AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 6

Extensive Separations (CLEAN) Processing Strategy Compared to TRUEX Strategy and Sludge Wash Ion Exchange

B. J. Knutson
G. Jansen
B. D. Zimmerman
S. E. Seeman
Westinghouse Hanford Company

L. Lauerhass
M. Hoza
Pacific Northwest Laboratory

Date Published
August 1994

Prepared for the U.S. Department of Energy
Office of Environmental Management
Office of Technology Development

**Westinghouse
Hanford Company**

P.O. Box 1970
Richland, Washington 99352

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Approved for Public Release

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

LEGAL DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced from the best available copy.
Available in paper copy and microfiche.

Available to the U.S. Department of Energy
and its contractors from
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831
(615) 576-8401

Available to the public from the U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

Printed in the United States of America

DISCLM-1.CHP (1-91)

RELEASE AUTHORIZATION		
Document Number:	WHC-EP-0791	
Document Title:	Extensive Separations (CLEAN) Processing Strategy Compared to TRUEX Strategy and Sludge Wash Ion Exchange	
Release Date:	August 22, 1994	
<p>*****</p> <p>This document was reviewed following the procedures described in WHC-CM-3-4 and is:</p> <p>APPROVED FOR PUBLIC RELEASE</p> <p>*****</p>		
WHC Information Release Administration Specialist:		
<div style="display: flex; justify-content: space-between; align-items: flex-end;"> <div style="text-align: center;"> <hr style="width: 200px; margin: 0 auto;"/> <p>(Signature)</p> </div> <div style="text-align: center;"> <p>M. N. Boston</p> <hr style="width: 150px; margin: 0 auto;"/> </div> <div style="text-align: center;"> <p>8/22/94</p> <hr style="width: 150px; margin: 0 auto;"/> <p>(Date)</p> </div> </div>		

Document Title: Extensive Separations (CLEAN) Processing Strategy Compared to TRUEX Strategy and Sludge Wash Ion Exchange

Prepared by: B. J. Knutson 8/18/94
B. J. Knutson, Principal Engineer
Westinghouse Hanford Company Date

Prepared by: L. Lauerhass 8/18/94
L. Lauerhass, Research Engineer
Pacific Northwest Laboratory Date

Reviewed by: S. E. Seeman 8/18/94
S. E. Seeman, Manager
Systems Engineering Analysis Date

Approved by: G. W. Jackson 8/19/94
G. W. Jackson, Director
Systems Engineering Date

ACKNOWLEDGEMENT

The work of students K. C. Larson, B. M. Grace, W. J. Young, and M. E. Johnston of the Westinghouse Hanford Company in writing various spreadsheet scripts to process the model input and output data was invaluable in accomplishing this work. Funding for this project was provided by the U.S. Department of Energy, Office of Technology Development (EM-50), through the Efficient Separations and Processing Integrated Program.

This page intentionally left blank.

**EXTENSIVE SEPARATIONS (CLEAN) PROCESSING STRATEGY
COMPARED TO TRUEX STRATEGY AND
SLUDGE WASH ION EXCHANGE**

EXECUTIVE SUMMARY

Numerous pretreatment flowsheets have been proposed for processing the radioactive wastes in Hanford's 177 underground storage tanks. On one extreme are minimal treatment flowsheets containing a few separations that moderately concentrate radionuclides into a high-level waste (HLW) glass product. To the other extreme are complex flowsheets with dozens of separation processes intended to minimize the HLW volume and radiotoxicity of the low-level waste (LLW) glass or grout product. The CLEAN Option is an example of this latter type of pretreatment flowsheet whose analysis is the subject of this report. The CLEAN Option is examined along with two other flowsheet alternatives to quantify the trade-off of greater capital equipment and operating costs for aggressive separations with the reduced waste disposal costs and decreased environmental/health risks.

The effect on the volume of HLW glass product and radiotoxicity of the LLW glass or grout product is predicted with current assumptions about waste characteristics and separations processes using a mass balance model. The prediction is made on three principal processing options:

- Washing of tank wastes with removal of cesium and technetium from the supernatant, with washed solids routed directly to the glass (referred to as the Sludge Wash C processing strategy)
- The previous steps plus dissolution of the solids and removal of transuranic (TRU) elements, uranium, and strontium using solvent extraction processes (referred to as the Transuranic Extraction Option C (TRUEX-C) processing strategy)
- An aggressive yet feasible processing strategy for separating the waste components to meet several main goals or objectives (referred to as the CLEAN Option processing strategy), such as the LLW is required to meet the U.S. Nuclear Regulatory Commission Class A limits; concentrations of

technetium, iodine, and uranium are reduced as low as reasonably achievable; and HLW will be contained within 1,000 borosilicate glass canisters (0.625 m³/canister) that meet current Hanford Waste Vittrification Plant (HWVP) glass specifications.

Key characteristics of the different processing strategies, which could be compared quantitatively, are summarized in the results summary table. Costs are provided for the CLEAN option with and without compact processing units (CPUs).

Results Summary Table.

COMPARISON	WITH CPUs	<----- WITHOUT CPUs ----->		
	CLEAN	CLEAN	TRUEX-C	SLUDGE WASH C
UTILIZES COMPACT PROCESSING UNITS (CPUs)?	YES	NO	NO	NO
TOTAL COST (\$BILLION)	\$31.1B	\$41.2B	\$32.5B	\$36.4B
PROCESSING COST	\$7.6B	\$14.3B	\$5.2B	\$3.7B
HLW TREATMENT & DISPOSAL COST	2.5	2.5	6.0	15.3
LLW TREATMENT & DISPOSAL COST	2.4	2.4	3.5	2.7
TERTIARY WASTE TREATMENT & DISPOSAL COST	9.5	12.8	8.9	5.9
TANK WASTE RETRIEVAL COST	8.1	8.1	8.1	8.1
OTHER	0.4	0.4	0.4	0.4
IMPACT OF 1 WT% P2O5 GLASS LIMIT ON TOTAL COST	\$0.1B	\$0.1B	\$1.6B	\$17.5B
TERTIARY WASTE CONTRIBUTION TO TOTAL COST	30%	31%	27%	16%
WITH P2O5 GLASS LIMIT RELAXED:				
HLW GLASS CANISTERS (0.625 M3/CANISTER)	750	750	8880	41450
LLW GLASS-IN-SULFUR VAULTS	65	65	76	60
TERTIARY WASTE SALT GROUT VAULTS	169	237	155	98
LLW CLASSIFICATION	CLASS A	CLASS A	CLASS B	CLASS B
LLW ONSITE & OFFSITE SHORT TERM RELATIVE HEALTH RISK INDEX	1.0	1.0	49.5	71.2
RELATIVE OCCUPATIONAL HEALTH RISK INDEX:				
BETA RADIATION	19.2	19.2	8.7	1.0
GAMMA RADIATION	1.24	1.24	1.20	1.00
Na2O CONTENT OF LOW LEVEL WASTE	74 WT%	74 WT%	85 WT%	89 WT%
RELATIVE PROCESS STRATEGY TECHNICAL RISK INDEX	>9.8	9.8	5.0	1.0

The following conclusions are supported by the study results.

- The reduction in the HLW glass canister count achieved by the CLEAN Option sharply decreases the associated HLW treatment and disposal cost relative to the TRUEX-C and Sludge Wash C flowsheets.
- The greater number of separation processes in the CLEAN flowsheet is reflected in higher separation costs when compared to the alternative options.
- Of the three options examined (excluding CLEAN Option with CPUs), TRUEX-C has the lowest total cost. TRUEX-C demonstrates the most economic trade-off of separation complexity with HLW disposal cost reduction.
- A 24% reduction in the total cost of the CLEAN Option is achieved if CPUs (for alkaline ion exchange processing of supernate and salt cake to remove cesium, strontium, and technetium) are used instead of a Central Processing Facility. A similar total cost impact is expected if CPUs are used in the TRUEX-C and Sludge Wash C flowsheets.
- The contribution of tertiary waste to total cost is substantial for all flowsheets. Tertiary costs varied from 16% (for Sludge Wash C) to 31% (for CLEAN Option) of the total cost.
- With regard to health risk posed by LLW, the CLEAN Option is substantially superior to the other options. The CLEAN Option flowsheet is the only option in this study capable of producing Class A LLW.
- The CLEAN Option poses greater occupational health risk because more extensive separation operations increase worker exposure to radioactivity.

The total costs cited for the different flowsheets do not take into consideration a number of intangible factors important in flowsheet selection.

- The CLEAN Option carries more technical risk than the alternative flowsheets because it relies more heavily on emerging technologies still undergoing development. For example, there is considerable uncertainty in the optimistic acid side dissolution assumptions so critical to CLEAN Option's dramatic HLW volume reduction relative to alternative pretreatment strategies.
- The more than an-order-of-magnitude improvement in short-term onsite and offsite health risk achieved by the CLEAN Option could make this option preferable to lower cost alternatives.
- Credit is not taken in the CLEAN Option for reducing HLW volume to the point that a separate vitrification facility may not be needed. If vitrification can be incorporated directly into the separations plant as an acid process, the cost of permitting and approval efforts for an additional stand-alone facility could be avoided, and costs associated with neutralization, material transport, and storage of waste at a separate facility would be eliminated.

Additional conclusions resulting from this study include the following.

- LLW processing and disposal costs are comparable for LLW glass-in-sulfur and grout products.
- Residual waste (or heel) remaining in the tanks after sludge retrieval represents the dominant onsite and offsite health hazard.

Numerous assumptions were made for each of the three processing strategies. Four assumptions, which strongly affect total cost and merit further technical effort to substantiate, are as follows:

- The 1 wt% P_2O_5 maximum limit for HWVP borosilicate glass
- The 20 wt% Na_2O maximum limit for LLW borosilicate glass

- The effectiveness of the organic destruction step in destroying metal complexants in the supernatant
- The extent of sludge dissolution for sludge treatments proposed in the three processing strategies.

The results of this study suggest investigating the following issues in future work under this project.

- Determine the cost impact of including a sodium salt removal process in the pretreatment flowsheet to substantially decrease the volume of LLW that must be processed.
- Quantify the effect on costs of substituting developing ion-exchange technologies (cesium and strontium) for baseline technologies.
- Consider a greater range of disposal alternatives by not recombining the waste fractions produced by a processing strategy, such as the CLEAN Option.
- Reevaluate the process strategies using different tank group feedstreams (perhaps 10 to 12 for single-shell tanks) versus an all tank (single- and double-shell tank) mixed waste feedstream currently used in the analyses. Sludge dissolution factors included in the process models would change for each specific tank sludge waste group based on experimental/analytical data. This course of analysis could be phased in as appropriate.

This page intentionally left blank.

CONTENTS

1.0	SUMMARY	1-1
1.1	BACKGROUND	1-8
1.2	PRIOR STUDY	1-8
1.3	WASTE MINIMIZATION PHILOSOPHY	1-9
2.0	TECHNICAL ISSUES	2-1
2.1	WASTE STREAM	2-1
2.2	SOLID-LIQUID SEPARATION	2-1
2.3	SOLIDS DISSOLUTION	2-2
2.4	HIGH- AND LOW-LEVEL WASTE FORM MINIMIZATION	2-2
2.5	GENERATION OF SECONDARY AND TERTIARY WASTE	2-3
3.0	PROCESS DESCRIPTION AND IMPORTANT ASSUMPTIONS	3-1
3.1	WASTE STREAM	3-1
3.1.1	Supernatant	3-1
3.1.2	Sludge	3-2
3.2	HIGH- AND LOW-LEVEL WASTE STREAMS	3-3
3.3	SOLVENT EXTRACTION	3-5
3.4	SOLVENT WASTE MINIMIZATION	3-5
3.5	SODIUM HYDROXIDE AND NITRIC ACID RECYCLE	3-6
4.0	RESULTS	4-1
4.1	TERTIARY WASTE GENERATION	4-1
4.2	COSTS	4-1
4.3	GLASS COMPOSITION OPTIMIZATION	4-4
4.4	WASTE PRODUCT MASS BALANCES	4-6
4.5	RELATIVE HEALTH HAZARD ESTIMATES	4-7
4.5.1	Long-Term Offsite Health Hazard	4-7
4.5.2	Long-Term Onsite Health Hazard	4-7
4.5.3	Short-Term Onsite And Offsite Health Hazard	4-8
4.5.4	Occupational Exposure	4-9
4.5.5	Waste Classification and Radionuclide Concentrations	4-10
4.6	PROCESS STRATEGY TECHNICAL RISK	4-10
5.0	CONCLUSIONS	5-1
6.0	REFERENCES	6-1
APPENDICES		
A	GENERAL DESCRIPTION OF ASPEN PLUS	A-1
B	DETAILED CLEAN OPTION MODEL: ASPEN PLUS IMPLEMENTATION	B-1
C	HANFORD STRATEGIC ANALYSIS MODEL: ASPEN PLUS IMPLEMENTATION	C-1
D	GLOBAL LEVEL MODEL: ASPEN PLUS IMPLEMENTATION	D-1
E	TERTIARY NONPROCESS WASTE GENERATION	E-1
F	COST ESTIMATION MODELS	F-1
G	GLASS COMPOSITION OPTIMIZATION	G-1
H	ASPEN PLUS GLOBAL MODEL MASS BALANCE RESULTS	H-1
I	RELATIVE HEALTH RISK ESTIMATES	I-1
J	TANK WASTE INVENTORIES	J-1
K	PROCESS STRATEGY TECHNICAL RISK	K-1

LIST OF FIGURES

1-1	Process Strategy Flowsheet Comparison	1-10
3-1	High-Level Waste Oxide Stream Content for Flowsheet Options	3-7
3-2	Radionuclide Fraction to Low-Level Waste	3-7
4-1	Tertiary Waste Generation	4-12
4-2	Cost Summary for Primary and Tertiary Waste Processing	4-13
4-3	High-Level Waste Glass Canister Summary	4-14
4-4	Low-Level Waste Glass and Grout Vault Summary	4-14
4-5	Normalized Long and Short Term Onsite Health Hazard	4-15
4-6	Occupational Health Hazard Summary	4-15
4-7	Total Technical Risk Index by Process Strategy	4-16
4-8	Average Technical Risk Index by Process Strategy	4-16

LIST OF TABLES

3-1	High-Level Waste Oxide Stream Content for Flowsheet Options	3-8
3-2	Radionuclide Fraction to Low-Level Waste	3-8
4-1	Total Cost Summary for Process Strategies	4-17
4-2	Summary of Glass Optimization Results	4-18
4-3	Summary of Waste Product Generation	4-19

LIST OF TERMS

CE	crown ether
CMPO	N-diisobutylcarbamoylmethylphosphine oxide
CPU	compact processing unit
DF	decontamination factor
DOE	U.S. Department of Energy
DST	double-shell tank
EDTA	ethylenediaminetetraacetic acid
ESPIP	Efficient Separations and Process Integrated Program
GTCC	Greater than Class C
HHI	Health Hazard Index
HLW	high-level waste
HWVP	Hanford Waste Vitrification Plant
IX	ion exchange
LLW	low-level waste
NRC	U.S. Nuclear Regulatory Commission
OTHHI	Other upper limit
SCWO	supercritical water oxidation
SE	solvent extraction
SLS	solid/liquid separation
SOLEX	Solvent Extraction Option
SREX	strontium extraction
SST	single-shell tank
TBP	tributyl phosphate
TCIX	technetium ion exchange
TOC	total organic carbon
TPA	Tri-Party Agreement
TRU	transuranic
TRUEX	transuranic extraction
TRUEX-C	Transuranic Extraction Option C
WHC	Westinghouse Hanford Company

**EXTENSIVE SEPARATIONS (CLEAN) PROCESSING STRATEGY
COMPARED TO TRUEX STRATEGY AND
SLUDGE WASH ION EXCHANGE**

1.0 SUMMARY

The effect on the volume of high-level waste (HLW) glass and radiotoxicity of the low-level waste (LLW) grout or glass is predicted with current assumptions about waste characteristics and separations processes using a mass balance model. The prediction is made on three principal processing options: (1) washing of tank wastes with removal of cesium and technetium from the supernatant, with washed solids routed directly to the glass (referred to as the Sludge Wash C processing strategy); (2) the previous steps plus dissolution of the solids and removal of transuranic (TRU) elements, uranium, and strontium using solvent extraction processes (referred to as the Transuranic Extraction Option C [TRUEX-C] processing strategy); and (3) an aggressive yet feasible processing strategy for separating the waste components to meet several main goals or objectives (referred to as the CLEAN Option processing strategy). Among the goals or objectives of the CLEAN Option strategy are the following: LLW meets U.S. Nuclear Regulatory Commission (NRC) Class A limits, concentrations of technetium and iodine in the LLW fraction are reduced as low as reasonably achievable, and HLW will be contained within 1,000 borosilicate glass canisters that meet current Hanford Waste Vitrifaction Plant (HWVP) canister size and glass composition specifications. (Each canister is assumed to be 2 ft in diameter by 10 ft in length with a glass volume of 0.625 m³).

Recent Tri-Party Agreement (TPA) changes have adopted an Enhanced In-Tank Sludge Wash process strategy as the technical baseline. Figure 1-1 shows generally how the current baseline process strategy relates to the three process strategies evaluated in this report. The Enhanced In-Tank Sludge Wash process strategy will be evaluated in a future report.

The predicted HLW volumes and radiotoxicity of the LLW depend on the following assumptions:

- Assumed composition of the waste stream
- Assumed distribution of various components in the waste between the sludge and supernatant phases
- Assumed fraction of various components in the sludge that dissolve in the assumed acid dissolution step(s)
- Assumed maximum allowable mass fraction of phosphate in the HLW or LLW glass
- Assumed relationship of certain glass properties to glass composition
- Assumed use of a stripping agent for the transuranic extraction (TRUEX) step that is not an organophosphate

- Assumed fraction of TRU elements complexed in the supernatant and the extent of destruction of complexants in a supercritical water oxidation step
- Assumed ability of a sodium titanate sorption step to remove the remaining, presumably complexed, dissolved species
- Assumed extent of extraction and stripping of various components in the TRUEX and strontium extraction (SREX) solvent extraction processes
- Assumed ion exchange (IX) removal efficiency for radionuclides (i.e., americium, strontium, cesium, and technetium).

The amounts of actinide elements in the waste supernatant that are routed to the LLW form are consequences of the following key assumptions: (1) their assumed concentrations in the supernatant, (2) the assumption that these concentrations are the result of complexation, and (3) that 99% of the complexants are destroyed in an oxidation step.

The amount of HLW glass produced may be controlled by the masses of waste components in the sludge that remain undissolved (especially for the TRUEX-C and Sludge Wash C process strategies). The CLEAN Option processing strategy contains three acid dissolution steps to overcome these dissolution problems. In the flowsheets considered for this report, undissolved solids are routed directly to HLW glass. Based on the assumed waste composition, these solids may include substantial mass fractions of phosphate (especially for the TRUEX-C and Sludge Wash C process strategies). The assumed allowable mass fraction of phosphate as P_2O_5 in the glass is 1 wt%; based on this limit the HLW loading in the glass must be constrained to accommodate the phosphate in the undissolved solids. The amount of HLW glass that would be required if the maximum phosphate mass fraction constraint is relaxed was also calculated for comparison and also depends mainly on the extent to which sludge remains undissolved.

Based on a draft letter report issued in July 1993 (Knutson et al. 1993), the HLW stream, if calcined, would be nearly the same in composition as the calcined undissolved solids stream (for the TRUEX-C and Sludge Wash C process strategies) because on average 90% of the HLW equivalent oxides are contributed by the undissolved solids stream. Therefore, the reduction in waste mass, on a calcined basis, from the feed to the HLW of a factor of 22 is limited by the assumed 90% dissolution of species in the solids. Therefore, EM-30/50 should focus on the solids dissolution pretreatment step because it has the largest impact on the glass waste product. Certainly, the CLEAN Option processing strategy focuses on this aspect along with additional element separations to meet its low HLW glass canister count and LLW toxicity goals.

