST-315								
Volume	22,104 m ³	2,054 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³	22,104 m ³
Density	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³	1,141 kg/m ³
Total Mass	25,104 kg	2,342 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg	25,104 kg
Number of Packages	1	1	1	1	1	1	1	1

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2735, Rev 0

[illegible]

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNP-2735, Rev D

STREAM KYS	ST-001	ST-002	ST-003	ST-004	ST-005	ST-006	ST-007	ST-008	ST-009	ST-010
NORMAL CASE - TOTAL STREAM	2007/08/01 08:00 100% FLOW	2007/08/01 08:00 100% FLOW	2007/08/01 08:00 100% FLOW	2007/08/01 08:00 100% FLOW	2007/08/01 08:00 100% FLOW	2007/08/01 08:00 100% FLOW	2007/08/01 08:00 100% FLOW	2007/08/01 08:00 100% FLOW	2007/08/01 08:00 100% FLOW	2007/08/01 08:00 100% FLOW
Volume	62 707 m3	0 012 m3		62 707 m3	13 342 m3	14 342 m3	14 342 m3			
Density	1 000	1 000		1 000	1 000	1 000	1 000			
Total Mass	72 086 498 kg	13 342 kg		72 086 498 kg	14 342 000 kg	14 342 000 kg	14 342 000 kg			
Number of Species										
SOLIDS										
Volume	22 074 m3	0 012 m3		22 074 m3	11 342 m3	12 342 m3	12 342 m3			
Density	1 000	1 000		1 000	1 000	1 000	1 000			
Total Mass	22 074 000 kg	12 342 kg		22 074 000 kg	11 342 000 kg	12 342 000 kg	12 342 000 kg			
SiO2	14 254 780 kg	11 342 kg		14 254 780 kg	6 814 555 kg	7 529 100 kg	7 529 100 kg			
Al2O3	10 100 000 kg			10 100 000 kg						
Fe2O3	0 557 kg			0 557 kg						
Fe	109 162 kg			109 162 kg						
NaOH										
Al(OH)3	355 573 kg			355 573 kg						
Al										
Fe(OH)3	873 521 kg			873 521 kg						
CaO	17 294 kg			17 294 kg						
NaOH2	5 676 437 kg			5 676 437 kg						
NaOH	25 287 285 kg			25 287 285 kg						
NaOH (NaOH2)	44 400 kg			44 400 kg						
NaOH (NaOH2)	142 272 kg			142 272 kg						
Na	20 627 C			20 627 C						
Al	19 558 C			19 558 C						
Ca	173 100 C			173 100 C						
Fe	777 702 C			777 702 C						
FeO										
Al2O3										
SiO2										
SOLIDS - RESIDUE										
Volume	0 002 m3			0 002 m3						
Density	2 277			2 277						
Total Mass	4 554 kg			4 554 kg						
SiO2	3 000 kg			3 000 kg						
Al2O3	0 000 kg			0 000 kg						
Fe2O3	0 557 kg			0 557 kg						
Fe	0 557 kg			0 557 kg						
NaOH	0 557 kg			0 557 kg						
Al(OH)3	0 557 kg			0 557 kg						
Al	0 557 kg			0 557 kg						
Fe(OH)3	0 557 kg			0 557 kg						
CaO	0 557 kg			0 557 kg						
NaOH2	0 557 kg			0 557 kg						
NaOH	0 557 kg			0 557 kg						
NaOH (NaOH2)	0 557 kg			0 557 kg						
NaOH (NaOH2)	0 557 kg			0 557 kg						
Na	0 557 C			0 557 C						
Al	0 557 C			0 557 C						
Ca	0 557 C			0 557 C						
Fe	0 557 C			0 557 C						
FeO										
RESIDUE										
Volume										
Density										
Total Mass										
SiO2										
Al2O3										
Fe2O3										
Fe										
NaOH										
Al(OH)3										
Al										
Fe(OH)3										
CaO										
NaOH2										
NaOH										
NaOH (NaOH2)										
NaOH (NaOH2)										
Na										
Al										
Ca										
Fe										
FeO										
TOTAL ACTIVITIES										
Volume	20 012 m3			20 012 m3						
Density	1 000			1 000						
Total Mass	20 012 000 kg			20 012 000 kg						
SiO2	14 254 780 kg			14 254 780 kg						
Al2O3	10 100 000 kg			10 100 000 kg						
Fe2O3	0 557 kg			0 557 kg						
Fe	109 162 kg			109 162 kg						
NaOH	355 573 kg			355 573 kg						
Al(OH)3	873 521 kg			873 521 kg						
Al	17 294 kg			17 294 kg						
Fe(OH)3	5 676 437 kg			5 676 437 kg						
CaO	25 287 285 kg			25 287 285 kg						
NaOH2	44 400 kg			44 400 kg						
NaOH	142 272 kg			142 272 kg						
Na	20 627 C			20 627 C						
Al	19 558 C			19 558 C						
Ca	173 100 C			173 100 C						
Fe	777 702 C			777 702 C						
FeO										
CO2 ACTIVITIES										
Volume										
Density										
Total Mass										
SiO2										
Al2O3										
Fe2O3										
Fe										
NaOH										
Al(OH)3										
Al										
Fe(OH)3										
CaO										
NaOH2										
NaOH										
NaOH (NaOH2)										
NaOH (NaOH2)										
Na										
Al										
Ca										
Fe										
FeO										

APPENDIX D
KW1 STREAM

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SLOUDGE TREATMENT CONVENTIONAL FLOW SHEET

1 1

INTEREST

1
L. 100-4248-1.7
2000-01-01
2000-01-01

SLUDGE TREATMENT CONCENTRATION

0 TREATMENT 01 SLUDGE TREATMENT

Requirements

STREAM KW2	Requirements		Obtained results
PCB in liq	Req on [PCB] < 0.5 ppb		0.00 ppb
PCB in sol	Req on [PCB] < 2 ppm		0.000 ppm
Concentration	Req on [PCB] < 40 g/l		40.07 g/l
Na(NO3) concentration	Req on [OH-] 0.24 M		0.24 M
NaOH Concentration	Req on [OH-]+[NO2-] 0.04 M		0.04 M
NaOH + Na(NO2) Concentration	Req on [NO2-] none		0.73 M
Na(NO2) concentration			
Volume generated m3			107 m3
PCB (ppm)	Req on [PCB] < 2 ppm		0.000 ppm
U g/ml	Req on [U] < 0.028 g/ml		0.0182 g/ml
Pu(Total)	Req on [Pu] < 1.5 C/m3		0.204 C/m3
238 Pu	Req on [238Pu] < 0.028 C/m3		1.241 C/m3
239 Pu	Req on [239Pu] < 0.028 C/m3		2.482 C/m3
240 Pu	Req on [240Pu] < 0.028 C/m3		2.482 C/m3
Am	Req on [Am] < 0.05 C/m3		3.257 C/m3
TRU	Req on [TRU] < 100 nC/g	Req on [TRU] > 100 nC/g	5.365 nC/g
Volume generated m3			0.1 m3
Number of 0.2 m3 drums			0.6

DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF-2735 Rev. D

[illegible]

DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF-2735, Rev 0

STREAM NAME	at 75 m/s	7/11/11	at 75 m/s
Normal Case	Normal Case	Normal Case	Normal Case
1 Batch 160 kg solids	1 Batch 160 kg solids	1 Batch 160 kg solids	1 Batch 160 kg solids
Volume			0.131 m3
Density			1.468
Total Mass			194.995 kg
1. SOLIDS			
Volume			0.131 m3
Density			1.468
Total Solids Content - Sol.			128.885 kg
H2O			134.885 kg
H2O2			
H2O3			
H2O4			
H2O5			
H2O6			
H2O7			
H2O8			
H2O9			
H2O10			
H2O11			
H2O12			
H2O13			
H2O14			
H2O15			
H2O16			
H2O17			
H2O18			
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H2O355			
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H2O359			
H2O360			
H2O361			
H2O362			

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2735, Rev. 0

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APPENDIX E
KW3 STREAM

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SUNBATH TREATMENT

SLUDGE TREATMENT
MAINTENANCE BALANCE

STREAN KORT 5
Normal Case C# Batch 100-4g solids
SOLUBILITY 21

WASTEWATER TREATMENT
CONCENTRATION

STANDARD 1000
Minimum 1000

1000 kg wet weight

Requirements

STREAM KW3	Requirements		Obtained results
Effluent sent to FWWS	FWWS Requirements		
PCB in kg	< 0.5 ppb		0.01 ppb
PCB in sol	< 2 ppm		0.008 ppm
Concentration	< 40 g/l		39.92 g/l
Na(NO3) concentration	Req on [OH-] 0.25 M		2.61 M
NaOH Concentration	Req on [OH-]+[NO2-] 1.04 M		0.26 M
NaOH + Na(NO2) Concentration	Req on [NO2-] none		1.04 M
Na(NO2) concentration			0.76 M
Volume generated m3			205 m3
Effluent sent to EREF or sent as-is to WAPP	EREF Requirements		
PCB (ppm)	< 2 ppm		152.172 ppm
U g/ml	< 0.026 g/ml		0.0182 g/ml
Pu(Total)	Cu/m3		19.732 Cu/m3
238 Pu	< 1.5 Cu/m3		2.146 Cu/m3
239 Pu	< 0.029 Cu/m3		4.293 Cu/m3
240 Pu	< 0.026 Cu/m3		4.293 Cu/m3
Am	< 0.05 Cu/m3		4.815 Cu/m3
TRU	< 100 nanoCu/g	> 100 nanoCu/g	10.388 nCu/g
Volume generated m3			0.1 m3
Number of 0.2 m3 drums			0.5

DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF-2735 Rev 0

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DETAILED STREAM DATA SHEET FOR ONE DAILY BATCH

HNF-2735, Rev 0

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DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2735, Rev. 0

[illegible]

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HNF-2735, Rev 0

STREAM ROWS	ST-001	ST-002	ST-003	ST-004	ST-005	ST-006	ST-007	ST-008	ST-009	ST-010	ST-011
Normal Case	100% (100% of 1000)	100% (100% of 1000)	100% (100% of 1000)	100% (100% of 1000)	100% (100% of 1000)	100% (100% of 1000)	100% (100% of 1000)	100% (100% of 1000)	100% (100% of 1000)	100% (100% of 1000)	100% (100% of 1000)
TOTAL STREAM											
Volume	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³
Density	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³
Temperature	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C
Number of particles	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
LIQUID											
Volume	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³
Density	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³
Temperature	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C
Number of particles	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
SOLIDS + RESINS											
Volume	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³
Density	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³
Temperature	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C
Number of particles	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
RESINS											
Volume	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³
Density	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³
Temperature	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C
Number of particles	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
TOTAL ACTIVITIES											
Volume	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³
Density	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³
Temperature	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C
Number of particles	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Other Activities											
Volume	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³	1000 m ³
Density	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³	1000 kg/m ³
Temperature	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C	20.0 °C
Number of particles	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

DETAILED STREAM DATA SHEET FOR THE WHOLE STREAM

HDF-2735, Rev. 0

STREAM NAME	ST 101 debris / materials	ST 102 solid / liquid waste up to 1000g	ST 103 acceptance up over 1000g to garbage
Nominal Case :			
TOTAL STREAM			
Volume			7 810 kg
Density			4 000
Total Mass			1 000 000 kg
Mass of primary			
LIQUID			
Volume			1 200 m³
Density			7 000
Total Mass LIQUID = 840			1 000 000 kg
TO			1 000 000 kg
TOC			1 000 000 kg
TOC2			1 000 000 kg
TOC3			1 000 000 kg
TOC4			1 000 000 kg
TOC5			1 000 000 kg
TOC6			1 000 000 kg
TOC7			1 000 000 kg
TOC8			1 000 000 kg
TOC9			1 000 000 kg
TOC10			1 000 000 kg
TOC11			1 000 000 kg
TOC12			1 000 000 kg
TOC13			1 000 000 kg
TOC14			1 000 000 kg
TOC15			1 000 000 kg
TOC16			1 000 000 kg
TOC17			1 000 000 kg
TOC18			1 000 000 kg
TOC19			1 000 000 kg
TOC20			1 000 000 kg
TOC21			1 000 000 kg
TOC22			1 000 000 kg
TOC23			1 000 000 kg
TOC24			1 000 000 kg
TOC25			1 000 000 kg
TOC26			1 000 000 kg
TOC27			1 000 000 kg
TOC28			1 000 000 kg
TOC29			1 000 000 kg
TOC30			1 000 000 kg
TOC31			1 000 000 kg
TOC32			1 000 000 kg
TOC33			1 000 000 kg
TOC34			1 000 000 kg
TOC35			1 000 000 kg
TOC36			1 000 000 kg
TOC37			1 000 000 kg
TOC38			1 000 000 kg
TOC39			1 000 000 kg
TOC40			1 000 000 kg
TOC41			1 000 000 kg
TOC42			1 000 000 kg
TOC43			1 000 000 kg
TOC44			1 000 000 kg
TOC45			1 000 000 kg
TOC46			1 000 000 kg
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TOC74			1 000 000 kg
TOC75			1 000 000 kg
TOC76			1 000 000 kg
TOC77			1 000 000 kg
TOC78			1 000 000 kg
TOC79			1 000 000 kg
TOC80			1 000 000 kg
TOC81			1 000 000 kg
TOC82			1 000 000 kg
TOC83			1 000 000 kg
TOC84			1

APPENDIX F
SOLID RESIDUES GROUTING

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BLUDGE TREATMENT
CLINICAL GLOW SHEET