Recent TPA changes have also designated glass as the final waste product form for the LLW stream. The LLW glass is expected to be stored as gravel-sized glass chunks (cullet) within a sulfur cement matrix in underground vaults. However, no extensive analyses or experimental glass formulation data relative to expected LLW stream compositions are available. Therefore, the analyses in this report used the HLW glass composition specifications and

associated optimization models for the LLW glass streams also. It is expected that the LLW glass will have different glass composition and property limits that will be defined in future work.

Significant reductions in the HLW glass canister and LLW glass-in-sulfur vault counts were achieved when the P_2O_5 high constraint limit was relaxed in the glass optimization calculations. With these aggressive pretreatment strategies it is clear that more glass property data and glass melting data in HLW and LLW waste composition ranges could possibly allow relaxing current composition constraints. If such limits were relaxed, higher waste oxide loadings in the glass could be achieved (and hence, reduced glass canister and vault counts, reduced costs, etc.) and other pretreatment process choices would be seen. Indeed, the critical component constraints have not been explored as a function of the mass fraction of major glass components, such as SiO_2 or Na_2O , and, therefore, should be taken as current estimates and not as scientifically established values that cannot be challenged if they represent severe constraints on the rest of a tank waste remediation system. Therefore, there should be additional focus on HLW and LLW immobilization activities with emphasis on currently constraining limits, such as P_2O_5 , Na_2O , etc.

The majority of LLW glass mass inventory (kilograms) is due primarily to the large amount of Na_2O in the LLW oxide streams. Indeed, Na_2O constitutes 74, 85, and 89% of the LLW oxide stream for the CLEAN Option, TRUEX-C, and Sludge Wash C process strategies, respectively. Removing this sodium would substantially reduce the LLW glass mass inventory. One alternative for reducing Na_2O in the LLW streams is a "Clean" Salt process (or Fractional Crystallization of $NaNO_3$) (Herting 1992), where separation and production of "Clean" sodium salts (such as $NaNO_3$) is achieved. If these "Clean" sodium salts are fed to an electrodialysis salt splitting process, $NaOH$ and HNO_3 could be produced for use in other processing. Alternatively, the "Clean" sodium salts could possibly be used in industrial applications or perhaps find disposal in lower cost drum storage instead of glass. This process will be evaluated in a later report.

The three process strategy cost estimates were based on the use of a central processing facility. Included in this report for one of the three process strategies, namely, the CLEAN Option, were cost estimates for the use of a combination of compact processing units (CPUs) for processing supernate and salt cake, along with a central facility for processing sludge. This report also considers both the primary LLW to salt grout and to glass-in-sulfur product options as part of the analyses along with their cost impact comparisons.

Costs associated with processing the primary waste stream and those associated with processing the tertiary nonprocess waste streams (i.e., wastes that did not result directly from splitting or partitioning of the main process streams) are calculated separately. In a previous report (Knutson et al. 1993) the costs associated with tertiary waste processing and disposal for the TRUEX-C and Sludge Wash C process strategies were overestimated. This report includes better estimates of the tertiary waste processing costs for each of these process strategies.

Summarizing the cost estimate results, the CLEAN Option without CPUs had total costs of \$41.2B, which were approximately 27% greater than those for the TRUEX-C process strategy (\$32.5B), approximately 13% greater than those for the Sludge Wash C process strategy (\$36.4B), and approximately 32% greater than the CLEAN Option with CPUs (\$31.1B). Cost comparison ratios for the primary LLW to grout option were comparable to those for the primary LLW to glass option stated above.

Using CPUs reduced the total CLEAN Option process strategy cost by approximately 24%. Similar cost reductions could potentially apply to the TRUEX-C and Sludge Wash C process strategies if similar CPU use is included. Comparing the primary LLW to glass option to the LLW to salt grout option shows that total primary LLW processing and disposal costs were essentially the same for both options. However, the costs associated with both the HLW and LLW glass products can vary dramatically, depending on which glass composition optimization models and associated composition constraints are used. For example, the P_2O_5 constraint was relaxed for all process strategy glass product results. If this constraint was included, cost increases of \$1.6B, \$17.5B, and \$0.085B would be seen for the TRUEX-C, Sludge Wash C, and CLEAN Option process strategies, respectively.

The tertiary waste processing costs were approximately 31, 27, 16, and 30% of the total costs for the CLEAN Option without CPUs, TRUEX-C, Sludge Wash C, and CLEAN Option with CPUs process strategies, respectively. These percentages essentially apply to either the primary LLW to grout or glass product options. The ratios of tertiary to primary costs were approximately 45, 37, 19, and 44% for these same process strategies, respectively.

Note that all process strategy costs assume that a 0% heel (i.e., the unretrieved waste) was left in the waste tanks. Generally, if a 5% heel was assumed, the process strategy costs would be reduced by approximately 5 to 6% because of the reduced process stream flows (Knutson et al. 1993).

For the primary LLW glass product option, the CLEAN Option process strategy without CPUs had primary waste processing costs approximately 20% greater than those for the TRUEX-C process strategy, approximately 7% less than those for Sludge Wash C, and approximately 31% greater than those for the CLEAN Option with CPUs. However, the tertiary waste process costs for the CLEAN Option without CPUs were approximately 45% greater than those for the TRUEX-C process strategy, approximately 117% greater than those for the Sludge Wash C process strategy, and approximately 35% greater than for the CLEAN Option with CPUs.

To further show the basis of the cost differences between the process strategies the costs were combined into major process categories. The costs associated with tank waste retrieval and liquid waste partitioning are substantial (approximately \$8.1B) and are assumed to be the same for each process strategy. Costs associated with waste tank immobilization were estimated to be \$0.43B, again, assumed to be the same for each process strategy. Again, the primary LLW treatment and disposal costs for the salt grout and glass-in-sulfur product options were essentially the same.

The costs for separation of solids and liquids along with solids dissolution for the CLEAN Option process strategy without CPUs required approximately 1.3 and \$0.99B more than the TRUEX-C and Sludge Wash C process strategies, respectively. The costs for nuclide removal from alkaline liquids for the CLEAN Option process strategy without CPUs required approximately 1.0 and \$1.2B more than the TRUEX-C and Sludge Wash C process strategies, respectively. The costs for nuclide removal from acidic liquids for the CLEAN Option process strategy without CPUs required approximately 2.6 and \$4.2B more than the TRUEX-C and Sludge Wash C process strategies, respectively. The costs for removal and purification of bulk chemicals for the CLEAN Option process strategy without CPUs required approximately \$4.2B more than the TRUEX-C and Sludge Wash C process strategies.

Combining the above four processing categories, the CLEAN Option process strategy without CPUs required approximately 9.1, 10.6, and \$6.7B more than the TRUEX-C, Sludge Wash C, and CLEAN Option with CPUs process strategies, respectively. The trade-off for these higher processing costs for the CLEAN Option process strategy is seen in the reduced HLW and LLW processing and disposal costs as compared to the TRUEX-C and Sludge Wash C process strategies. When the HLW and LLW processing and disposal costs are included with the four processing categories, the CLEAN Option process strategy without CPUs required approximately 4.6 and \$6.7B more than the TRUEX-C and CLEAN Option with CPUs process strategies, respectively, but \$2.4B less than the Sludge Wash C process strategy for the primary LLW to glass option.

However, the increased processing in the CLEAN Option process strategy generated more tertiary waste than the other process strategies. Thus, the tertiary waste treatment and disposal costs for the CLEAN Option process strategy without CPUs required approximately 4.0, 6.9, and \$3.3B more than the TRUEX-C, Sludge Wash C, and CLEAN Option with CPUs process strategies, respectively. Consequently, reductions in the HLW and LLW treatment and disposal costs for the CLEAN Option process strategy compared to the other process strategies were offset by the increased cost of tertiary waste treatment and disposal.

In summary, the cost savings associated with CPU use was significant and should be incorporated into any process strategy. The large tertiary waste costs could be decreased significantly if process design is also focused on reducing the amount of tertiary waste produced. More glass composition constraint evaluation and experimentation on key waste oxide stream components could allow relaxing the current constraints, resulting in significantly reduced HLW glass canister and LLW glass vault counts (i.e., higher waste oxide loadings in glass) and their associated costs. The trade-off for the higher processing costs for the CLEAN Option process strategy without CPUs is seen in the reduced HLW and LLW processing and disposal costs as compared to the TRUEX-C and Sludge Wash C process strategies. However, the increased processing in the CLEAN Option process strategy generated more tertiary waste and higher associated treatment and disposal costs, offsetting the reductions in the HLW and LLW treatment and disposal costs.

The toxicity of the primary LLW stream is significantly affected by complexation in alkaline supernatant, especially after the organic destruction step. Therefore, greater understanding of this complexation is needed to assure successful process definition and development.

The relative long-term offsite health hazard estimates suggest that this health hazard is comparable for all of the process strategies. The greatest long- and short-term onsite health hazard (controlled by excavation rather than by a drilling scenario) would be in the HLW glass product if the environment were not protected from it by geologic and geochemical barriers in and around the repository. The CLEAN Option long- and short-term onsite health hazards were more than an order of magnitude greater for the HLW glass product than the TRUEX-C and Sludge Wash C process strategies because of the greater HLW concentration. However, it is highly unlikely that any excavation would uncover a deep repository. The drilling scenario with different controlling components would probably produce more short-term hazard from the repository than the excavation scenario during the first 500 years.

Excluding the HLW glass product, the tank heel (i.e., the unretrieved tank waste) stream dominates both long- and short-term onsite health hazards. Otherwise, the only significant variations in the long- and short-term onsite health hazards between the pretreatment process strategies occurs for the primary LLW grout product and the uranium product. Assuming that the uranium product does not remain onsite but is added to the U.S. national stockpile, only the primary LLW grout product health hazards are compared. For the primary LLW grout product long-term onsite health hazard, the TRUEX-C process strategy was a factor of approximately 5 and 7 higher than for the CLEAN Option and Sludge Wash C process strategies, respectively. For the primary LLW grout product short-term onsite health hazard, the CLEAN Option process strategy was more than an order of magnitude lower than for the TRUEX-C and Sludge Wash C process strategies, respectively. While no estimate of the primary LLW glass product onsite health hazard is included, it is expected to be lower than that resulting from primary LLW grout because the glass represents a more stable waste form than grout.

Considering occupational exposure, the assumed plant designs for the CLEAN Option flowsheets result in about 3 and 24% more occupational gamma exposure, a factor of 2.3 and 12.1 more occupational alpha exposure, and a factor of 2.2 and 19.2 more occupational beta exposure, than the TRUEX-C and Sludge Wash C plant designs, respectively. These larger health hazards for the CLEAN Option result from its greater processing requirements.

Generally, more efficient removal of major exposure-causing components in the first process elements to contact the tank waste would lower the occupational exposure in all process strategies. For example, the CLEAN Option process strategy has alkaline-side cesium removal before strontium and technetium removal, thereby reducing gamma exposure in these subsequent removal operations. However, cesium removal follows after other removal operations in the acid-side processing. If the acid-side cesium removal could also be placed before the other acid-side removal operations, it would reduce the gamma exposure in those subsequent removal operations.

Considering waste product classification, the tank waste feedstreams, the HLW glass stream destined for a HLW repository, and the tank heel stream are classified as Greater than Class C (GTCC). The primary LLW grout streams are LLW Class A for the CLEAN Option process strategy, while the TRUEX-C and Sludge Wash C process strategies were LLW Class B because of the strontium limits. Using uranium LLW classification limits proposed by Kocher and Croff (Kocher and Croff 1988), the uranium product stream was also GTCC for the CLEAN and Sludge Wash C process strategies, while the TRUEX-C process strategy uranium stream was LLW Class C. Higher decontamination factors (DFs) may be needed for the atmospheric release of the vitrification offgas where different limits apply than for solid LLW.

Finally, an assessment of the technical risk associated with each process strategy was made by developing a technical risk estimation method based on tabulated data on alternative process technology development levels and extents (Sutherland et al. 1993). These process development data were tabulated using the following categories:

- Maturity of particular process technologies--extent and scale of testing with simple or realistic simulants (e.g., laboratory, bench, pilot-plant, full-scale, operating full-scale facility)
- Potential benefit of particular process technologies--activity level and timeliness of testing and development
- Current U.S. Department of Energy (DOE) funding level of particular process technologies--extent of funding and the associated advance of maturity.

To allow an assessment of the technical risk associated with each of the process strategies, weighting factors were assigned to the above process technology development levels and extents in each category. Using these weights, numerical estimates of technical risk factor indexes were calculated for particular process technologies in each development category. These process technology technical risk factor indexes were combined for processes in each process strategy to assess the technical risk of each strategy.

Summarizing the technical risk assessment results, the DOE current level of effort contributes considerably to the technical risk of many process technologies, representing the slow advance of the process maturity. These processes (e.g., solids dissolution, SREX, NaOH/HNO₃ recycle, technetium ion exchange [TCIX], and uranium separation associated with the TRUEX process) may require renewed or increased levels of effort to provide successful application of a tank waste pretreatment process strategy. The CLEAN Option process strategy without CPUs had a total combined category technical risk index that was a factor of approximately 2 and 10 times higher than the TRUEX-C and Sludge Wash C process strategies, respectively. The process average combined category technical risk index for the CLEAN Option process strategy without CPUs was nearly the same as the TRUEX-C process strategy and a factor of approximately 3 higher than for the Sludge Wash C process strategy. The CLEAN Option using the new and developing CPU concept should be considered to have more technical risk than the CLEAN Option based only on a central processing facility concept.

1.1 BACKGROUND

This report describes work done in accordance with the fiscal year 1993/1994 milestone to provide an evaluation of the CLEAN Option processing strategy, for the combined tasks "Technology Evaluation and Process Definition--Unit Process Level" (RL332008) and "Technology Evaluation and Process Definition--Global Level" (RL411205). The objectives of the combined tasks are as follows:

- Determine and compare incentives for including pretreatment technologies in an integrated tank waste remediation system
- Determine the incentive in terms of the overall cost and operating schedule of the integrated system
- Consider the costs of retrieval and disposal
- Link technologies into an integrated system by modeling process flowsheet mass balances in a common modeling format.

Work done in the combined tasks is first reviewed with developers of the technologies being evaluated and second with a peer review group defined by Efficient Separations and Process Integrated Program (ESPIP) management. The results are provided to the ESPIP to help direct the program and communicate the benefits of the program to those who will use the separations technologies that are developed.

1.2 PRIOR STUDY

A prior study of pretreatment options conducted by EM-30 was issued by the Westinghouse Hanford Company (WHC) as the *Tank Waste Technical Options Report* (Boomer et al. 1993). That report included a number of options, each defined in terms of a set of separations technologies integrated into a pretreatment system. The "SLUDGE WASH-C," "TRUEX-A" (later named Solvent Extraction Option [SOLEX] A or SOLEX-A), "TRUEX-C" (later named SOLEX-C), and "CLEAN" options of that report have been considered in this task and are described below.

The so-called TRUEX or SOLEX options include the TRUEX technology as part of a subsystem used to separate radionuclides from dissolved solids. It is important to understand that the designation "TRUEX" for a process strategy involving many steps and processes does not imply that all consequences of the strategy result from inclusion of the TRUEX process per se, as is discussed further below.

In a previous letter report, *Advanced Chemical Separations Study: TRUEX-A Versus Sludge Wash C* (Knutson et al. 1992), the consequences of including solvent extraction (SE) and other separation technologies to separate cesium, technetium, TRUs, etc., from solids and supernatant in Hanford waste tanks were described. Two pretreatment system options, one including sludge dissolution ("TRUEX-A") and one for which solids are not treated other than by water washing ("SLUDGE WASH-C"), which had been proposed as part of the Technical Options Report, were assumed for our previous report.

The predicted benefits of including the TRUEX technology depend on other technologies included in the flow sheet and on how they were integrated into the pretreatment system and on assumptions made about the performance of the TRUEX technology.

An alternate pretreatment option, "TRUEX-C," which includes complexant destruction, was a better choice for comparison to the "SLUDGE WASH-C" option, because both include complexant destruction and TCIX. This option and the SLUDGE WASH-C option were compared and the evaluation results were described in a letter report *Advanced Chemical Separations Study: TRUEX Strategy Compared To Sludge Wash Ion Exchange* (Knutson et al. 1993). This report included the development of an expanded set of performance measures to use in the comparison calculations, including unit process cost formulations, HLW glass composition optimization, revised tertiary waste estimate formulations, and several short- and long-term relative health risk indexes.

This report compares the "CLEAN" option processing strategy to the "TRUEX-C" and "SLUDGE WASH-C" processing strategies. A summary of these process strategies is given briefly below with more detailed discussion given in Appendix B.

1.3 WASTE MINIMIZATION PHILOSOPHY

In pretreatment approaches designed to greatly minimize the volume of HLW glass, the sludge portion of the waste must be dissolved so that the radionuclide components (e.g., TRUs and ⁹⁰Sr) can be separated from the inert components (e.g., iron, chromium, aluminum, and bismuth). The separations processes then give two acidic streams: (1) the radionuclides stream that is routed to HLW vitrification and (2) the inert component stream that is routed to LLW.

In the TRUEX-C and CLEAN Option flowsheets, it was assumed that both of these acidic streams were neutralized with sodium hydroxide: the radionuclide stream for interim storage in carbon steel tanks before vitrification and the inert component stream in preparation for salt grouting or vitrification. These neutralizations form sodium nitrate, which may lead to increased volumes of both the HLW and LLW forms. However, these volume increases result from the assumed course of action and are not a necessary consequence of treating the dissolved sludge solutions. An alternate approach of providing direct calcination of the HLW acidic waste stream was evaluated in the previous report (Knutson et al. 1993).

The CLEAN Option processing strategy focuses on achieving a high degree of dissolution of the sludge solids with further acid-stream and alkaline-stream separation of key elements having large contributions to HLW glass to reduce the glass canister counts below a specified goal (1,000 canisters). Another goal is to produce a LLW stream that can be classified as NRC Class A.

Figure 1-1. Process Strategy Flowsheet Comparison.

2.0 TECHNICAL ISSUES

2.1 WASTE STREAM

The contents of the waste tanks are known only approximately. The assumed composition of the waste stream to be treated can affect conclusions drawn about the relative worth of different pretreatment options. The Hanford tank waste stream radioactive and mass inventories assumed for this report were based on a review of available data as discussed in Appendix J. These tank waste streams are defined as though all waste (sludge, supernatant, and salt cake) from all tanks (single- and double-shell) were blended together and processed in a single campaign. This assumption allows the effects of pretreatment options and the various included technologies to be evaluated without forcing discussions about the large number of permutations among retrieval and blending options. Also, it is consistent with assuming that pretreatment will be done in a single, central processing facility. As EM-30 focuses on other specific approaches, such as retrieval and pretreatment of a portion of the waste in a tank or from some subset of the tanks, those approaches can be incorporated in the global systems model to evaluate separations technology in the particular context of each approach. Indeed, the CLEAN Option processing strategy considers the use of a combination of CPUs for processing tank supernate and salt cake and a central facility for processing tank sludge. Cost savings resulting from this approach are discussed in this report.

2.2 SOLID-LIQUID SEPARATION

In the sludge wash and SE models for solid/liquid separation (SLS) that had been assumed so far in work done as part of Hanford EM-30 activities (Boomer et al. 1993), a centrifugation step is included to provide a gross solid-liquid separation before filtration. A subsequent filtration step is currently modeled as a perfect solid-liquid separation. Although a perfect separation is not possible, we retained this model because it is simple. If a process were constructed that provided a very efficient separation of strontium from dissolved sludge, then most of the strontium passing to the LLW form could be the result of an imperfect SLS failing to prevent strontium-laden solids from escaping into the alkaline liquid stream. Whenever efficient separation of strontium from dissolved sludge is proposed, the actual performance of solid-liquid separation steps will need to be considered.

The CLEAN Option flowsheet employs centrifuges for SLS in six different portions of the flowsheet: initial treatment of feed from waste tank retrieval, after the Organic Destruction processing, after caustic dissolution, after both acid dissolution steps, and after the chromium reduction step before caustic production and recycling. Each of these centrifuge operations and downstream filters is assumed to achieve 0% solid in clarified supernate. Appendix B includes more detailed discussion regarding the SLS model assumptions.