ANALOG FREIGHT SCHEDULE

ALU, BTR AND ORIGIN OF SOLID RESIDUE
Normal Case

Requirements

ALL STREAMS-GROUTING OF SOLID RESIDUES	Requirements	Obtained results
Nominal Case		
PCB in liq	< 0.6 ppb	0.00 ppb
PCB in sol	< 2 ppm	0.001 ppm
Concentration	< 40 g/g	0.01 g/g
Na(NO ₃) concentration		0.02 M
NaOH Concentration	Req on [OH-] 0.01 M	0.01 M
NaOH + Na(NO ₂) Concentration	Req on [OH-]+[NO ₂ -] none	0.02 M
Na(NO ₂) concentration	Req on [NO ₂ -] 0.01 M	0.01 M
Volume generated m ³		33 m ³
Other Values Limit to ERDF	ERDF Requirements	
PCB (ppm)		22.426 ppm
U g/ml	< 0.026 g/ml	0.0001 g/ml
Pu(Total)	Ci/m ³	0.035 Ci/m ³
238 Pu	< 1.5 Ci/m ³	0.007 Ci/m ³
239 Pu	< 0.029 Ci/m ³	0.014 Ci/m ³
240 Pu	< 0.020 Ci/m ³	0.014 Ci/m ³
Am	< 0.05 Ci/m ³	0.029 Ci/m ³
TRU	< 100 nanoCi/g	31 nCi/g
Volume generated m ³		32.9 m ³
Number of 4.6 m ³ liners		8.7

DETAILED STREAM DATA SHEET

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ALL STREAMS ROUTIN Monthly Case	ST-001 ST-001 ST-001	ST-002 ST-002 ST-002	ST-003 ST-003 ST-003	ST-004 ST-004 ST-004	ST-005 ST-005 ST-005	ST-006 ST-006 ST-006	ST-007 ST-007 ST-007	ST-008 ST-008 ST-008	ST-009 ST-009 ST-009	ST-010 ST-010 ST-010
ST-001 ST-001 ST-001										
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APPENDIX G
SUMMARY STREAM

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BLOOD TREATMENT CHEMICAL FLUXION UNIT

Requirements

TOTAL STREAMS	Requirements	Obtained results
Nominal Case		
Effluent sent to TRU	TRU Requirements	TRU Results
PCB in liq	< 0.5 ppb	0.01 ppb
PCB in sol	< 2 ppm	0.262 ppm
Concentration	< 40 g/l	21.85 g/l
Na(NO ₃) concentration		1.20 M
NaOH Concentration	Req on [OH-] 0.30 M	0.30 M
NaOH + Na(NO ₂) Concentration	Req on [OH-]+[NO ₂ -] 1.20 M	1.20 M
Na(NO ₂) concentration	Req on [NO ₂ -] none	0.90 M
Volume generated m3		1,620 m3
Gravel washed sent to ERDF	ERDF Requirements	ERDF Results
PCB (ppm)		22.428 ppm
U (g/ml)	< 0.026 g/ml	0.0001 g/ml
Pu(Total)	Cu/m3	0.036 Cu/m3
238 Pu	< 1.5 Cu/m3	0.007 Cu/m3
239 Pu	< 0.028 Cu/m3	0.014 Cu/m3
240 Pu	< 0.029 Cu/m3	0.014 Cu/m3
Am	< 0.05 Cu/m3	0.029 Cu/m3
TRU	< 100 nanoCu/g	31 nCu/g
Volume generated m3		32.0 m3
Number of 4.8 m3 drums		6.7
Filters : Gravel sent to ERDF or sent as-is to TRU	ERDF Requirements	TRU Requirements
PCB (ppm)		< 2 ppm
U (g/ml)	< 0.026 g/ml	
Pu(Total)	Cu/m3	
238 Pu	< 1.5 Cu/m3	
239 Pu	< 0.028 Cu/m3	
240 Pu	< 0.029 Cu/m3	
Am	< 0.05 Cu/m3	
TRU	< 100 nanoCu/g	> 100 nanoCu/g
Volume generated m3		9.7 m3
Number of 0.2 m3 drums		48.4

DETAILED STREAM DATA SHEET

HNF-2735, Rev 0

[illegible]

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	Mumatec Hanford Corporation Sludge Treatment Project	Date August 26, 1998
Project Title/Work Order		EDT No. 624546
K Basin Sludge Treatment Process Description, HNF-2735		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
<i>Central Files</i>	<i>81-07</i>	<i>X</i>			
Correspondence Control	A3-01	X			
<u>Fluor Daniel Hanford, Inc.</u>					
M. J. Wiemers	R3-11	X			
<u>DEAS Hanford, Inc.</u>					
D. E. Bullock	R3-86	X			
D. R. Prehctel	X3-85	X			
<u>Mumatec Hanford Corporation</u>					
L. de Lamartinié	H7-20	X			
T. A. Flament	H7-20	X			
S. C. Klimper	H7-20	X			
W. C. Miller	H5-25	X			
F. W. Moore	H7-20	X			
K. L. Pearce	H7-20	X			
W. W. Rutherford	H7-20	X			
A. G. Westra	R3-86	X			
K Basins File	X3-85	X			