2.3 SOLIDS DISSOLUTION

The components present in undissolved solids can define a substantial fraction of the glass volume when advanced separations are used to treat the dissolved waste. Therefore, the actual solids phases in the sludge and their behavior during acid dissolution need to be understood to better determine the benefit of integrating an advanced separations technology into a pretreatment system. For example, the solids currently assumed to appear in a blended Hanford waste tank stream include an aluminosilicate mineral, termed "cancrinite," with the nominal composition $2\text{NaAlSiO}_4 \cdot 0.52\text{NaNO}_3 \cdot 0.68\text{H}_2\text{O}$. For our current TRUEX model, this species is assumed to be insoluble in the sludge dissolution step, and, consequently, all of this material is routed directly to the HLW form. Similarly, the fate of sodium titanate, which is added as part of a sorption step and which is routed to the sludge dissolution step in the TRUEX and Sludge Wash C models, is not known, and it is assumed to be insoluble. These assumptions are discussed further below. Such assumed behavior during sludge dissolution leads to a prediction that part of the waste feed will be sent to the HLW form irrespective of subsequent processing steps, such as TRUEX SOLEX.

The CLEAN Option flowsheet contains three dissolution steps along with undissolved sludge recycle to minimize the amount of sludge routed to HLW. Caustic leaching, the first operation in the dissolution cycle, is critical for solubilizing cancrinite (50% is assumed to dissolve with each pass) and nickel ferrocyanide ($\text{Ni}_2\text{Fe}(\text{CN})_6$) (90% is assumed to dissolve with each pass).

One CLEAN Option dissolution cycle involves sequential sludge processing through the following steps: (1) caustic leach, (2) nitric acid/oxalic acid dissolution, and (3) nitric acid/hydrofluoric acid dissolution, where SLS occurs after each of these steps. Solids remaining after the third step are returned to the caustic leach step as part of a 9-cycle batch processing scheme that achieves approximately 96% dissolution of cancrinite. Appendix B includes more detailed discussion regarding the solids dissolution model assumptions.

2.4 HIGH- AND LOW-LEVEL WASTE FORM MINIMIZATION

A facility, such as the HWVP, will mix waste with glass formers whose composition is selected based on the composition of the waste to be vitrified. In this context it is assumed that large volumes of waste of nearly constant composition will be processed in a series of campaigns. An appropriate glass former composition will be selected to maximize the waste loading in the resulting glass; substantially different waste loadings can result. The three general types of constraints on waste loading are: (1) constraints on the properties of the homogeneous glass when in the melter (e.g., viscosity) or on the properties of the glass after cooling (e.g., durability); (2) constraints on heat loading (or possibly radiation levels); and (3) constraints on the solubility in molten glass of species, such as SO_3 , Cr_2O_3 , and noble metal oxides that can render the molten glass inhomogeneous, or constraints on the loading of species, such as P_2O_5 that can inhibit the vitrification rate in some melter designs.

Allowable mass fractions in glass of certain critical components have been estimated for the HWVP project as follows: $\text{Cr}_2\text{O}_3 < 0.005$; $\text{F}^- < 0.017$; $\text{P}_2\text{O}_5 < 0.01$; $\text{SO}_3 < 0.05$; Rh_2O_3 , PdO , and $\text{Ru}_2\text{O}_3 < 0.025$. Of these, the constraint on phosphate is probably the most disadvantageous, because phosphate is abundant in the waste. The critical component constraints have not been explored as a function of the mass fraction of major glass components, such as SiO_2 or Na_2O , and, therefore, should be taken as current estimates and not as scientifically established values that cannot be challenged if they represent severe constraints on the rest of a tank waste remediation system.

The current glass optimization models used in this report are based on analyses and experimental data relative to the anticipated HLW stream compositions as described in Appendix G. Recent TPA changes have also designated glass as the final waste product form for the LLW stream. The LLW glass is expected to be stored as gravel-sized glass chunks (cullet) within a sulfur cement matrix in underground vaults. However, no extensive analyses or experimental glass formulation data relative to expected LLW stream compositions are available. Therefore, this report uses the HLW glass composition specifications and associated optimization models for the LLW glass streams also. It is expected that the LLW glass will have different glass composition and property limits that will be defined in future work.

The majority of LLW glass mass inventory (kilograms) is due primarily to the large amount of Na_2O in the LLW oxide streams. Indeed, Na_2O constitutes 74, 85, and 89 wt% of the LLW oxide stream for the CLEAN Option, TRUEX-C, and Sludge Wash C process strategies, respectively. Removing this sodium would substantially reduce the LLW glass mass inventory. One alternative for reducing Na_2O in the LLW streams is a "Clean" Salt process (or Fractional Crystallization of NaNO_3) (Herting 1992), where separation and production of "Clean" sodium salts (such as NaNO_3), is achieved. If these "Clean" sodium salts are fed to an electrodialysis salt splitting process, NaOH and HNO_3 could be produced for use in other processing. Alternatively, the "Clean" sodium salts could possibly be used in industrial applications or perhaps find disposal in lower cost drum storage instead of glass. This process will be evaluated in a later report.

2.5 GENERATION OF SECONDARY AND TERTIARY WASTE

Whenever separation processes are added to any given separations scheme, further addition of process chemicals and associated generation of waste will occur. We use the term "secondary waste" to describe waste resulting directly from the routing of process chemicals to an effluent stream, to distinguish it from "primary waste," which is the waste retrieved from HLW tanks. Secondary waste can be minimized by recycle and careful selection and integration of the separation processes. The predicted generation of secondary waste is computed as part of the mass balance model approach reported here.

We use the term "tertiary waste" to describe various nonprocess waste streams or wastes that did not result directly from splitting or partitioning of the main process streams (described in Appendix E). This waste includes trash and incidental capture of liquid and solid emissions. For example, included as noncombustible materials (e.g., glass, metal, and soil) are items,

such as contaminated or irradiated equipment, waste and spill site soil, silver-coated packing material, smoke detectors, and basin sediment sources (e.g., ^{57}Co , ^{137}Cs , ^{239}Pu , ^{235}U). Included as combustible materials (e.g., absorbents, cellulose, plastic, rubber, liquids) are items such as toxic cleanup material, laboratory waste, filter cartridges, deionizer resins, contaminated clothing, lubricants, solvent waste. Included as aqueous wastes are items such as scintillation solution, high- and low-activity waste, decontamination solutions. Because data for cell air and offgas rates were not available, the volume of filters (e.g., high-efficiency particulate air filters and in-tank precipitation filters) resulting from offgas treatment was substituted.

The generation of tertiary waste is estimated and included in the mass balances. However, these estimates are necessarily rough, being based on the generation of similar wastes during operation of large chemical plants at Savannah River, Hanford, and other DOE sites as described in Appendix E. The estimates are probably conservative relative to operation of future facilities, assuming waste minimization will be a design and operating objective. The mass balances also include estimates of the chemical adds for tertiary waste treatment.

3.0 PROCESS DESCRIPTION AND IMPORTANT ASSUMPTIONS

3.1 WASTE STREAM

The masses, concentrations, and compositions of certain process streams are described in Appendix B. The component names have been adopted from the Technical Options Report and often do not describe the expected chemical form of the elements or compounds. For example, silicon will exist as SiO_2 or silicate minerals in the solid phase or as the silicate anion or silicic acid in solution but is described in the data set as "Si+4," which does not exist in the materials dealt with during tank waste processing. Similarly, "TOC" represents total organic carbon and is arbitrarily assigned a molecular weight equal to the atomic weight of carbon. Such component names describe the occurrence of an element where often the actual chemical and physical form are unknown. All that is required to perform the calculations supporting this report is to maintain a mass balance, which is often achieved by using "stand in" component formulae, such as "Si+4" and "TOC."

Table B1 of Appendix B lists the thirty most abundant species, by mass, of the species defined for the waste feed streams representing the Hanford single- and double-shell tanks (SSTs and DSTs), respectively. The waste is primarily a NaNO_3 - NaOH - NaNO_2 - Na_3PO_4 - Na_2CO_3 - Na_2SO_4 mixture with substantial aluminum in both the supernatant (presumably as the aluminate anion) and precipitated (presumably as an aluminum hydroxide or an aluminosilicate). In the supernatant, sodium is the dominant cation by far, with a mole concentration more than 50 times greater than the next most abundant cation, potassium. The assumed solid phase includes primarily the sodium aluminosilicate "cancrinite," nickel ferrocyanide, and an aluminum-uranium-zirconium-sodium-iron-caesium cation mixture balanced by the principal anions phosphate, hydroxide, nitrate, and carbonate.

3.1.1 Supernatant

Table B2 of Appendix B describes important characteristics and assumptions pertaining to the supernatant. This stream is assumed to be subjected to supercritical water oxidation (SCWO) to destroy most of the organic complexants that are assumed to hold some otherwise insoluble species in solution. The SCWO step is assumed to destroy 99% of the complexant and to, thereby, cause 99% of certain species in the supernatant to precipitate to form corresponding solid species. Those species assumed to be affected are apparent in Table B2. Some aluminum is also assumed to be precipitated (assumed 30%).

Because it is assumed that 1% of complexants are not destroyed by SCWO, it would be consistent to propose that the remaining species of precipitated elements are in a complexed form and possibly not available for chemical separations, depending on the power of the separating agent. This calls into question the efficacy of the sodium titanate sorption step in the TRUEX-C and Sludge Wash C processing strategies.

3.1.2 Sludge

Tables B3 and B13 of Appendix B describe characteristics and assumptions pertaining to the solid portion of the waste stream (sludge), including acid dissolution of the solids for the CLEAN Option and TRUEX-C process strategies, respectively. The assumed solids in the waste feed are essentially an aluminum-sodium-iron-zirconium-uranium mixture of hydroxides, phosphates, carbonates, and nitrates.

The CLEAN Option process strategy uses three dissolution steps along with undissolved sludge recycle to minimize the amount of sludge routed to HLW. One dissolution cycle involves sequential sludge processing involving caustic leach, nitric acid/oxalic acid dissolution, and nitric acid/hydrofluoric acid dissolution, where SLS occurs after each of these steps. Table B3 shows the extents of dissolution assumed by component for each dissolution process. Note that the caustic leach step is assumed to significantly solubilize cancrinite (50% dissolution with each pass) and nickel ferrocyanide ($\text{Ni}_2\text{Fe}(\text{CN})_6$) (90% dissolution with each pass).

In the CLEAN Option ASPEN PLUS¹ model, 95% of the undissolved solids from the second acid dissolution step are returned for caustic leaching to begin another dissolution cycle, with the remaining 5% solids diverted to HLW treatment. Recycling 95% of the undissolved solids is necessary to achieve the same total dissolution of cancrinite (96%) as is attained in the proposed 9-cycle batch processing scheme, which cannot be modeled in ASPEN PLUS. Although recycling 95% of the undissolved solids slightly overpredicts (relative to the 9-cycle batch scheme) the amount of solid components that accompany cancrinite to HLW treatment, the impact of this overprediction on total HLW volume is not significant because cancrinite is the dominant constituent of the undissolved solids.

For the TRUEX-C process strategy the fraction of these solids assumed to dissolve is adopted from the Technical Options Report (Boomer et al. 1993) and is shown in Table B13 as taken from the draft letter report (Knutson et al. 1993). Even though a slightly different feedstream was used in the previous report the results shown in Table B13 are still indicative of the dissolution performance in the TRUEX-C process strategy. None of the cancrinite ("CANCR") or nickel ferrocyanide ($\text{Ni}_2\text{Fe}(\text{CN})_6$) is assumed to dissolve. The fraction assumed to be dissolved for all other species is close to 90% and could, as well, be taken as exactly 90% for the purposes of this report. The undissolved solids that would result are relatively enhanced in cancrinite and nickel ferrocyanide because of the assumed dissolution characteristics, as shown in the last columns in Table B13. The actual undissolved solids also contain contributions from process recycle streams; in particular, sodium titanate is routed from alkaline stream processing and is assumed, for the purpose of this study, not to dissolve in the acid dissolution step.

¹ASPEN PLUS is a trademark of Aspen Technology, Inc.

3.2 HIGH- AND LOW-LEVEL WASTE STREAMS

All three of the process strategies produce waste fractions that are assumed to be recombined into HLW and LLW mixtures. Only the CLEAN Option and TRUEX-C process strategies produce a purified uranium stream for shipment to national stockpiles. Also, any bulk chemical recovery is used mostly for recycle within the process flowsheet. The following discussion considers the HLW and LLW streams and their composition related to the objectives of each process strategy. An alternative to mixing the waste fractions is considered following that discussion.

Tables 3-1 and 3-2 provide the HLW oxide stream content and radionuclide fraction reporting to LLW for each of the process strategies, respectively. Figures 3-1 and 3-2 show this same data. Note that the CLEAN Option process strategy has a concentrated HLW oxide stream that is high in strontium, aluminum, silicon, sodium, barium, and thorium oxides. The TRUEX-C process strategy has a HLW oxide stream dominated by aluminum, silicon, sodium, iron, uranium, nickel, cerium, and phosphorus. The Sludge Wash C process strategy has a HLW oxide stream dominated by aluminum, silicon, sodium, iron, uranium, zirconium, and phosphorus. If the phosphorus upper constraint limit of 1 wt% for the HLW glass composition cannot be relaxed, as assumed in these analyses, the phosphorus would have a major impact on the magnitude of the final HLW glass product for the TRUEX-C and Sludge Wash C process strategies (Section 4.3).

Considering the radionuclide fraction sent to the LLW stream, the assumed CLEAN Option process strategy was effective at reducing the ^{90}Sr reporting to LLW to a level that allows the LLW to achieve an NRC Class A classification. The amount of LLW ^{90}Sr assumed in the other process strategies only allowed them to attain an NRC Class B classification. The other major radionuclides that required significant removal to meet NRC Class A limits were ^{137}Cs , ^{239}Pu , and ^{241}Am . Nickel-63 removal was not added to the CLEAN Option flowsheet but may be needed for processing specific tanks without sufficient blending with other waste streams.

The ^{99}Tc , ^{129}I , and ^{238}U can be prime contributors to the long-term radioactivity-related risk even at concentrations allowed by the LLW Class A limits. Thus, the CLEAN Option flowsheet included steps to reduce these radionuclide concentrations in the LLW fraction. As shown in Table 3-2 and Figure 3-2, the CLEAN Option has reduced the amount of ^{99}Tc and ^{238}U reporting to the LLW. Only the ^{238}U in the Sludge Wash C process strategy has a lower value. The separated uranium undergoes purification in the CLEAN Option and TRUEX-C process strategies so that it can be added to the existing uranium stockpiles.

The CLEAN Option flowsheet also includes separations to send the ^{232}Th and ^{151}Sm to the HLW fraction. Thorium separation is included because it is likely to occur with plutonium while the samarium separation can occur with the americium separation from the bulk chemical lanthanides.

Although not evaluated in this report, the following observations provide possible disposal alternatives to mixing separated waste fractions into HLW and LLW mixtures. If the waste fractions produced by a processing strategy, such as the CLEAN Option, are not recombined into the two HLW and LLW mixtures, a HLW repository may not be technically necessary for anything but spent fuel.

- The concentrated high radiation, high-heat ^{137}Cs fraction can be placed in underground storage sites stable enough for the ^{137}Cs to decay to LLW in 300 to 500 years or in safe surface storage if temporary uses, such as food irradiation, are attractive enough to promote temporary withdrawal from storage.
- The concentrated high-heat ^{90}Sr fraction can be stored for 300 to 500 years similarly to the ^{137}Cs but without gamma shielding, and some parts of it may still find temporary use in radioisotopic power generators.
- The thousands of tons of separated and purified uranium can be added to the nation's stockpile with little penalty (already assumed in the report).
- The vast bulk of the tank waste (mainly NaNO_3 or NaOH if denitrated) can be decontaminated from ^{137}Cs to drinking water levels of radioactivity and reintroduced as a chemical feedstock into chemical plants producing nonfood products.
- Other groundwater insoluble, long-lived radioactivities from fission products (e.g., ^{93}Zr and ^{151}Sm) and neutron activation products (e.g., ^{63}Ni) should also be acceptable to an alpha waste repository because they have little radiation field and little heat generation.
- Each of the soluble long-lived fractions (^{14}C with a 5,000-year half-life, ^{99}Tc with a 243,000-year half-life, and ^{129}I with a 16-million-year half-life) have their own peculiar disposal problems, which require further study. They are not well suited to disposal even in a HLW repository, and they will eventually return to the environment before they have decayed much. They have such low specific activities even when concentrated into small volumes that the level of danger to mankind and the environment is questionable. Transmutation, isotopic dilution, dispersal in the ocean, and even containment on the earth's moon where there can be no water or air pollution have been suggested.

If a CLEAN Option solution to the Hanford tank waste problem proves workable and the above alternatives are included in the processing strategy, its technology and disposal options could be attached to nuclear fuel reprocessing plants worldwide. This could cancel the need for HLW repositories in countries that do not choose spent fuel as their nuclear waste.

3.3 SOLVENT EXTRACTION

The CLEAN Option processing strategy makes use of three SE processes: (1) a tributyl phosphate (TBP) SE step to remove tetravalent and hexavalent actinides (pentavalent neptunium is converted to the hexavalent state for removal also), (2) a N-diisobutylcarbamoylmethylphosphine oxide (CMPO) SE process for removal of trivalent actinides (trivalent lanthanides are also removed), and (3) a crown ether (CE) SE process for removal of strontium and technetium. These SE processes are discussed briefly below and in more detail in Appendix B.

The solvent composition for the first SE process is the same, 30% TBP in hydrocarbon diluent, as is usually used in the well-known plutonium-uranium extraction process. In the first extraction contactor of this TBP cycle, uranium, plutonium, neptunium, and thorium are extracted into the TBP organic phase. The extracted plutonium, neptunium, and thorium are selectively stripped back into an aqueous phase in a second contactor (to be routed to HLW glass for disposal), and the uranium is stripped in a third contactor.

The raffinate from the first TBP cycle is routed to a CMPO SE process to remove trivalent lanthanides, americium, and bismuth. The solvent used is 0.2M CMPO + 1.4M TBP in hydrocarbon diluent, a typical solvent composition proposed for the TRUEX process. In this extraction step, the lanthanides, americium, and bismuth in the dissolved sludge solution are extracted by the solvent. The raffinate from this extraction retains essentially all the cesium, strontium, and technetium and undergoes further processing for removal of these components as described in Appendix B. Americium and trivalent actinides are stripped from the CMPO extract into dilute nitric acid in the second contactor. Bismuth is retained in the extract and is removed from the solvent in a sodium carbonate wash step with added EDTA complexant to prevent bismuth precipitation.

The raffinate from the first CMPO cycle, which contains all of the components of the dissolved sludge solution, except the actinides, the lanthanides, and the bismuth, is fed to a CE SE step in which strontium and technetium are removed.

The assumed performance of these various SE processes is described in Appendix B.

3.4 SOLVENT WASTE MINIMIZATION

Inevitably, some fraction of solvent used in extraction steps will dissolve and entrain in the aqueous phase. Aqueous streams exiting the overall extraction process (i.e., extraction, stripping, and washing) are evaporated to concentrate the streams. However, evaporation also serves to distill the solvent, which then condenses in high enough concentration to be immiscible in the condensate.

In the CLEAN Option flowsheet the TBP and CMPO solvent losses are assumed to be minimal (0.001%) because downstream evaporators recover and recycle any solvent carried away in the aqueous outlet streams of the extraction, stripping, and solvent wash steps.

In the assumed TRUEX-C flowsheet, adopted from the Technical Options Report (Boomer et al. 1993), the solvent is separated by decanting and then recycled to the extraction process to minimize the generation of tertiary waste.

3.5 SODIUM HYDROXIDE AND NITRIC ACID RECYCLE

A major feature of the CLEAN Option process strategy is the recycle of process chemicals (especially sodium hydroxide) to minimize the "growth" of waste during processing. The CLEAN Option flowsheet includes a calcination process, based on work under way in EM-55's Underground Storage Tank Integrated Demonstration, primarily as a means of destroying nitrates, nitrites, and organic complexants so that the LLW waste form will be less toxic and will have greater stability. Calcination also allows the recovery of sodium hydroxide. Sodium hydroxide results from the calcination step because of the presence of sodium in the waste being treated; and, consequently, when the calcine product is redissolved, it is alkaline and suitable for tank storage if desired. All of the sodium hydroxide will ultimately be disposed of in the LLW disposal form, but, during process operations, a portion can be reused.

Because the tank wastes contain large quantities of sodium and recycled sodium hydroxide is used to neutralize excess acids, recycling of nitric acid is not needed to minimize the increase in LLW disposal volume. However, the CLEAN Option flowsheet also includes nitric acid recovery primarily to minimize the release of nitrate destruction products to the atmosphere, to decrease the processing load on calcination and NO_x destruction operations, and to provide flowsheet flexibility for other low-sodium waste streams. The bulk of the nitric acid recovery occurs from recovery of the NO and NO_x that are evolved when the concentrated acidic LLW and HLW waste solutions are denitrated by reaction with sucrose. Other nitric acid recovery occurs during evaporation steps.

The TRUEX-C process strategy assumes that nitric acid added to dissolve solids and to keep various species in solution during separation steps is destroyed rather than neutralized by the addition of sodium hydroxide. The impact of adding a HLW calcination step to avoid sodium hydroxide addition for neutralizing acidic HLW was evaluated in the previous report (Knutson et al. 1993).

Figure 3-1. High-Level Waste Oxide Stream Content for Flowsheet Options.

Figure 3-2. Radionuclide Fraction to Low-Level Waste.

Table 3-1. High-Level Waste Oxide Stream Content for Flowsheet Options.

Oxide	CLEAN (wt%)	TRUEX (wt%)	Sludge Wash C (wt%)
SRO	23.28	1.04	0.32
AL2O3	16.61	25.72	32.08
SiO2	15.68	18.24	6.03
NA2O	13.35	22.43	10.47
BAO	13.35	0.82	3.21
THO2	6.50	0.29	0.09
ZNO	1.83	0.01	0.02
TC2O7	1.53	0.07	0.02
FE2O3	1.48	4.32	6.68
U3O8	1.23	4.72	9.71
ZRO2	1.13	1.18	4.25
CS2O	0.83	0.04	0.01
NI2O3	0.58	4.76	1.52
HF	0.58	0.08	0.35
BI2O3	0.44	1.73	1.66
CR2O3	0.30	0.52	1.53
MNO2	0.23	0.37	1.09
CE2O3	0.19	5.17	1.58
PBO2	0.12	1.93	2.89
P2O5	0.06	4.67	14.19
LA2O3	0.05	0.85	0.26
CAO	0.05	0.39	1.17
TiO2	0.00	0.38	0.12
Total	99.41	99.74	99.25

TRUEX = transuranic extraction.

Table 3-2. Radionuclide Fraction to Low-Level Waste.

Radionuclide	CLEAN (% to LLW)	TRUEX (% to LLW)	Sludge Wash C (% to LLW)
²⁴¹ Am	0.16	0.92	0.11
¹³⁷ Cs	0.02	1.29	1.38
⁶³ Ni	100.00	86.29	0.10
²³⁷ Np	1.10	0.94	0.09
²³⁹ Pu	0.10	0.95	0.07
¹⁵¹ Sm	0.13	0.97	0.06
⁹⁰ Sr	0.01	0.95	0.06
⁹⁹ Tc	0.56	0.97	0.68
²³⁸ U	0.20	0.60	0.11
⁹³ Zr	2.35	91.74	2.40

LLW = low-level waste.

TRUEX = transuranic extraction.

4.0 RESULTS

The sections below present summaries of the analysis results. More detailed discussion of these results along with summary figures and tables will be found in the appropriate appendices. The ASPEN PLUS software is described in Appendix A. Appendices B, C, and D give broader descriptions of the detailed, higher, and global-level ASPEN PLUS models, respectively. Appendix E describes the tertiary nonprocess waste generation models. Appendix F describes the cost estimation models. Appendix G describes the glass composition optimization models. Appendix H describes the global model mass balance results with summary tables showing the waste product inventories. Appendix I describes the relative health hazard estimates. Finally, Appendix J describes the tank waste radiological and mass inventory estimates.

4.1 TERTIARY WASTE GENERATION

Figure 4-1 shows the tertiary waste generation and treatment inventory for each process strategy in terms of its main components (noncombustible materials, solids treatment adds, combustible materials, aqueous wastes, evaporator and IX adds, and process offgas representing filter volume) as compared to the primary waste feedstream. This data is summarized from results described in Appendix E.

As shown in Figure 4-1, the tertiary waste flows were larger than the primary waste feedstream flow; the total tertiary to primary waste flow ratios were 4.4, 2.9, 1.8, and 3.1 for the CLEAN Option without CPUs, TRUEX-C, Sludge Wash C, and CLEAN Option with CPUs process strategies, respectively. In terms of individual processes, the cesium, strontium, and TCIX processes produced the most tertiary waste because of their high throughput and high SE cycle equivalency assignment (Appendix E).

It should be clear from the data that the tertiary waste generation is substantial and cannot be ignored when evaluating process technologies. The CLEAN Option with and without CPUs generates the largest amount of tertiary waste owing to its intensive chemical processing strategy. Indeed, the cost for processing this tertiary waste is very substantial. The large tertiary waste costs could be decreased significantly if process design is also focused on reducing the amount of tertiary waste produced.

4.2 COSTS

Table 4-1 shows the cost estimates for each processing strategy as summarized from results described in Appendix F. Appendix F discusses the development of the cost estimation models and has tables and figures summarizing the detailed capital and expense costs by process. Figure 4-2 shows some of the cost results.

As shown in Table 4-1 and Figure 4-2, using CPUs reduced the total CLEAN Option process strategy cost by approximately 24%. Thus, the cost savings associated with CPU use was significant and should be incorporated into any process strategy. Similar cost reductions could potentially apply to the TRUEX-C and Sludge Wash C process strategies if similar CPU use is included. Comparing the primary LLW to glass option to the LLW to salt grout option shows that total primary LLW processing and disposal costs were essentially the same for both options.

The costs associated with the HLW and LLW glass products can vary dramatically, depending on which glass optimization models and associated constraints are used (Appendix G). For example, the P_2O_5 constraint was relaxed for all process strategy glass product results. If this constraint was included, cost increases of \$1.6B, \$17.5B, and \$0.085B would be seen for the TRUEX-C, Sludge Wash C, and CLEAN Option process strategies, respectively. Thus, more glass composition constraint evaluation and experimentation on key waste oxide stream components could allow relaxing the current constraints, resulting in significantly reduced HLW glass canister and LLW glass vault counts (i.e., higher waste oxide loadings in glass [Appendix G]) and their associated costs.

As shown in Table 4-1 and Figure 4-2, the tertiary waste processing costs were approximately 31, 27, 16, and 30% of the total costs for the CLEAN Option without CPUs, TRUEX-C, Sludge Wash C, and CLEAN Option with CPUs process strategies, respectively. These percentages essentially apply to either the primary LLW to grout or glass product options. The ratios of tertiary to primary costs were approximately 45, 37, 19, and 44% for these same process strategies, respectively. The large tertiary waste costs could be decreased significantly if process design is also focused on reducing the amount of tertiary waste produced.

Note that all process strategy costs assume that a 0% heel was left in the waste tanks. Generally, if a 5% heel was assumed, the process strategy costs would be reduced by approximately 5 to 6% because of the reduced process stream flows (Knutson et al. 1993).

For the primary LLW glass product option, the CLEAN Option process strategy without CPUs had primary waste processing costs approximately 20% greater than those for the TRUEX-C process strategy, approximately 7% less than those for Sludge Wash C, and approximately 31% greater than those for the CLEAN Option with CPUs. However, the tertiary waste process costs for the CLEAN Option without CPUs were approximately 45% greater than those for the TRUEX-C process strategy, approximately 117% greater than those for the Sludge Wash C process strategy, and approximately 35% greater than for the CLEAN Option with CPUs.

To further show the basis of the cost differences between the process strategies, the costs were combined into major process categories. The costs associated with tank waste retrieval and liquid waste partitioning are substantial (approximately \$8.1B) and are assumed to be the same for each process strategy. Costs associated with waste tank immobilization were estimated to be \$0.43B, again, assumed to be the same for each process strategy. Again, the primary LLW treatment and disposal costs for the salt grout and glass-in-sulfur product options were essentially the same.

The costs for separation of solids and liquids along with solids dissolution for the CLEAN Option process strategy without CPUs required approximately 1.3 and \$0.99B more than the TRUEX-C and Sludge Wash C process strategies, respectively. The costs for nuclide removal from alkaline liquids for the CLEAN Option process strategy without CPUs required approximately 1.0 and \$1.2B more than the TRUEX-C and Sludge Wash C process strategies, respectively. The costs for nuclide removal from acidic liquids for the CLEAN Option process strategy without CPUs required approximately 2.6 and \$4.2B more than the TRUEX-C and Sludge Wash C process strategies, respectively. The costs for removal and purification of bulk chemicals for the CLEAN Option process strategy without CPUs required approximately \$4.2B more than the TRUEX-C and Sludge Wash C process strategies.

Combining the above four processing categories together the CLEAN Option process strategy without CPUs required approximately 9.1, 10.6, and \$6.7B more than the TRUEX-C, Sludge Wash C, and CLEAN Option with CPUs process strategies, respectively. The trade-off for these higher processing costs for the CLEAN Option process strategy is seen in the reduced HLW and LLW processing and disposal costs as compared to the TRUEX-C and Sludge Wash C process strategies. When the HLW and LLW processing and disposal costs are now included with the four processing categories, the CLEAN Option process strategy without CPUs required approximately 4.6 and \$6.7B more than the TRUEX-C and CLEAN Option with CPUs process strategies, respectively, but \$2.4B less than the Sludge Wash C process strategy for the primary LLW to glass option.

However, the increased processing in the CLEAN Option process strategy generated more tertiary waste than the other process strategies. Thus, the tertiary waste treatment and disposal costs for the CLEAN Option process strategy without CPUs required approximately 4.0, 6.9, and \$3.3B more than the TRUEX-C, Sludge Wash C, and CLEAN Option with CPUs process strategies, respectively. Consequently, reductions in the HLW and LLW treatment and disposal costs for the CLEAN Option process strategy compared to the other process strategies were offset by the increased cost of tertiary waste treatment and disposal.

In summary, the cost savings associated with CPU use was significant and should be incorporated into any process strategy. The large tertiary waste costs could be decreased significantly if process design is also focused on reducing the amount of tertiary waste produced. More glass composition constraint evaluation and experimentation on key waste oxide stream components could allow relaxing the current constraints, resulting in significantly reduced HLW glass canister and LLW glass vault counts (i.e., higher waste oxide loadings in glass) and their associated costs. The trade-off for the higher processing costs for the CLEAN Option process strategy without CPUs is seen in the reduced HLW and LLW processing and disposal costs as compared to the TRUEX-C and Sludge Wash C process strategies. However, the increased processing in the CLEAN Option process strategy generated more tertiary waste and higher associated treatment and disposal costs, offsetting the reductions in the HLW and LLW treatment and disposal costs.

4.3 GLASS COMPOSITION OPTIMIZATION

The current glass optimization models are based on analyses and experimental glass formulation data relative to expected HLW stream compositions. Recent TPA changes have also designated glass as the final waste product form for the LLW stream. However, because no extensive analyses or experimental glass formulation data relative to expected LLW stream compositions are available, the HLW glass composition specifications and associated optimization models were used for the LLW glass streams also. It is expected that the LLW glass will have different glass composition and property limits that will be defined in future work.

To obtain feasible solutions when optimizing the glass composition the Fe_2O_3 lower limit of 2 wt% was removed in all HLW and LLW glass calculations. This was because the waste oxide streams resulting from processing all SST and DST wastes together (i.e., as a blended waste stream) contained Fe_2O_3 in quantities of small overall mass fraction, requiring unattainable high waste loadings to achieve the lower constraint limit. The Fe_2O_3 lower limit was originally based on maintaining sufficient Fe_2O_3 in the glass to act as a redox buffer to protect against uranium+5 reduction to uranium+4. This lower limit should be reexamined to determine if it is necessary.

The limiting constraint in most models was the P_2O_5 upper limit of 1 wt%. When this constraint was removed the HLW glass streams were limited by the Other upper limit (OTHHI) (this limit represents everything other than the nine main components considered in the Composition Variability Study discussed in Appendix G) of 10 wt% while the LLW glass streams were limited by the Na_2O upper limit of 20 wt%.

Relaxing the OTHHI was definitely considered to be extrapolating outside the range of applicability of the glass property models and constraints. However, relaxing the P_2O_5 upper limit was not considered to represent a large extrapolation outside the range of model applicability. Although the same reasoning could be applied to the Na_2O upper limit, only the P_2O_5 upper limit was relaxed for the process strategy comparisons. Thus, for the LLW glass compositions the limiting constraint was the Na_2O upper limit of 20 wt% and for the HLW glass compositions the limiting constraint was the OTHHI of 10 wt%.

Table 4-2 shows the HLW and LLW glass production results for each processing strategy as summarized from Tables G5 through G7 of Appendix G. Appendix G discusses the development of the glass composition optimization models and has tables and figures summarizing the glass composition calculations. Figures 4-3 and 4-4 show the HLW and LLW glass production data in terms of canisters and vaults, respectively.

The impact of the glass composition constraints on waste loading in the glass is shown in Table 4-2. Waste loadings of approximately 19 wt%, 36 wt%, and 26 wt% were achieved in the CLEAN Option, TRUEX-C, and Sludge Wash C HLW glass products, respectively, without the P_2O_5 upper limit of 1 wt% in place. The resulting P_2O_5 weight fraction in glass was 1.7 and 3.6% for the TRUEX-C and Sludge Wash C HLW glass products, respectively. However, with the P_2O_5 upper limit, the HLW waste loadings were significantly lower, approximately 21 and 7 wt% for the TRUEX-C and Sludge Wash C models, respectively. No impact

on the CLEAN Option HLW glass resulted from relaxing the P_2O_5 limit because it was not the limiting constraint. Increasing the OTHHI of 10 wt% will also have a significant impact on the HLW glass production as shown by the comparison of the CLEAN Option HLW glass stream results in Table 4-2. When the OTHHI was relaxed, the CLEAN Option HLW glass stream showed a 39% reduction of canisters (750 down to 457), with a substantial increase in waste loading from 19 to 32 wt%.

The LLW glass had waste loadings from 22 to 24 wt% with the P_2O_5 upper limit in place. When the P_2O_5 upper limit was relaxed and the Na_2O upper limit became binding, only the CLEAN Option LLW glass waste loading increased significantly from 22 to 27 wt%. Increasing the Na_2O upper limit will also have a significant impact on the LLW glass production as shown by the comparison of the Sludge Wash C LLW glass stream results with and without the Na_2O upper limit of 20 wt% relaxed, where an 8% reduction of vaults (60 down to 55) was seen. The resulting Na_2O weight fraction in glass was 21.5%. The *Tank Waste Technical Options Report* (Boomer et al. 1993) suggests that a higher Na_2O limit of 25 wt% is possible because of the ability to recycle out of specification glass cullet. It also claims that higher Na_2O limits in borosilicate glass compositions are reported in other literature. Increasing this limit will have a significant impact on the LLW glass production as shown by the comparison of the Sludge Wash C results.

Note that the CLEAN Option HLW glass canister count was dramatically lower than the other process strategies, with only approximately 5 and 1% of the TRUEX-C and Sludge Wash C process strategy glass product magnitudes with the P_2O_5 upper limit, respectively, and only approximately 8 and 2% without the P_2O_5 upper limit, respectively. Relaxing the P_2O_5 upper limit reduced the TRUEX-C and Sludge Wash C HLW canister counts by 41 and 72%, respectively, and the LLW vault counts by 18 and 0.4% for the CLEAN Option and TRUEX-C process strategies, respectively.

The CLEAN Option LLW glass-in-sulfur vault total was highest for the P_2O_5 limiting case but ranged between the TRUEX-C and Sludge Wash C results without the P_2O_5 upper limit, showing vault counts of 86 and 109% of the TRUEX-C and Sludge Wash C results, respectively. Note the large amount of glass mass inventory (kilograms) associated with the LLW glass. This is due to the large amount of Na_2O in the LLW oxide streams. Indeed Na_2O constitutes 74, 85, and 89 wt% of the LLW oxide stream for the CLEAN Option, TRUEX-C, and Sludge Wash C process strategies, respectively. Removing this sodium would dramatically reduce the LLW glass mass inventory. One alternative for reducing Na_2O in the LLW streams is a "Clean" Salt process (or Fractional Crystallization of $NaNO_3$) (Herting 1992), where separation and production of "Clean" sodium salts (e.g., $NaNO_3$) is achieved. If these "Clean" sodium salts are fed to an electrodialysis salt splitting process, NaOH and HNO_3 could be produced for use in other processing. Alternatively, the "Clean" sodium salts could possibly be used in industrial applications or perhaps find disposal in lower cost drum storage instead of glass. This process will be evaluated in a later report.

As discussed in the previous report on the evaluation of the TRUEX-C and Sludge Wash C process strategies (Knutson et al. 1993), over 90% of the HLW glass oxides in those two models come from the undissolved solids stream that

is sent to glass before TRUEX processing and eventual neutralization. Therefore, significant glass oxide reduction for those two models must come in the acid dissolution process step.

Based on previous work (Knutson et al. 1993), a 5% heel left in the tanks during retrieval would result in an approximately 5% reduction in the HLW glass canister counts (Knutson et al. 1993).

With these aggressive pretreatment strategies it is clear that more glass property data and glass melting data in HLW and LLW waste composition ranges could possibly allow relaxing current composition constraints. If such limits were relaxed, higher waste oxide loadings in the glass could be achieved (and hence, reduced glass canister and vault counts, costs, etc.) and other pretreatment process choices would be seen. Indeed, the critical component constraints have not been explored as a function of the mass fraction of major glass components (e.g., SiO_2 or Na_2O) and, therefore, should be taken as current estimates and not as scientifically established values that cannot be challenged if they represent severe constraints on the rest of a tank waste remediation system. Therefore, there should be additional focus on HLW and LLW immobilization activities with emphasis on currently constraining limits (e.g., P_2O_5 , Other, and Na_2O).

4.4 WASTE PRODUCT MASS BALANCES

Table 4-3 contains a brief summary of the waste product generation for the CLEAN Option, TRUEX-C, and Sludge Wash C process strategies extracted from Table H2 of Appendix H. Appendix H contains the process stream mass balance results for the global CLEAN Option, TRUEX-C, and Sludge Wash C process models, along with tables summarizing the waste product results. Figures 4-3 and 4-4 show the HLW and LLW glass/grout production data in terms of canisters and vaults, respectively.

As discussed previously, a large amount of tertiary waste is generated for each of the process strategies. With tertiary waste treatment, approximately 38% of the tertiary waste is destined for grout, approximately 26% of the tertiary waste is destined for water treatment, and 36% is destined for landfill burial. Note that the CLEAN Option process strategy produces a factor of 1.5 and 2.4 more tertiary waste than the TRUEX-C and Sludge Wash C process strategies, respectively, because of its more process-intensive strategy.

Using CPUs to process the supernate and salt cake reduced the CLEAN Option tertiary waste generation by approximately 29%. This reduction was estimated by processing only the sludge portion of the tank waste (i.e., approximately 36 and 4% of the SST and DST waste, respectively) through a central processing facility.

Figure 4-4 shows the LLW vault requirements for both primary and tertiary waste. Note that the primary LLW to glass option required only 30% of the vaults as the LLW salt grout option required. Also, note that the CLEAN Option tertiary LLW waste required nearly the same number of salt grout vaults as the primary LLW. Using CPUs, the CLEAN Option tertiary LLW waste required only 73% of the salt grout vaults as the primary LLW. The TRUEX-C and Sludge

Wash C process strategies had tertiary grout vault requirements that were approximately 57 and 50% of those associated with primary LLW, respectively.

Based on primary LLW to glass option production ratios the CLEAN Option process strategy produces 14% less primary LLW glass than the TRUEX-C process strategy and 9% more than the Sludge Wash C process strategy.

Based on the primary LLW to salt grout option production ratios the CLEAN Option process strategy produces 15% less primary LLW salt grout than the TRUEX-C process strategy and 19% more than the Sludge Wash C process strategy.

Based on HLW glass production ratios the CLEAN Option process strategy produces only 8 and 2% of the HLW glass than the TRUEX-C and Sludge Wash C process strategies produce, respectively.

Again, the LLW and HLW glass production results are based on the glass composition optimization results discussed in Appendix G. Relaxation of key glass component constraints can have a significant impact on the glass production results shown above.

Note that all process strategies assumed that a 0% heel was left in the waste tanks. Generally, if a 5% heel was assumed, the process strategy would decrease the HLW glass product by 4 to 5% as compared to the 0% heel case, while decreasing the LLW product by 2 to 3% (Knutson et al. 1993).

4.5 RELATIVE HEALTH HAZARD ESTIMATES

4.5.1 Long-Term Offsite Health Hazard

The comparison results show that the relative long-term health hazard for the CLEAN Option process strategy is within 1% of the health hazard for the TRUEX-C and Sludge Wash C process strategies for the 0% tank waste heel case. Based on previous analyses of the TRUEX-C and Sludge Wash C process strategies (Knutson et al. 1993), these relative health hazards will increase by a factor of approximately 2.4 if the heel percentage increases from 0 to 5%. This health hazard increase is associated with more radioactive waste products left behind in the tanks that will be immobilized in place. Thus, the data suggest that the relative long-term health hazard is comparable for all process strategies.

4.5.2 Long-Term Onsite Health Hazard

Figure 4-5 gives a graphical summary of the long- and short-term onsite health hazards normalized to the initial feedstream values as taken from data shown in Appendix I. Appendix I describes the relative health hazard estimates for the various process strategies and has tables and figures summarizing those estimates.

As shown in Figure 4-5, the greatest long-term onsite waste health hazard would be in the HLW glass product if the environment were not protected from it by formidable barriers around the repository. The uranium product has the highest Health Hazard Index (HHI) for the Sludge Wash C process because it is highly concentrated. However, it is assumed that the uranium product does not remain onsite but is added to the U.S. national stockpile. Thus, the tank heel (requiring dome fill) stream dominates the onsite health hazard. Otherwise, the primary LLW grout stream contains the only significant variation between pretreatment process strategies, where the TRUEX-C process strategy value was a factor of approximately 5 and 7 higher than for the CLEAN Option and Sludge Wash C process strategies, respectively. Note that while no estimate of the primary LLW glass HHI is included, it is expected to be lower than that resulting from primary LLW grout because the glass represents a more stable long-term waste form than grout.

The contributions of each component to the normalized long-term onsite HHI for the HLW glass (Appendix I) showed that the CLEAN Option HLW glass has substantially more contribution to the long-term onsite HHI (compared to the original total feedstream value) from plutonium, technetium, americium, thorium, neptunium, and heavy lanthanides, because of the more extensive separation processing performed for these elements. This greater processing in the CLEAN Option also produced less contribution to HLW glass from uranium, fission products (FP2), and ⁶³Ni (OTH3) compared to the other process strategies.

Overall, the CLEAN Option long-term onsite HHI was more than an order of magnitude greater for the HLW glass product than the TRUEX-C and Sludge Wash C process strategies because of the greater HLW concentration. However, it is highly unlikely that any excavation would uncover a deep repository. The drilling scenario with different controlling components would produce more health hazard from the repository than the excavation scenario.

The contributions of each component to the normalized long-term onsite HHI for primary LLW grout show that the CLEAN Option had larger contributions from the iodine, fission products (FP2), ⁶³Ni (OTH3), thorium, and neptunium than the TRUEX-C and Sludge Wash C process strategies because of the greater primary LLW concentration. However, the overall long-term onsite HHI for primary LLW grout is substantially lower when compared to the initial feedstream.

4.5.3 Short-Term Onsite And Offsite Health Hazard

Figure 4-5 gives a summary of the long- and short-term onsite health hazards normalized to the initial feedstream values as taken from data shown in Appendix I. Appendix I describes the relative health hazard estimates for the various process strategies and has tables and figures summarizing those estimates.

As shown in Figure 4-5, the greatest short-term onsite waste health hazard would be in the HLW glass stream if the environment were not protected from it by formidable barriers around the repository. Excluding the HLW glass product, the tank heel (requiring dome fill) stream dominates the short-term onsite health hazards. Otherwise, the only significant variations in the

short-term onsite health hazards between the pretreatment process strategies occurs for the primary LLW grout product stream and the uranium product stream. Assuming that the uranium product does not remain onsite but is added to the U.S. national stockpile, only the primary LLW grout product health hazards are compared. The CLEAN Option process strategy has a primary LLW grout product health hazard value that is more than an order of magnitude less than the TRUEX-C and Sludge Wash C process strategy values. Note that while no estimate of the primary LLW glass HHI is included, it is expected to be lower than that resulting from primary LLW grout because the glass represents a more stable short-term (up to 500 years) waste form than grout.

The contributions of each component to the normalized short-term onsite HHI for the HLW glass (Appendix I) showed that the CLEAN Option HLW glass has substantially more contribution to the short-term onsite HHI (compared to the original total feedstream value) from plutonium, cesium, strontium, technetium, americium, thorium, neptunium, and heavy lanthanides resulting from the more extensive separation processing performed for these elements. This greater processing in the CLEAN Option also produced less contribution to HLW glass from uranium, fission products (FP2), and ^{63}Ni (OTH3) compared to the other process strategies.

Overall, the CLEAN Option short-term onsite HHI was more than an order of magnitude greater for the HLW glass product than the TRUEX-C and Sludge Wash C process strategies because of the greater HLW concentration. However, it is highly unlikely that any excavation would uncover a deep repository in the first 500 years after closure. The drilling scenario with different controlling components would probably produce more health hazard from the repository than the excavation scenario during the first 500 years.

The contributions of each component to the normalized short-term onsite HHI for primary LLW grout show that the CLEAN Option had larger contributions from the iodine, fission products (FP2), ^{63}Ni (OTH3), thorium, and neptunium than the TRUEX-C and Sludge Wash C process strategies because of the greater primary LLW concentration. However, the CLEAN Option had substantially smaller contributions from cesium and strontium because of the more extensive separation processing performed for these elements. Overall, the short-term onsite HHI for primary LLW grout is substantially lower when compared to the initial feedstream.

4.5.4 Occupational Exposure

The previous report (Knutson et al. 1993) considered occupational exposure resulting from ^{137}Cs weighted by the feedstream and tertiary waste flows to particular processes, along with the relative alpha contamination from ^{238}U and ^{239}Pu and beta contamination from ^{90}Sr . To increase the accuracy and detail of the occupational exposure calculations more components were evaluated in this report.

Figure 4-6 gives a summary of the occupational exposure health hazard estimates as taken from data shown in Appendix I. Appendix I describes the relative health hazard estimates for the various process strategies and has tables and figures summarizing those estimates.

As shown in Figure 4-6, the plant designs for the CLEAN Option flowsheets result in about 3 and 24% more occupational gamma exposure, a factor of 2.3 and 12.1 more occupational alpha exposure, and a factor of 2.2 and 19.2 more occupational beta exposure, than the TRUEX-C and Sludge Wash C plant designs, respectively. These larger indexes for the CLEAN Option result from its greater processing requirements.

Considering the contributions of various processes in each process strategy to the occupational exposure (Appendix I), the IX processes were weighted more heavily in terms of exposure than the solid separation steps because they were assumed to have the same amount of tertiary waste as a single cycle of SE. The solid separation steps are only assumed to generate 0.25% as much tertiary waste as one SE cycle judged from equipment floor space in the Savannah River Purex F and H canyons (Appendix E).

Generally, more efficient removal of major exposure causing components in the first process elements to contact the tank waste would lower the occupational exposure in all process strategies. For example, the CLEAN Option process strategy has alkaline-side cesium removal before strontium and technetium removal, thereby reducing gamma exposure in these subsequent removal operations. However, cesium removal follows after other removal operations in the acid-side processing. If the acid-side cesium removal could also be placed before the other acid-side removal operations, it would reduce the gamma exposure in those subsequent removal operations.

4.5.5 Waste Classification and Radionuclide Concentrations

The tank waste feedstreams, the HLW glass stream destined for a HLW repository, and the tank heel stream are classified as either TRU or GTCC. The primary LLW to grout option streams are LLW Class A for the CLEAN Option process strategy, while the TRUEX-C and Sludge Wash C process strategies were LLW Class B because of the strontium limits. Higher DFs may be needed for the atmospheric release of the vitrification offgas where different limits apply than for solid LLW. Using uranium LLW classification limits proposed by Kocher and Croff (Kocher and Croff 1988), the uranium product stream was also GTCC for the CLEAN and Sludge Wash C process strategies, while the TRUEX-C process strategy uranium stream was LLW Class C.

4.6 PROCESS STRATEGY TECHNICAL RISK

Figures 4-7 and 4-8 give a summary of the process strategy technical risk estimates as taken from data shown in Appendix K. Appendix K describes the process strategy technical risk estimation method and has tables and figures summarizing those estimates.

The assessment of the technical risk associated with each process strategy was made by developing a technical risk estimation method based on

tabulated data on alternative process technology development levels and extents (Sutherland et al. 1993). These process development data were tabulated using the following categories:

- Maturity of particular process technologies--extent and scale of testing with simple or realistic simulants (e.g., laboratory, bench, pilot plant, full-scale, operating full-scale facility)
- Potential benefit of particular process technologies--activity level and timeliness of testing and development
- Current DOE funding level of particular process technologies--extent of funding and the associated advance of maturity.

To allow an assessment of the technical risk associated with each of the process strategies, weighting factors were assigned to the above process technology development levels and extents in each category. Using these weights, numerical estimates of technical risk factor indexes were calculated for particular process technologies in each development category. These process technology technical risk factor indexes were combined for processes in each process strategy to assess the technical risk of each strategy.

Summarizing the technical risk assessment results, the DOE current level of effort contributes considerably to the technical risk of many process technologies, representing the slow advance of the process maturity. These processes (e.g., solids dissolution, SREX, NaOH/HNO₃ recycle, TCIX, and uranium separation associated with the TRUEX process) may require renewed or increased levels of effort to provide successful application of a tank waste pretreatment process strategy. The CLEAN Option process strategy without CPUs had a total combined category technical risk index that was a factor of approximately 2 and 10 times higher than the TRUEX-C and Sludge Wash C process strategies, respectively. The process average combined category technical risk index for the CLEAN Option process strategy without CPUs was nearly the same as the TRUEX-C process strategy and a factor of approximately 3 higher than for the Sludge Wash C process strategy. The CLEAN Option using the new and developing CPU concept should be considered to have more technical risk than the CLEAN Option based only on a central processing facility concept.

Figure 4-1. Tertiary Waste Generation.

	NONCOM	TREAT	COMBU	AQUE	EVAP/IX	OFFGAS	TOT TERT.	TOT PRIM.
CLEAN	8.66E+8	8.86E+8	4.33E+8	1.01E+9	1.04E+8	7.12E+5	3.30E+9	7.57E+8
TRUEX-C	5.66E+8	5.80E+8	2.83E+8	6.63E+8	6.78E+7	4.66E+5	2.16E+9	7.57E+8
SLUDGE WASH C	3.56E+8	3.65E+8	1.78E+8	4.17E+8	4.26E+7	2.93E+5	1.36E+9	7.57E+8
CLEAN W/ CPUs	6.15E+8	6.29E+8	3.07E+8	7.19E+8	7.36E+7	5.05E+5	2.34E+9	7.57E+8

Figure 4-2. Cost Summary for Primary and Tertiary Waste Processing
(amounts given in \$ Million).

PRIMARY LLW TO GROUT	PRIMARY	TERTIARY	TOTAL
CLEAN	28970	12660	41630
TRUOX-C	24250	8557	32807
SLUDGE WASH C	30840	5683	36523
CLEAN W/ CPUs	22240	9352	31592
PRIMARY LLW TO GLASS			
CLEAN	28373	12840	41213
TRUOX-C	23665	8856	32521
SLUDGE WASH C	30499	5919	36418
CLEAN W/ CPUs	21641	9506	31147

Figure 4-3. High-Level Waste Glass Canister Summary.

Figure 4-4. Low-Level Waste Glass and Grout Vault Summary.

Figure 4-5. Normalized Long- and Short-Term Onsite Health Hazard.

Figure 4-6. Occupational Health Hazard Summary.

Figure 4-7. Total Technical Risk Index by Process Strategy.

Figure 4-8. Average Technical Risk Index by Process Strategy.

Table 4-1. Total Cost Summary for Process Strategies.

Model:	Primary LLW to grout				Primary LLW to glass			
	CLEAN	TRUEX-C	SLUDW-C	CLEAN +CPUs	CLEAN	TRUEX-C	SLUDW-C	CLEAN +CPUs
Waste stream								
Primary	28,970	24,250	30,840	22,240	28,373	23,665	30,499	21,641
Tertiary	12,660	8,557	5,683	9,352	12,840	8,856	5,919	9,506
Total	41,630	32,807	36,523	31,592	41,213	32,521	36,418	31,147
Tertiary/ Primary	0.44	0.35	0.18	0.42	0.45	0.37	0.19	0.44

Percentage of cost:

Primary	69.6	73.9	84.4	70.4	68.8	72.8	83.7	69.5
Tertiary	30.4	26.1	15.6	29.6	31.2	27.2	16.3	30.5

CLEAN/"MODEL" cost:

Primary	--	1.19	0.94	1.30	--	1.20	0.93	1.31
Tertiary	--	1.48	2.23	1.35	--	1.45	2.17	1.35
Total	--	1.27	1.14	1.32	--	1.27	1.13	1.32

CLEAN +CPUs/"MODEL" cost:

Primary	0.77	0.92	0.72	--	0.76	0.91	0.71	--
Tertiary	0.74	1.09	1.65	--	0.74	1.07	1.61	--
Total	0.76	0.96	0.86	--	0.76	0.96	0.86	--

LLW grout versus glass product cost:

Primary	--	--	--	--	0.98	0.98	0.99	0.97
Tertiary	--	--	--	--	1.01	1.03	1.04	1.02
Total	--	--	--	--	0.99	0.99	1.00	0.99

NOTE: Dollar amounts are given in millions.

CPU = compact processing unit.

LLW = low-level waste.

SLUDW-C = Sludge Wash C.

TRUEX-C = Transuranic Extraction Option C.

Table 4-2. Summary of Glass Optimization Results.

Model:	High-level waste glass			Low-level waste glass		
	CLEAN	TRUEX-C	SLUDW-C	CLEAN	TRUEX-C	SLUDW-C
With the P_2O_5 high constraint						
Glass (kg)	1.24 E+06	2.47 E+07	2.47 E+08	6.74 E+08	6.49 E+08	5.08 E+08
Canisters	750	14,997	149,991	--	--	--
Vaults	--	--	--	79	76	60
Load (wt%)	19.3	21.4	7.0	22.3	23.5	22.5
Without the P_2O_5 high constraint						
Glass (kg)	1.24 E+06	1.47 E+07	6.84 E+07	5.53 E+08	6.46 E+08	5.08 E+08
Canisters	750	8,880	41,450	--	--	--
Vaults	--	--	--	65	76	60
Load (wt%)	19.3	36.1	25.5	27.2	23.6	22.5
Without the Na_2O high constraint						
Glass (kg)	--	--	--	--	--	4.71 E+08
Vaults	--	--	--	--	--	55
Load (wt%)	--	--	--	--	--	24.3
Without the OTHHI high constraint						
Glass (kg)	7.55 E+05	--	--	--	--	--
Canisters	457	--	--	--	--	--
Load (wt%)	31.7	--	--	--	--	--
Without P_2O_5 /with P_2O_5						
Reduct (%)	1.00 0.0	0.59 40.8	0.28 72.4	0.82 17.9	1.00 0.4	1.00 0.0

CLEAN/"MODEL":

With P_2O_5	--	0.05	0.01	--	1.04	1.33
Without P_2O_5	--	0.08	0.02	--	0.86	1.09

Low-level waste glass (kg)/high-level waste glass (kg):

With P_2O_5	--	--	--	544.39	26.23	2.05
Without P_2O_5	--	--	--	446.91	44.11	7.43

OTHHI = Other upper limit.

SLUDW-C = Sludge Wash C.

TRUEX-C = Transuranic Extraction Option C.

Table 4-3. Summary of Waste Product Generation.

Model:	CLEAN	TRUEX-C	Sludge Wash C	CLEAN +CPUs
Waste production ratio: kg of waste product produced per kg of initial primary waste.				
Total TERW	4.36	2.85	1.79	3.10
HLW glass	0.002	0.019	0.090	--
LLW glass	0.73	0.85	0.67	--
Salt grout	2.58	3.04	2.17	--
TERW grout	2.66	1.74	1.09	1.89
All grout	5.24	4.78	3.27	4.47
Ratio of CLEAN results to other models				
HLW glass	--	0.08	0.02	--
LLW glass	--	0.86	1.09	--
Salt grout	--	0.85	1.19	--
TERW grout	--	1.53	2.43	1.41
All grout	--	1.10	1.60	1.17

CPU = compact processing unit.

HLW = high-level waste.

LLW = low-level waste.

TERW = tertiary waste.

TRUEX-C = Transuranic Extraction Option C.

This page intentionally left blank.

5.0 CONCLUSIONS

The cost savings associated with CPU use was significant (approximately 24% for the CLEAN Option process strategy) and should be incorporated into any process strategy. The large tertiary waste costs (ranging from approximately 16% [for Sludge Wash C] to 31% [for CLEAN Option] of the total process strategy cost) could be decreased significantly if process design is also focused on reducing the amount of tertiary waste produced. Overall, the CLEAN Option without CPUs had a total cost of \$41.2B, which was approximately 27% greater than that for the TRUEX-C process strategy (\$32.5B), approximately 13% greater than that for the Sludge Wash C process strategy (\$36.4B), and approximately 32% greater than the CLEAN Option with CPUs (\$31.1B).

Comparing the primary LLW to glass option to the LLW to salt grout option shows that total primary LLW processing and disposal costs were essentially the same for both options. Therefore, the choice of a LLW glass-in-sulfur product appears very advantageous compared to grout from a waste form stability aspect and also for its potential for future retrievability and processing.

The costs associated with the HLW and LLW glass products can vary dramatically, depending on which glass optimization models and associated composition constraints are used. For example, the P_2O_5 constraint was relaxed for all process strategy glass product results. If this constraint was included, cost increases of \$1.6B, \$17.5B, and \$0.085B would be seen for the TRUEX-C, Sludge Wash C, and CLEAN Option process strategies, respectively. Therefore, more glass composition constraint evaluation and experimentation on key waste oxide stream components could allow relaxing the current constraints, resulting in significantly reduced HLW glass canister and LLW glass vault counts (i.e., higher waste oxide loadings in glass) and their associated costs.

The large amount of glass mass inventory (kilograms) associated with the LLW glass was due primarily to the large amount of Na_2O in the LLW oxide streams. Indeed, Na_2O constitutes 74, 85, and 89 wt% of the LLW oxide stream for the CLEAN Option, TRUEX-C, and Sludge Wash C process strategies, respectively. Removing this sodium would substantially reduce the LLW glass mass inventory. One alternative for reducing Na_2O in the LLW streams is a "Clean" Salt process (or Fractional Crystallization of $NaNO_3$) (Herting 1992), where separation and production of "Clean" sodium salts (such as $NaNO_3$) is achieved. If these "Clean" sodium salts are fed to an electrodialysis salt splitting process, $NaOH$ and HNO_3 could be produced for use in other processing. Alternatively, the "Clean" sodium salts could possibly be used in industrial applications or perhaps find disposal in lower cost drum storage instead of glass. This process will be evaluated in a later report.

The aggressive pretreatment process flowsheet that represented the CLEAN Option process strategy was successful in meeting the major goals of producing less than 1,000 HLW canisters along with a LLW Class A waste stream. Again, this success depends on the previously discussed process modeling assumptions.

Credit is not taken in the CLEAN Option for reducing HLW volume to the point that a separate vitrification facility may not be needed. If vitrification can be incorporated directly into the separations plant as an acid process, the cost of permitting and approval efforts for an additional stand-alone facility could be avoided, and costs associated with neutralization, material transport, and storage of waste at a separate facility would be eliminated.

The toxicity of the LLW stream is significantly affected by complexation in alkaline supernatant, especially after the organic destruction step. Therefore, greater understanding of this complexation is needed to ensure successful process definition and development.

The relative long-term offsite health hazard estimates suggest that this health hazard is comparable for all of the process strategies. The greatest long- and short-term onsite health hazard (controlled by excavation rather than by a drilling scenario) would be in the HLW glass product if the environment were not protected from it by geologic and geochemical barriers in and around the repository. The CLEAN Option long- and short-term onsite health hazards were more than an order of magnitude greater for the HLW glass product than the TRUEX-C and Sludge Wash C process strategies because of the greater HLW concentration. However, it is highly unlikely that any excavation would uncover a deep repository. The drilling scenario with different controlling components would probably produce more short-term hazard from the repository than the excavation scenario during the first 500 years.

Thus, excluding the HLW glass product, the tank heel stream dominates both long- and short-term onsite health hazards. Otherwise, the only significant variations in the long- and short-term onsite health hazards between the pretreatment process strategies occurs for the primary LLW grout product and the uranium product. Assuming that the uranium product does not remain onsite but is added to the U.S. national stockpile, only the primary LLW grout product health hazards are compared. For the primary LLW grout product long-term onsite health hazard, the TRUEX-C process strategy was a factor of approximately 5 and 7 higher than for the CLEAN Option and Sludge Wash C process strategies, respectively. For the primary LLW grout product short-term onsite health hazard, the CLEAN Option process strategy was more than an order of magnitude lower than for the TRUEX-C and Sludge Wash C process strategies, respectively. While no estimate of the primary LLW glass product onsite health hazard is included, it is expected to be lower than that resulting from primary LLW grout because the glass represents a more stable waste form than grout.

Considering occupational exposure, the plant designs for the CLEAN Option flowsheets result in about 3 and 24% more occupational gamma exposure, a factor of 2.3 and 12.1 more occupational alpha exposure, and a factor of 2.2 and 19.2 more occupational beta exposure, than the TRUEX-C and Sludge Wash C plant designs, respectively. These larger health hazards for the CLEAN Option result from its greater processing requirements.

Generally, more efficient removal of major exposure-causing components in the first process elements to contact the tank waste would lower the occupational exposure in all process strategies. For example, the CLEAN Option process strategy has alkaline-side cesium removal before strontium and

technetium removal, thereby reducing gamma exposure in these subsequent removal operations. However, cesium removal follows after other removal operations in the acid-side processing. If the acid-side cesium removal could also be placed before the other acid-side removal operations, it would reduce the gamma exposure in those subsequent removal operations.

Considering waste product classification, the tank waste feedstreams, the HLW glass stream destined for a HLW repository, and the tank heel stream are classified as GTCC. The primary LLW grout streams are LLW Class A for the CLEAN Option process strategy, while the TRUEX-C and Sludge Wash C process strategies were LLW Class B because of the strontium limits. Higher DFs may be needed for the atmospheric release of the vitrification offgas where different limits apply than for solid LLW. Using uranium LLW classification limits proposed by Kocher and Croff (Kocher and Croff 1988), the uranium product stream was also GTCC for the CLEAN and Sludge Wash C process strategies, while the TRUEX-C process strategy uranium stream was LLW Class C.

The DOE current level of effort contributes considerably to the technical risk of many process technologies, representing the slow advance of the process maturity. These processes (e.g., solids dissolution, SREX, NaOH/HNO₃ recycle, TCIX, and uranium separation associated with the TRUEX process) may require renewed or increased levels of effort to provide successful application of a tank waste pretreatment process strategy. The CLEAN Option process strategy without CPUs had a total combined category technical risk index that was a factor of approximately 2 and 10 times higher than the TRUEX-C and Sludge Wash C process strategies, respectively. The process average combined category technical risk index for the CLEAN Option process strategy without CPUs was nearly the same as the TRUEX-C process strategy and a factor of approximately 3 higher than for the Sludge Wash C process strategy. The CLEAN Option using the new and developing CPU concept should be considered to have more technical risk than the CLEAN Option based only on a central processing facility concept.

Future work could consider possible disposal alternatives to mixing separated waste fractions into HLW and LLW mixtures. If the waste fractions produced by a processing strategy, such as the CLEAN Option, are not recombined into the two HLW and LLW mixtures, a HLW repository may not be technically necessary for anything but spent fuel.

Also, the process strategies could be reevaluated using different tank group feedstreams (perhaps 10 to 12 for SSTs) versus an all-tank (SST and DST) mixed waste feedstream currently used in the analyses. Sludge dissolution factors included in the process models would change for each specific tank sludge waste group based on experimental/analytical data. This course of analysis could be phased in as appropriate.

This page intentionally left blank.

6.0 REFERENCES

- Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, Westinghouse Hanford Company, Richland, Washington.
- Herting, D. L., 1992, "Clean Salt Process End-Of-Fiscal-Year Report," Internal Memo, #12110-PCL92-078, October 1, 1992, Westinghouse Hanford Company, Richland, Washington.
- Knutson, B. J., et al., 1992, "Advanced Chemical Separation Study: TRUEX-A Versus Sludge Wash C," DRAFT letter report, August 1992, Westinghouse Hanford Company, Richland, Washington.
- Knutson, B. J., et al., 1993, "Advanced Chemical Separation Study: TRUEX Strategy Compared To Sludge Wash Ion Exchange," DRAFT letter report, July 1993, Westinghouse Hanford Company, Richland, Washington.
- Kocher, D. C., and A. G. Croff, 1988, *A Proposed Classification System For High-Level And Other Radioactive Wastes*, Research Sponsored by DOE Contract DE-AC05-84OR21400, Radioactive Waste Management and the Nuclear Fuel Cycle, Vol. LL(3), pp. 227-268, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Sutherland, D. G., et al., 1993, *Pretreatment Status Report On The Identification And Evaluation Of Alternative Processes*, WHC-SD-WM-PRS-012, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

This page intentionally left blank.

APPENDIX A

GENERAL DESCRIPTION OF ASPEN PLUS

This page intentionally left blank.

GENERAL DESCRIPTION OF ASPEN PLUS

ASPEN PLUS¹ (Advanced System for Process Engineering) is a software system for computer aided process design. The code was designed for performing rigorous steady state material and energy balances for plants in the process industries. It is a tool that can be used by engineers to model any type of process for which there is a continuous flow of materials and energy from one processing unit to the next. Input to the model consists of information normally contained in process flowsheets. The program input files contain keywords that define the flowsheet connectivity, the chemical components within the flow streams, the methods for calculating thermodynamic properties (i.e., equations of state), and unit operation information, such as type of equipment, operation sequence, and performance specifications. The code will perform the necessary calculations, including equilibrium calculations, to produce a material and energy balance that describes the flowsheet. The output includes flow rates and compositions of feed, product, internal, and recycle streams. Key equipment specifications and energy consumption are also determined, and capital and operating costs of the modeled process can be estimated. ASPEN PLUS also includes capabilities for running sensitivity analysis case studies, optimizing the process for a specified parameter (i.e., cost), and data regression for estimating various equilibrium and physical property parameters. User-defined FORTRAN blocks can be used to supplement or supersede the calculations performed by ASPEN PLUS to control chemical makeup calculations or change process unit specifications based on stream characteristics.

Material balances are rigorously calculated using the internal physical and thermodynamic property models selected by the user. ASPEN PLUS contains several property models for this purpose, including models for equations of state, enthalpy, activity coefficients, transport properties, and others. Some of the physical property parameters required to use these property models are contained in ASPEN PLUS data banks for common chemical components. However, binary and ternary ion interaction parameters and chemical equilibrium data for solid dissolution and precipitation for most of the Hanford tank waste species are not available in the data banks. Special data libraries were developed to represent the ionic species and chemical compounds unique to the Hanford waste streams. These user-defined data libraries include information related to specie radioactivity and toxicity.

An expert system interface to ASPEN PLUS, called ModelManager², provides the user with a graphical tool to facilitate model development, evaluation, and representation. The expert system includes built-in checks to prevent over- and under-specification of model parameters during model development, allows interactive control and display of the ASPEN PLUS model run data, and provides data spreadsheet and table development.

The ASPEN PLUS computational model consists of process blocks and streams. Each block represents a process or group of processes which make up a function. Streams represent the flow of materials by appropriate means into

¹ASPEN PLUS is a trademark of Aspen Technology, Inc.

²ModelManager is a trademark of Aspen Technology, Inc.

and out of the processes. Each block can have one or more input streams and one or more output streams, depending on which particular process is represented by that block. Each input and output stream flow is divided into components, or groups of materials, based on their chemical and radiological properties.

For mass flow calculations, four different types of process blocks are used. The first process type is a "mixer" (MIXER), which consists of one or more input streams and one output stream. The mass flow in the output stream is just the sum (or mix) of the mass flows of the input streams. The second process type is a "splitter" (FSPLIT), which separates (or splits the flow) of one or more input streams into two or more output streams. For each of the chemical components in a stream, the mass flow of each output stream is some fraction of the sum of the mass flow input into the process. This fraction is referred to as the separation factor. Because of the conservation of mass, the separation factors for each component for all of the streams must sum to unity. For a splitter, the separations for each component of a particular output stream are equal. In other words, all outlet streams have the same composition and properties.

The third process type modeled is a "separator" (SEP, SEP2). A separator is a type of splitting process which has one or more input streams and two or more output streams. For a separator, the component separation values within a particular stream may be different, which distinguishes a separator from a splitter. Again, the mass flow for the output stream is defined by the sum of the input streams multiplied by a separation factor between zero and one, and the sum of the separation factors for each component over all the output streams must sum to unity. This representation results in an algebraic computational model. The separation factor in a separator varies inversely with the commonly used decontamination factor, which is the ratio of the concentration of a component in an exit stream to its concentration in the feed stream. This definition differs significantly from the classical separation factor, which is the ratio of two components in one exit stream divided by the ratio of the same two components in another exit stream.

The last process type modeled is a "reactor" (RSTOIC, RYIELD). The reactor is used to simulate chemical reactions. All reactors may have any number of input or feed streams, which are mixed internally. The RYIELD reactor process simulates a reactor with specified reaction yields of each component. The RSTOIC reactor process simulates a reactor with specified reaction stoichiometry and reaction extents. In both reactor simulations, no reaction kinetics parameters are required.

In addition to the above process blocks, user-defined FORTRAN blocks were created to automate (i.e., provide run-time calculations of) many of the process-dependent calculations. These include feed flow dependent chemical makeup calculations, tertiary nonprocess waste generation calculations, process cost calculations, and glass composition optimization calculations.

APPENDIX B

DETAILED CLEAN OPTION MODEL: ASPEN PLUS¹ IMPLEMENTATION

¹ASPEN PLUS is a trademark of Aspen Technology, Inc.

LIST OF TERMS

APM	ammonium phosphomolybdate
CE	crown ether
CMPO	N-diisobutylcarbamoylmethylphosphine oxide
CSIX	cesium ion exchange
DCH 18-Cr-6	dicyclohexano 19-crown-6 ether
DTPA	diethylene-triamine-penta-acetic acid
EDTA	ethylenediaminetetraacetic acid
HLW	high-level waste
IDEF	Integrated Computer-Aided Manufacturing (ICAM) Definition (Language)
LLW	low-level waste
NOx	oxides of nitrogen
NPH	normal paraffin hydrocarbon
PFD	process flow diagram
PUREX	plutonium-uranium extraction
SCWO	supercritical water oxidation
SE	solvent extraction
SLS	solid/liquid separation
SOLEX	Solvent Extraction Option
SREX	strontium extraction
TBP	tributyl phosphate
TCIX	technetium ion exchange
THFTCA	tetrahydrofuran tetracarboxylic acid
TOC	total organic content
TRU	transuranic
TRUEX	transuranic extraction
TRUEX-C	Transuranic Extraction Option C
UREX	uranium extraction

DETAILED CLEAN OPTION MODEL: ASPEN PLUS IMPLEMENTATION

B1.0 INTRODUCTION

The ASPEN PLUS unit process model developed for this report is a streamlined model of the CLEAN process flow diagram (PFD) presented in *Tank Waste Technical Options Report*, WHC-EP-0616, (Boomer et al. 1993). Figure B1 shows the ASPEN PLUS block diagram representing the CLEAN Option flowsheet model. The stream numbers mentioned in the CLEAN Option model description refer to this block diagram. Figure B2 shows the Sludge Wash C, Transuranic Extraction Option C (TRUEX-C), and CLEAN Option process strategies as they relate to the waste separations technology options defined in the *Tank Waste Technical Options Report* (Boomer et al. 1993). Following the CLEAN Option model description are descriptions of the Sludge Wash C and TRUEX-C models (Knutson et al. 1993) that are added for completeness.

Following the TRUEX-C and Sludge Wash C model descriptions is a CLEAN Option flowsheet representation using the ICAM (Integrated Computer-Aided Manufacturing) Definition (IDEF) Language software tool (Pajunen 1992). The IDEF tool provided integration of the CLEAN Option process strategy within the total Hanford cleanup system (Appendix C). It also provided a flowsheet description at increasingly decomposed states (i.e., a hierarchical representation) or levels of detail, from which an appropriate detail level could be selected for implementation using ASPEN PLUS. Figure B5 shows the IDEF hierarchy of functions with the global level representation highlighted.

The streamlined CLEAN Option model described in this appendix is based upon an example flowsheet proposed by J. L. Swanson (Swanson 1993) and is the same, except for removal of the following processing steps:

1. Evaporative removal of water from feed to basic-side separations
2. Precipitation of ferric hydroxide before basic-side separations
3. Caustic fusion of solids after the second acid dissolution step.

Sufficient detail is contained in the model for performing a material balance calculation. Process equipment shown in the PFD in WHC-EP-0616 (Boomer et al. 1993) is not included in the model if it does not impact the distribution of components between the waste streams produced by the flowsheet. For example, identical process trains, which run in parallel, are modeled as a single train; a mixing tank followed by a unit operation (e.g., reactor or extraction step) is modeled as an appropriate unit operation block with multiple feed streams.

The amount of process unit detail contained in the material balance model closely follows the level of process unit information presented in *Clean Option: An Alternative Strategy for Hanford Tank Waste Remediation*, Volume 2, *Detailed Description of First Example Flowsheet* (Swanson 1993). In fact, this reference is the source for most of the design specifications and bases for chemical additions. In addition, it contains the rationale for the selection and sequencing of the various process steps comprising the CLEAN flowsheet option.

The process descriptions included in this appendix are only intended as summaries of information presented in WHC-EP-0616 (Boomer et al. 1993) and PNL-8388 (Swanson 1993). For further details, the reader is referred to these sources.

B2.0 SOLID-LIQUID SEPARATION TREATMENT/ASSUMPTIONS

The CLEAN flowsheet employs centrifuges for solid/liquid separation (SLS) in six different portions of the flowsheet: initial treatment of feed from waste tank retrieval, after the organic destruction processing, after caustic dissolution, after both acid dissolution steps, and after the chromium reduction step before caustic production and recycling. The common assumptions regarding separation efficiency and operation for all of these SLS steps are as follows.

- a. Centrifuge operation and downstream filters achieve 0% solid in clarified supernate.
- b. Polyelectrolyte solution is blended in line with the slurry feed to the centrifuge to coagulate colloidal solids and, thereby, improve solids recovery. This solution has a weight equivalent to 19% of the solids in the centrifuge feed and has a composition of 1 wt% polyelectrolyte and 99 wt% water.
- c. Supernate entrainment in the solids from the centrifuge is 12% of the solid weight in the centrifuge feed.
- d. Centrifuge wash water amount is 4 times the total solids weight. Of this 400% solid weight equivalent wash water, 88 solid wt% accompanies the solid to the centrifuge catch tank; the remainder accompanies the clarified supernate.
- e. Dilution water equivalent in weight to 200% solids is added to the catch tank to produce a pumpable slurry, which is 25 wt% solid.

B3.0 INITIAL SOLID-LIQUID SEPARATION

Sludge and dissolved salt cake from waste storage tanks undergo SLS as the first processing step. The simplified slate of components and their distribution between liquid and solid phases is provided in Table B1. The solid slurry from the centrifuge is fed to the caustic dissolution section. The clarified liquid is routed to the organic destruction step.

B4.0 ORGANIC DESTRUCTION

Supercritical water oxidation (SCWO) destroys organics complexed with metal ions and precipitates the multivalent metals out of solution as their hydroxides. Process conditions for SCWO are 500 °C and 3,000 psi. For simplicity, organic destruction is modeled with the following reactions in which only the total organic content (TOC) of organic complexes is considered (except for ferrocyanide):

Table B2 contains the fractional component conversions for organic and ferrocyanide destruction, as well as metal hydroxide precipitation.

With cooling and pressure reduction of the outlet stream from the reactor, evolved CO_2 and N_2 gases are readily separated and sent to offgas treatment. Subsequent SLS results in a solid slurry containing metal hydroxides that are routed to caustic dissolution; liquid from the centrifuge is one of several feeds to the basic-side separations.

B5.0 SOLID DISSOLUTION

Three dissolution steps along with undissolved sludge recycle are included in the flowsheet to minimize the amount of sludge routed to high-level waste (HLW). One dissolution cycle involves sequential sludge processing through the following steps: (1) caustic leach, (2) nitric acid/oxalic acid dissolution, and (3) nitric acid/hydrofluoric acid dissolution, where SLS occurs after each of these steps. Several hours of digestion at approximately 90 °C is anticipated for all these processes, under the following base/acid conditions:

Caustic Leach: $[\text{OH}^{-}] = 4.0M$

Nitric/Oxalic
Acid Dissolution: $[\text{H}^{+}] = 4.5M$
 $[\text{C}_2\text{O}_4^{-2}] = 0.3M$ (approx. 1 mole/mole
cations dissolved)

Nitric/HF acid
Dissolution: $[\text{H}^{+}] = 4.5M$
 $[\text{F}^{-}] = 1.0M$ (approx. 1 mole/mole
cations dissolved)

The extents of dissolution assumed by component are shown in Table B3 for each dissolution process.

In the ASPEN PLUS model, 95% of the undissolved solids from the second acid dissolution step are returned for caustic leaching to begin another dissolution cycle, with the remaining 5% solids diverted to HLW treatment. Recycling 95% of the undissolved solids is necessary to achieve the same total

dissolution of cancrinite (96%) as is attained by J. Swanson's proposed 9-cycle batch processing scheme (Swanson 1993), which cannot be modeled in ASPEN PLUS. Although recycling 95% of the undissolved solids slightly overpredicts (relative to the 9-cycle batch scheme) the amount of solid components that accompany cancrinite to HLW treatment, the impact of this overprediction on total HLW volume is not significant because cancrinite is the dominant constituent of the undissolved solids.

Offgas from both acid dissolution processes contains NO_2 formed by nitrite ion acidification. The offgas is contacted with water and oxygen to convert 90% of the NO_2 to nitric acid. This regenerated nitric acid is recycled to the dissolvers to reduce nitric acid feed requirements.

B6.0 TRIBUTYL PHOSPHATE SOLVENT EXTRACTION OF TRANSURANIC COMPONENTS

The tributyl phosphate (TBP) solvent extraction (SE) process is designed for the removal of uranium, plutonium, neptunium, and thorium. The combined feed to this process consists of the dissolved sludge stream from the acid dissolution portion of the flowsheet and a waste solution from the subsequent uranium purification cycle. The solvent composition is the same, 30% TBP in hydrocarbon diluent, as is usually used in the well-known plutonium-uranium extraction (PUREX) process.

In the first extraction contactor of this TBP cycle, uranium, plutonium, neptunium, and thorium are extracted into the TBP organic phase, which is then scrubbed with nitric acid to increase the separation from the bulk metal ions, some of which have a slight extractability. The raffinate from this contactor contains lanthanides and the remaining components of the dissolved sludge solution and is routed to N-diisobutylcarbamoylmethylphosphine oxide (CMPO) SE of lanthanides. The extracted plutonium, neptunium, and thorium are selectively stripped back into an aqueous phase in the second contactor (to be routed to HLW glass for disposal), and the uranium is stripped in the third contactor. The uranium is purified further in another TBP cycle, described in Section B7.0, so that it can be added to the existing uranium stockpile. The solvent is then washed with sodium carbonate solution to prepare it for reuse.

Table B4 presents the percentage split of feed components among the various product streams (see Figure B1) from this process. The dissolved sludge stream is assumed to be decontaminated from uranium and plutonium by factors of 10^4 and from thorium and neptunium by factors of 10^2 . Cesium, strontium, americium, and trivalent lanthanides are virtually inextractable by TBP, and technetium extracts very little at the high acidity used here ($\sim 4M \text{ HNO}_3$). Thus, these elements will remain in the dissolved sludge stream in this step, along with the nonradioactive elements present in the stream. The TBP solvent loss is assumed to be minimal (0.001%) because downstream evaporators recover and recycle any solvent carried away in the aqueous streams.

B7.0 URANIUM PURIFICATION

Final uranium purification is accomplished in a second TBP cycle that is based on the 2D Cycle of the Hanford PUREX Plant. In this cycle, the uranium stream is first concentrated by evaporation and is then sent to a TBP extraction contactor; this contactor is run at low acidity and at a high degree of saturation of the TBP by uranium; hydroxylamine reductant is employed in the scrub stream to enhance removal of fission product and transuranic (TRU) elements. These conditions lead to a significant uranium "loss" from the contactor, but the "loss" is recovered by backcycling this stream (after evaporation) to the start of the first TBP cycle. Finally, the purified uranium is again stripped into dilute acid; this stream is concentrated by evaporation and then calcined to convert the uranium to UO_3 for transfer to the stockpile.

The distribution of key components among the outlet streams from this operation is shown in Table B5. The solvent from the second TBP cycle is also washed with carbonate to prepare it for reuse. The TBP solvent losses are assumed to be 0.001% because of downstream evaporators that will recover TBP from the aqueous streams.

B8.0 CMPO SOLVENT EXTRACTION FOR LANTHANIDE REMOVAL

The raffinate from the first TBP cycle is routed to a CMPO SE process to remove trivalent lanthanides, americium, and bismuth. This extraction process contains extraction, stripping, and solvent wash steps. The solvent used is 0.2M CMPO + 1.4M TBP in hydrocarbon diluent.

In the extraction step, 99.99% of the trivalent lanthanides and americium, and 99.5% of the bismuth in the dissolved sludge solution are extracted by the solvent. The raffinate from this extraction retains essentially all the cesium, strontium, and technetium and undergoes further processing for removal of these components as described in later sections.

Americium and trivalent actinides are stripped from the CMPO extract into dilute nitric acid in the second contactor. Bismuth is retained in the extract under these stripping conditions and is removed from the solvent in a subsequent sodium carbonate wash step. EDTA complexant is added in this wash step to prevent bismuth precipitation. The resulting carbonate solution containing bismuth is sent to low-level waste (LLW) treatment; the washed solvent is recycled to the CMPO extraction step.

Table B6 shows the distribution of key components among the outlet streams from this process. Solvent losses are assumed to be 0.001% because downstream evaporators will recover solvent from the aqueous outlet streams of the extraction, stripping, and solvent wash steps.

B9.0 AMERICIUM/LANTHANIDE SEPARATION BY BAND DISPLACEMENT CATION EXCHANGE

Two cation exchange resins loaded in sequential columns are used to separate americium and curium from lanthanides in the strip solution from the first CMPO cycle. Component distributions among the outlet streams from this operation are provided in Table B7.

In the first cation exchange column, americium, curium, and trivalent lanthanides are selectively sorbed onto the resin. Following a water wash of the resin, the trivalent ions are eluted with 0.05M Na₃ diethylene-triamine-penta-acetic acid (DTPA) solution onto a zinc-loaded cation exchange resin in the second column. Continued elution through a series of columns establishes discrete bands of metal ion-DTPA complexes, which allow americium and curium to be isolated as a middle cut. After elution, the first and second cation exchange resin columns are regenerated with HNO₃ and Zn(NO₃)₂ solutions, respectively. Subsequent water washes prepare the resin beds for the next cycle of operation.

B10.0 CROWN ETHER SOLVENT EXTRACTION FOR STRONTIUM AND TECHNETIUM REMOVAL

The raffinate from the first CMPO cycle, which contains all of the components of the dissolved sludge solution except the actinides, the lanthanides, and possibly the bismuth, is then fed to a crown ether (CE) SE step in which strontium and technetium are removed.

In this CE extraction cycle, the strontium and technetium are extracted from the dissolved sludge solution aqueous phase into the CE organic phase, which is then scrubbed with ~1M HNO₃ to remove less strongly extracted species. The strontium and technetium are then stripped from the organic phase into a dilute acid aqueous phase. As shown in Table B8, this aqueous dilute acid stream contains 99.99% of the strontium and barium and 99% of the technetium in the feed to this operation.

B11.0 STRONTIUM/BARIUM/TECHNETIUM SEPARATION BY BAND DISPLACEMENT CATION EXCHANGE

Two cation exchange resins loaded in sequential columns are used to separate strontium, barium and technetium in the dilute acid stream from the CE extraction step described in the previous section.

In the first cation exchange column, strontium and barium are selectively sorbed onto the resin. Following a water wash of the resin, these ions are eluted with 0.05M Na₃ EDTA solution onto a zinc-loaded cation exchange resin in the second column. Continued elution through a series of columns establishes discrete bands of metal ion-EDTA complexes, which allows 99.99% of

the strontium to be isolated as a middle cut. This strontium cut is handled as HLW and is assumed to include residual zinc and barium as detailed in Table B9. The first cut containing zinc and the last cut containing barium are routed to LLW treatment.

After elution, the first and second cation exchange resin columns are regenerated with HNO_3 and $\text{Zn}(\text{NO}_3)_2$ solutions, respectively. Subsequent water washes prepare the resin beds for the next cycle of operation.

B12.0 AMMONIUM PHOSPHOMOLYBDATE ION EXCHANGE FOR CESIUM REMOVAL

The final acid-side processing step uses ammonium phosphomolybdate (APM) to remove 99.99% of the cesium from the residual sludge solution produced by the CE extraction operation described in Section 10.0. It is assumed that the resin used is APM on an alumina substrate (10 wt% APM) to meet the mass and heat transfer requirements for this application. Because cesium cannot be readily eluted from APM, the loaded sorbent (50 g cesium/kg APM) is routed to the caustic leach step of the sludge dissolution process (Section 5.0). The APM and its associated cesium will dissolve under caustic conditions and become part of the feed to the basic-side ion exchange processes.

B13.0 RESORCINOL-FORMALDEHYDE ION EXCHANGE FOR CESIUM REMOVAL

The combined basic-side feed undergoes 99.99% cesium removal via ion exchange with a resorcinol-formaldehyde resin. Table B10 provides volumetric information on the regeneration/wash streams required for this ion exchange process. Once the column is loaded with cesium, sodium hydroxide and water washes flush feed from the column and prepare it for elution with formic acid. The acid solution containing cesium stripped from the resin is routed to HLW processing. A subsequent eluant flush, using water, is followed by regeneration with sodium hydroxide to prepare the column for the next cycle.

B14.0 CHELATING ION EXCHANGE FOR STRONTIUM REMOVAL

The basic stream remaining after cesium ion exchange (CSIX) is sent to a chelating cation exchange column containing resin, which removes 99.99% of the strontium, barium, and calcium. Volumetric information on regeneration streams is provided in Table B11.

After the resin has been loaded with strontium, barium, and calcium, it is flushed with sodium hydroxide and then water before eluting with 1M HNO_3 . This acid stream containing strontium is concentrated by an evaporator to $[\text{H}^+]=4.5\text{M}$ before being routing to the first acid dissolution step.

An eluant water wash followed by sodium hydroxide regeneration prepares the ion exchange column for the next cycle.

B15.0 ANION EXCHANGE REMOVAL OF TECHNETIUM

The basic stream remaining after strontium ion exchange undergoes anion exchange to achieve 99.5% removal of technetium. Table B12 contains regeneration stream volumetric data assumed for this operation.

In this process, the pertechnetate ion is removed from the basic-side solution by sorption on a strong-base anion exchange resin. After the resin bed is loaded, it is washed with sodium hydroxide to remove residual feed solution and then with dilute nitric acid to ensure conversion of the resin to the nitrate form before the elution step is complete. The technetium is eluted with 6M nitric acid; the bed is prepared for the next loading cycle by displacing the acid first with water and then with sodium hydroxide.

Using acid distillation, the technetium product is concentrated to 12M nitric acid and routed to HLW processing. The dilute acid stream resulting from the distillation is used in the next ion exchange cycle to reduce nitric acid consumption by this ion exchange process.

B16.0 INITIAL TREATMENT FOR ACIDIC LOW-LEVEL WASTE TREATMENT

The first treatment for the combined acidic LLW stream (No. 503 in Figure B1) is evaporation to reduce its volume. Vapor from this evaporation results in a dilute nitric acid stream, which is sent to acid recovery. The concentrated liquid from evaporation (5M HNO₃) then undergoes denitration by reaction with sucrose according to the following overall stoichiometry:

Sufficient sucrose is supplied to this denitration step to achieve 0.5M HNO₃ in the liquid after complete sucrose conversion. This liquid is next fed to a calcination step as discussed in the next section. The oxides of nitrogen (NO_x) produced by denitration is sent to the acid recovery portion of the flowsheet for conversion back to HNO₃.

B17.0 LOW-LEVEL WASTE CALCINATION

The combined basic LLW stream (No. 500 in Figure B1) is concentrated by evaporation of water to achieve 7M NaOH in the condensate (stream No. 517 in Figure B1) from the calcination step about to be described. This concentrated LLW stream from evaporation (stream No. 502 in Figure B1) is mixed with the

dilute acid stream (No. 512 in Figure B1) obtained from the initial acidic LLW treatment and fed to a calcination process for destruction of organic complexants and conversion of nitrates and nitrites to hydroxide. The reaction stoichiometry for conversion to caustic is described by the following reactions, where 90% conversion of nitrate and nitrite is assumed.

The 10% remaining sodium nitrate and sodium nitrite decompose to NO_x, which is destroyed by addition of ammonia. The overall calcination/NO_x destruction stoichiometry is as follows.

It is assumed that 100% excess NH₃ is supplied, where unreacted NH₃ is oxidized to nitrogen and water.

After condensing the reactions products, nitrogen gas is separated from the caustic slurry (7M NaOH), which undergoes treatment as described in the next section.

B18.0 CAUSTIC TREATMENT FOR SODIUM HYDROXIDE REUSE

The caustic slurry produced in the calcination operation contains 7M sodium hydroxide, which can be recovered for process uses to minimize LLW disposal volume. To eliminate chromium from recycled sodium hydroxide, soluble Cr(VI) is reduced to insoluble Cr(III) with hydroxylamine. After solid-liquid separation, approximately 30% of this caustic stream must be recycled to meet flowsheet requirements for sodium hydroxide (e.g., the caustic leach step of the solid dissolution operation). The remaining portion of the caustic slurry is incorporated into a LLW form for disposal.

B19.0 HIGH-LEVEL WASTE STREAM TREATMENT

The HLW streams, from the separation steps described in the previous sections, are combined and concentrated by evaporation to a 3M HNO₃ solution. Dilute acid vapor from this operation is sent to acid recovery. The 3M HNO₃ solution and formic acid eluant containing cesium from resorcinol-formaldehyde ion exchange (Section 13.0) are mixed and undergo denitration by reaction with sucrose and formic acid destruction.

Sufficient sucrose is supplied to this denitration step to achieve 0.5M HNO₃ in the liquid after complete sucrose conversion. This liquid is next fed to the HLW glass vitrification process along with undissolved solids from the acid dissolution operation. The NO_x produced by denitration are sent to the acid recovery portion of the flowsheet for conversion back to HNO₃.

B20.0 NITRIC ACID RECYCLING

Acidic evaporator overheads (from HLW treatment, strontium ion exchange, and acidic LLW treatment) are contacted with NO_x streams (from denitration and calcination steps) with the addition of hydrogen peroxide and air to absorb and convert NO_x to nitric acid. Conversion of 80% NO_x to acid is accomplished by oxidation by oxygen.

The remaining 20% of the NO_x is oxidized by hydrogen peroxide.

The resulting dilute acid liquid is concentrated by acid fractionation to recover 99.5% of the nitric acid as 12M HNO₃. The weak acid overhead is used as water recycle.

B21.0 SLUDGE WASH C AND TRUEX-C MODEL DESCRIPTIONS

The following model descriptions find reference in the *Systems Engineering Study for the Closure of Single-Shell Tanks* (Boomer et al. 1991) and *Tank Waste Technical Options Report* (Boomer et al. 1993). In the latter document, the TRUEX-C process strategy is referred to as the Sorex Extraction (SOLEX) C Option. Figure B2 shows the Sludge Wash C and TRUEX-C process strategies as they relate to the waste separations technology options defined in the *Tank Waste Technical Options Report* (Boomer et al. 1993).

B21.1 SLUDGE WASH C

The following recoveries for radionuclides from combined sludge and salt to the fraction being disposed of offsite represent the principal process criteria for the Sludge Wash C process strategy:

Sr 99.9% Tc 99% Cs 99% Pu 99.9% Am 99.9%.

The Sludge Wash C process strategy is made up of the following process steps: (a) Sludge Washing, (b) Organic Destruction using SCWO, (c) Sodium Titanate Sorption, (d) CSIX and Waste Concentration, and (e) Technetium Ion Exchange (TCIX) and Waste Concentration. A flowsheet of the Sludge Wash C process strategy is shown in Figure B3.

Tank waste is fed from retrieval to the sludge washing step, where a supernatant-solids separation on the retrieved waste is performed with continuous centrifuges as the solids are washed with water. The solid fraction is then neutralized before being transferred to HLW/TRU treatment, while the centrate is filtered. The filtrate is then sent to CSIX, and the supernate is further processed with organic destruction.

To destroy organic complexants, which solubilize significant multivalent TRU, fission products, and cations in the alkaline supernatant from sludge washing, a SCWO process is used. In this process, complexants are oxidized, allowing multivalent cations to precipitate out in their hydroxide forms and be separated out later in the Sludge Wash C process, resulting in a clarified supernatant with lower concentrations of TRU and strontium. To facilitate oxidation, high pressure oxygen in excess quantities is injected into a heated supernatant and fed to a high temperature vessel where organic destruction occurs. The temperature and pressure of the treated stream are reduced and the liquid stream is further treated with a sludge washing operation to remove the precipitated salts resulting from the destruction process. The solids are sent on to HLW treatment, while the supernatant is further processed with sodium titanate sorption.

The liquid stream from organic destruction is then treated to remove residual strontium and transuranics that remained in solution during this process. The adsorbent used is 37% $\text{NaTi}_2\text{O}_5\text{H}$ loaded on a macroreticular resin. The adsorbent is sent to HLW/TRU treatment after each loading cycle.

Clarified supernatant from sodium titanate adsorption is further treated with a cation ion exchange process, where cesium is removed in a series of columns loaded with a strong base organic anion exchange resin, Duolite¹ CS-100. The cesium product solution is then neutralized with NaOH before being sent to HLW/TRU treatment, while the effluent regeneration streams are further processed using an anion exchange process.

To remove technetium from the CSIX effluent regeneration stream, a series/parallel configuration of ion exchange columns is used. Strong base resin is used for this process. The technetium product stream is neutralized before transfer to Tank Farm Storage/HLW treatment, while the supernatant is adjusted for hydroxide and nitrite content before being sent to LLW storage.

The process facility is sized to process all tank waste in 13 years of operation with a 60% online efficiency (2,850 operating days).

¹Duolite is a trademark of Rohm and Haas.

B21.1.1 Sludge Wash C Chemical Makeups

Fewer reagents are needed for chemical processing in Sludge Wash C than in the TRUEX-C process because of the complexity of the TRUEX-C design. Wash and dilution water is used in the sludge washing, SCWO, and SCWO Effluent clarification process steps. Oxygen gas is pressurized before utilization in the SCWO process. Nitric acid is used in the cesium and technetium ion exchange processes during column regeneration. Sodium hydroxide is used in these latter process steps and also added to neutralize various product streams before HLW/TRU treatment. Sodium titanate is the adsorbent used to remove residual strontium and TRUs from the SCWO effluent clarification section and is flushed out and replaced after loading has been accomplished.

B21.2 TRUEX-C

The TRUEX-C pretreatment option represents an additional degree of partitioning, which reduces the radionuclide content and increases the amount of inert solids going to onsite disposal, while increasing the radionuclide content and reducing the amount of inert solids destined for offsite disposal. The following recoveries for radionuclides from combined sludge and salt to the fraction being disposed of offsite represent the principal process criteria for the TRUEX-C process strategy:

Sr 99% Tc 99% Cs 99% Pu 99% Am 99% U 99%.

The TRUEX-C process strategy is made up of the following process steps: (a) Sludge Washing, (b) Organic Destruction using SCWO, (c) Sodium Titanate Sorption, (d) CSIX and Waste Concentration, (e) TCIX and Waste Concentration, (f) Dissolution, (g) Transuranic Extraction (TRUEX), (h) Technetium Removal, (i) Uranium Recovery, and (j) Strontium Extraction (SREX). A flowsheet of the TRUEX-C process strategy is shown in Figure B4.

Solvent Extraction Feed Clarification is included in the dissolution step, TRUEX is split into extraction/scrubbing and the stripping process blocks, and SREX raffinate and CSIX feed clarification are included in the CSIX step.

Tank waste is pumped as a slurry from retrieval and is first separated into supernatant and solid fractions with continuous centrifuges and filters in a sludge washing process. The solids are sent to dissolution, and the supernatant is routed to the CSIX and Waste Concentration process, where the cesium is removed with a strong base organic anion exchange resin. Table B13 describes characteristics and assumptions pertaining to the solid portion of the waste stream ("sludge"), including acid dissolution of the solids for the TRUEX-C process strategy, respectively. The assumed solids in the waste feed are essentially an aluminum-sodium-iron-zirconium-uranium mixture of hydroxides, phosphates, and nitrates.

The Solids Dissolution process uses dissolvers to decrease the amount of solids sent to offsite waste treatment and disposal. The slurry stream, made up of slurries from the sludge washing step, the Organic Destruction step, and the Sodium Titanate Sorption step, is split and pumped into large batch

dissolvers where the solids are first reacted with nitric acid and then with sodium oxalate solution to facilitate dissolution, each batch cycle taking 48 hours total, including recharging of dissolvers. Ninety percent dissolution of all solids is assumed except for cancrinite and nickel (0%).

Clarified dissolver solution is processed in the TRUEX process, a liquid-liquid extraction process employing two banks of centrifugal contactors. The process serves to selectively remove the actinides and lanthanides from the feed, and then separate uranium, technetium, and thorium from the actinides and lanthanides. A commercially available bifunctional organophosphorus reagent, octyl(phenyl)-N, CMPO with TBP in a normal paraffin hydrocarbon (NPH) diluent, is used as the extractant in the TRUEX process. Process products include a raffinate stream, a TRU rich stream, and a technetium and uranium stream (nearly 100% recovery here). The technetium-/uranium-rich stream from the TRUEX process is routed to a separation system where 99% of the technetium is removed by absorption on an amine-loaded substrate. The stream containing technetium is sent to Waste Concentration, the product of which is transferred to interim lag storage. Liquid-liquid extraction is again used to selectively extract and purify 84% of the uranium fed to TRUEX-C for resale. The raffinate stream from the TRUEX process is transferred to the SREX section where it is processed through centrifugal contactors for SREX, scrubbing, and stripping. The strontium-rich stream is sent to HLW/TRU lag storage.

The partitioning facility is sized to process all Tank waste in 13 year of operation with a 60% online efficiency (2,850 operating days). The process equipment includes evaporator capacity and tanks to replace existing tank farm evaporators.

B21.2.1 Modifications Made to Existing TRUEX-C Model

Flow split blocks were added to reroute the HLW around neutralization steps to provide an option for direct calcination of acidic HLW before neutralization. Also, reactor blocks were added to represent the oxidation of the HLW stream during either the calcination or vitrification process steps.

B21.2.2 TRUEX-C Chemical Makeup

Numerous chemical compounds are used throughout the TRUEX-C process, including nitric acid, polyelectrolyte, sodium hydroxide, sodium oxalate, octyl(phenyl)-N, CMPO with TBP in a NPH, oxalic acid, tetrahydrofuran tetracarboxylic acid (THFTCA), ascorbic acid, sodium carbonate and bicarbonate, ferrous sulfamate, and dicyclohexano 19-crown-6 ether (DCH 18-Cr-6) in an n-octanol diluent. Large volumes of water are also used in the TRUEX-C process. Ion exchange resin is also used and regenerated. However, it will probably require periodic changeout.

Nitric acid is used in the TRUEX-C for several process steps with varied reasons. It is added to the dissolution step to dissolve the solids and to create a 3M HNO_3 dissolver product, to the extraction, scrub, and strip

contactors of TRUEX, uranium extraction (UREX), and SREX to aid in the solvent-solvent extraction, and to the CSIX columns to remove the captured cesium and regenerate the column.

Sodium hydroxide is added to TRUEX-C to regenerate the CSIX columns and to neutralize excess H^+ to meet tank farm specifications.

Sodium oxalate is used in the dissolution step subsequent to nitric acid digestion to promote further dissolution of the solids. Enough is added so that the exiting dissolver solution is $0.2M\ C_2O_4^{2-}$.

Oxalic acid is added to TRUEX-C to increase the amount of iron and zirconium extracted.

A CMPO/TBP/NPH mixture is used to extract the actinides, lanthanides, thorium, uranium, and technetium from the feed to the TRUEX step. The TBP/NPH is the organic extractant used in the UREX process step and serves to selectively extract in excess of 99% of the uranium from the feed.

A THFCA/ascorbic acid/nitric acid solution is added to TRUEX to strip the uranium and technetium from the CMPO/TBP/NPH extractant.

Sodium carbonate is added to the TRUEX wash contactors to remove virtually all of the uranium, technetium, and thorium from the organic (THFCA/ $C_6H_6O_8/HNO_3$) solution and is added to the technetium absorption column downstream of the contactors to remove the captured technetium.

Sodium bicarbonate is used to wash organic degradation products and impurities from the recycled organic routed to the solvent feed tanks for the TRUEX, SREX, and UREX process steps.

Ferrous sulfamate is added to the UREX feed to change the valence of plutonium from 4 to 3. This increases the amount of plutonium that will be scrubbed out and, therefore, increases the U^{2+} purity.

DCH 18-Cr-6 in an n-octanol diluent is the extractant used on the SREX process.

Air is fed to the dissolver offgas equipment and used in the conversion of NO_x to HNO_3 . A jet steam stream is used to propel the tank contents from one process to another. It is assumed that this adds 3 wt% of water to the solution being jetted.

B22.0 REFERENCES

- Boomer, K. D., et al., 1991, *Systems Engineering Study for the Closure of Single-Shell Tanks*, WHC-EP-0405, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Knutson, B. J., et al., 1993, "Advanced Chemical Separation Study: TRUEX Strategy Compared To Sludge Wash Ion Exchange," Letter report, Westinghouse Hanford Company, Richland, Washington.

Pajunen, A. L., et al., 1992, *Hanford Strategic Analysis Study*, WHC-EP-0549, Westinghouse Hanford Company, Richland, Washington.

Swanson, J. L., 1993, *Clean Option: An Alternative Strategy for Hanford Tank Waste Remediation*, Volume 2, *Detailed Description of First Example Flowsheet*, PNL-8388, Pacific Northwest Laboratory, Richland, Washington.

This page intentionally left blank.

Figure B1. CLEAN Option Flowsheet.

Figure B2. Waste Separations Technology Options
as Defined in WHC-EP-0405, Rev. 0.

Figure B3. Sludge Wash C.

Figure B5. CLEAN Option IDEF Flowsheet Structure.

April 7, 1994
Joy Backs

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 1 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 3 of 66)

LEVEL
NODE: A232211
PAGE: 3

DIAGRAM TITLE:
SEPARATE SOLIDS AND LIQUIDS AND DISSOLVE SOLIDS

Westinghouse
Hanford Company
Systems Technology Group
8/5/94 2:59 PM

AIIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

2 of 6

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 4 of 66)

B-28

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 5 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 6 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 7 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 8 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 9 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 10 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 11 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 13 of 66)

B-37

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 14 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 15 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 16 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 17 of 65)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 18 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 19 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 21 of 66)

B-45

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 22 of 66)

Figure B6. CLEAN Option Northwest Laboratory Detailed Level.
(sheet 23 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 24 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 25 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 26 of 66)

NOTE: The operations on this page are NOT steady state.

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 27 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 28 of 66)

Westinghouse
Hanford Company

8/5/94 2:58 PM
Systems Technology Group

DIAGRAM TITLE:
REGENERATE IX BEDS

LEVEL
NODE: A232212223
PAGE: 28

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 29 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(Sheet 30 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 31 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 32 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 33 of 66)

B-57

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 34 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 35 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 36 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 37 of 66)

B-61

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 38 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 39 of 66)

B-63

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 40 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 41 of 66)

B-65

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 42 of 66)

B-66

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 43 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 44 of 66)

NOTE: The operations on this page are NOT steady state.

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 45 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 46 of 66)

B-70

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 47 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 48 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 49 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 50 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 51 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 52 of 66)

B-76

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 53 of 66)

B-77

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 54 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 55 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 56 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 57 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 58 of 66)

B-82

Westinghouse
Hanford Company

8/5/94 2:57 PM
Systems Technology Group

DIAGRAM TITLE:
RECOVER NITRIC ACID RCOVACID: SEP

LEVEL
NODE: A23221431
PAGE: 58

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 59 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 60 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 61 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 62 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 63 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 64 of 66)

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 65 of 66)

B-89

Figure B6. CLEAN Option Pacific Northwest Laboratory Detailed Level.
(sheet 66 of 66)

Westinghouse
Hanford Company

8/5/94 2:57 PM
Systems Technology Group

DIAGRAM TITLE:
COLLECT GAS MIXOGAS: MIX

LEVEL
NODE: A23227
PAGE: 66

Table B1. Thirty Most Abundant Species by Mass in Waste Feed Streams.

	SST MASS(Kg)		DST MASS(Kg)		COMBINED PHASES		LIQUID PHASE CONC. (mole)	SOLID PHASE (wt%)
	LIQUID	SOLID	LIQUID	SOLID	(Kg)	(gMole)		
TOTAL	5.56E+08	1.64E+07	1.83E+08	1.88E+06	7.57E+08	3.54E+10		
H2O	3.86E+08	0.00E+00	1.31E+08	0.00E+00	5.17E+08	2.87E+10		
NO3-	9.60E+07	9.74E+05	1.39E+07	5.81E+04	1.11E+08	1.79E+09	3.431	5.64%
NA+	5.12E+07	5.12E+05	1.67E+07	2.03E+05	6.86E+07	2.98E+09	5.713	3.91%
OH-	7.10E+06	2.05E+06	9.72E+06	5.83E+05	1.94E+07	1.14E+09	1.913	14.36%
NO2-	4.75E+06	4.86E+04	5.04E+06	1.46E+04	9.85E+06	2.14E+08	0.412	0.35%
PO4-3	5.50E+06	3.30E+06	2.01E+05	1.61E+04	9.02E+06	9.49E+07	0.116	18.11%
AL+3	5.53E+05	1.65E+06	2.11E+06	9.42E+04	4.40E+06	1.63E+08	0.191	9.51%
CO3-2	1.53E+06	1.67E+05	1.10E+06	1.69E+04	2.82E+06	4.70E+07	0.085	1.01%
CANCRINITE	0.00E+00	2.70E+06	0.00E+00	0.00E+00	2.70E+06	7.93E+06	0.000	14.76%
SO4-2	1.62E+06	3.36E+04	3.74E+05	5.67E+03	2.03E+06	2.11E+07	0.040	0.21%
K+	3.95E+05	4.69E+03	1.42E+06	1.69E+04	1.84E+06	4.71E+07	0.090	0.12%
UO2+2	8.16E+04	1.51E+06	1.34E+04	3.01E+04	1.63E+06	6.04E+06	0.001	8.40%
F-	7.69E+05	4.09E+04	3.65E+05	1.68E+04	1.19E+06	6.27E+07	0.116	0.32%
ZR02:2H2	2.14E+04	4.15E+05	1.72E+03	5.45E+05	9.83E+05	6.17E+06	0.000	5.24%
TOC	1.80E+05	2.01E+04	6.02E+05	1.32E+04	8.15E+05	6.79E+07	0.126	0.18%
FE+3	6.24E+03	6.24E+05	1.23E+03	1.01E+05	7.32E+05	1.31E+07	0.000	3.96%
BA+2	0.00E+00	5.00E+05	3.09E+02	1.45E+03	5.02E+05	3.65E+06	0.000	2.74%
N12FECN6	0.00E+00	4.98E+05	0.00E+00	0.00E+00	4.98E+05	1.51E+06	0.000	2.72%
CL-	3.80E+04	2.01E+03	4.46E+05	5.10E+02	4.87E+05	1.37E+07	0.026	0.01%
PB+4	0.00E+00	4.36E+05	2.69E+03	9.96E+02	4.40E+05	2.12E+06	0.000	2.39%
BI+3	6.41E+04	1.97E+05	0.00E+00	0.00E+00	2.61E+05	1.25E+06	0.001	1.08%
CE+3	2.33E+03	2.33E+05	2.45E+01	8.20E+02	2.36E+05	1.68E+06	0.000	1.28%
MNO2	9.50E+03	1.80E+05	1.19E+04	1.04E+04	2.12E+05	2.44E+06	0.000	1.04%
CR+3	1.14E+04	1.04E+05	3.20E+04	3.63E+04	1.83E+05	3.52E+06	0.002	0.76%
CA+2	6.42E+03	1.24E+05	3.69E+03	1.30E+04	1.47E+05	3.66E+06	0.000	0.75%
SI+4	0.00E+00	0.00E+00	1.34E+04	4.66E+04	6.00E+04	2.14E+06	0.001	0.25%
SR+2	4.67E+02	4.64E+04	3.23E+00	2.44E+02	4.71E+04	5.38E+05	0.000	0.26%
LA+3	2.81E+02	2.76E+04	4.54E+01	1.07E+04	3.87E+04	2.78E+05	0.000	0.21%
P2O5:24W	0.00E+00	2.01E+04	0.00E+00	0.00E+00	2.01E+04	3.29E+03	0.000	0.11%
TH+4	1.34E+02	1.29E+04	2.91E+01	7.97E+02	1.38E+04	5.96E+04	0.000	0.07%

Table B2. Key Species in the Supernatant and Supercritical Water Oxidation Impact.

Species	Starting Liquid Phase Mass(kg)	Precipitation/ Destruction by SCWO	<----- AFTER SCWO ----->	
			Liquid Phase Mass (kg)	Liquid Phase Conc. (molal)
TOTAL	7.39E+08			
H2O	5.17E+08			
NA+	6.79E+07		6.79E+07	5.71E+00
NO3-	1.10E+08		1.10E+08	3.43E+00
OH-	1.68E+07		1.68E+07	1.91E+00
NO2-	9.79E+06		9.79E+06	4.12E-01
Al+3	2.66E+06	30%	1.86E+06	1.33E-01
PO4-3	5.70E+06		5.70E+06	1.16E-01
F-	1.13E+06		1.13E+06	1.16E-01
K+	1.82E+06		1.82E+06	9.00E-02
CO3-2	2.64E+06		2.64E+06	8.50E-02
SO4-2	1.99E+06		1.99E+06	4.01E-02
CL-	4.84E+05		4.84E+05	2.64E-02
TOC	7.82E+05	99%	7.82E+03	1.26E-03
SI+4	1.34E+04		1.34E+04	9.25E-04
ZRO2:2H2	2.32E+04		2.32E+04	2.81E-04
MO+6	3.27E+03		3.27E+03	6.59E-05
MG+2	5.35E+02		5.35E+02	4.26E-05
W+6	3.87E+03		3.87E+03	4.07E-05
TCO4-	2.98E+03		2.98E+03	3.56E-05
PB+4	2.69E+03		2.69E+03	2.52E-05
CS+	1.67E+03		1.67E+03	2.43E-05
CR+3	4.34E+04	99%	4.34E+02	1.61E-05
UO2+2	9.49E+04	99%	9.49E+02	6.80E-06
BI+3	6.41E+04	99%	6.41E+02	5.94E-06
CA+2	1.01E+04	99%	1.01E+02	4.88E-06
MNO2	2.14E+04	99%	2.14E+02	4.77E-06
FE+3	7.46E+03	99%	7.46E+01	2.59E-06
CD+2	2.30E+03	99%	2.30E+01	3.96E-07
CE+3	2.35E+03	99%	2.35E+01	3.25E-07
FECN6-3	3.54E+03	99%	3.54E+01	3.23E-07
ZN+2	8.83E+02	99%	8.83E+00	2.61E-07
NI+3	5.78E+02	99%	5.78E+00	1.91E-07
SR+2	4.70E+02	99%	4.70E+00	1.04E-07
LA+3	3.26E+02	99%	3.26E+00	4.54E-08
BA+2	3.09E+02	99%	3.09E+00	4.35E-08
TH+4	1.63E+02	99%	1.63E+00	1.36E-08
SN+4	1.65E+01	99%	1.65E-01	2.68E-09
PU+4	1.54E+01	99%	1.54E-01	1.24E-09
SM+3	4.87E+00	99%	4.87E-02	6.27E-10
NP+4	4.53E+00	99%	4.53E-02	3.70E-10
AM+3	1.99E+00	99%	1.99E-02	1.58E-10
CM+3	3.84E-04	99%	3.84E-06	3.00E-14

Table B3. Component Dissolution by Base/Acid Process.

SOLID PHASE SPECIES	<----- % DISSOLUTION ----->		
	CAUSTIC	NITRIC / OXALIC	NITRIC / HF
AG+		90%	90%
AL+3	90%	50%	50%
AL ₂ O ₃	50%		
AM+3		90%	50%
APM-	90%		
AS+5		90%	90%
B+3		90%	90%
BA+2		90%	90%
BE+2		90%	90%
BI+3		90%	50%
C14		90%	90%
CA+2		90%	90%
CANCRINITE	50%		10%
CD+2		90%	90%
CE+3		90%	90%
CL-		90%	90%
CM+3		90%	90%
CO+3		90%	90%
CO ₃ -2		90%	90%
CR+3		90%	50%
CS+		90%	90%
CU+2		90%	90%
F-		90%	90%
FE+3		90%	50%
FECN6-3		90%	90%
HG+2		90%	90%
I-		90%	90%
K+		90%	90%
LA+3		90%	50%
LI+		90%	90%
MG+2		90%	90%
MN+2		90%	90%
MNO ₂		90%	50%
MO+6		90%	90%
NA+		90%	90%
NB+5		90%	90%
NI+3		90%	90%
NI ₂ FECN6	90%		
NO ₂ -		90%	90%
NO ₃ -		90%	90%
NP+4		90%	50%
OH-		90%	90%
P ₂ O ₅ :24W		90%	90%
PB+4		90%	90%
PO ₄ -3	90%	90%	90%
PU+4		90%	50%
RB+		90%	90%
RE+7		90%	90%
RH+3		90%	90%
RU+3		90%	90%
SB+5		90%	90%
SE+6		90%	90%
SI+4		90%	90%
SM+3		90%	90%
SN+4		90%	90%
SO ₄ -2	90%	90%	90%
SR+2		90%	90%
TCO ₄ -		90%	90%
TE+6		90%	90%
TH+4		90%	50%
TI+4		90%	90%
TL+3		90%	90%
TOC		90%	90%
UO ₂ +2		90%	90%
V+5		90%	90%
W+6		90%	90%
ZN+2		90%	90%
ZR+4		90%	90%
ZRO ₂ :2H ₂		90%	50%

Table B4. Tributyl Phosphate Extraction of Transuranics Section:
Component Distribution.

<---- Component distribution among outlet streams ----->

Stream (St)*	St No. 7	St No. 11	St No. 15	St No. 18	St No. 19
Species	<u>To Am/La Separation</u>	<u>To HLW</u>	<u>To Uran. Purif.</u>	<u>To Basic Side Feed</u>	<u>Solvent Recycle</u>
Am+3	99.99%	.01%			
B1+3	99.90%	.10%			
Ce+3	99.99%	.01%			
Cm+3	99.99%	.01%			
Fe+3	99.99%	.01%			
La+3	99.99%	.01%			
Np+4	1.00%	98.99%	.01%		
Pu+4	.01%	99.98%	.01%		
Sm+4	99.99%	.01%			
TcO4-	99.90%	.05%	.05%		
Th+4	1.00%	98.99%	.01%		
UO2+2	.01%	.10%	99.88%	.01%	
Zr+4	99.90%	.10%			
TBP Solvent			.001%		99.999%

Table B5. Uranium Purification Section: Component Distribution.

<---- Component distribution among outlet streams ----->

Stream (St)*	St No. 3	St No. 36	St No. 34	St No.31	St No. 35
Species	<u>To Extract. Transuranic</u>	<u>Uran. To Stockpile</u>	<u>To LLW</u>	<u>To Water Recycle</u>	<u>Solvent Recycle</u>
[H+]	2.4M			remainder	
Np+4	100%				
Pu+4	100%				
TcO4-	100%				
Th+4	100%				
[UO2+2]	0.18M	remainder	.01%		
Solvent				.001%	99.999%

*Stream identification numbers from Figure B1 CLEAN Option Flowsheet.

Table B6. CMPO Extraction Americium/Lanthanum Section:
Component Distribution.

<--- Component distribution among outlet streams --->

Stream ID*	Strm #42	Strm #45	Strm #51	Strm #52
Species	To Sr/Tc Extraction	To Am/La Separation	To LLW	Solvent Recycle
Am+3	.01%	99.98%	.01%	
Bi+3	.50%	1.00%	98.50%	
Ce+3	.01%	99.98%	.01%	
Cm+3	.01%	99.98%	.01%	
Cs+	100.00%			
Fe+3	99.99%	.01%		
H+	91.40%	8.57%	.03%	
La+3	.01%	99.98%	.01%	
Sm+3	.01%	99.98%	.01%	
Sr+2	100.00%			
TcO4-	99.90%	.05%	.05%	
Zr+4	99.90%	.10%		
Solvent			.001%	99.999%

Table B7. Americium/Lanthanum Band Displacement Section:
Component Distribution.

<--- Component distribution among outlet streams --->

Stream ID*	Strm #60	Strm #61	Strm #62
Species	To Acidic LLW	To Basic LLW	To HLW
Am+3	.01%	.01%	99.98%
Ce+3	.01%	99.89%	.10%
Cm+3	.01%	.01%	99.98%
La+3	.01%	99.99%	
Sm+3	.01%	remainder	100 mole/mole Am
DTPA-3 (from .05M DTPA strip solution)		remainder	1.00%
Na+ (from .05M DTPA strip solution)		remainder	10 mole/mole Am
Zn+2 (from Zn regeneration soln.)		remainder	0.1 mole/mole Am

*Stream identification numbers from Figure B1 CLEAN Option Flowsheet.

Table B8. Crown Ether Extraction Strontium/Technetium Section:
Component Distribution.

<--- Component distribution among outlet streams --->

Stream ID*	Strm #75	Strm #72	Strm #78	Strm #79
<u>Species</u>	<u>To Sr/Ba/Tc Separation</u>	<u>To Cs APM Extraction</u>	<u>Basic LLW</u>	<u>Solvent Recycle</u>
Ba+2	99.99%	.01%		
Sr+2	99.99%	.01%		
TcO4-	99.00%	1.00%		
HNO3	2.6M	remainder		
Solvent			.001%	99.999%

Table B9. Strontium/Barium Band Displacement Section:
Component Distribution.

<--- Component distribution ---->

Stream ID*	Strm #95	Strm #94
<u>Species</u>	<u>To Basic LLW</u>	<u>To HLW</u>
Ba+2	remainder	0.3 mole/mole Sr+2
Sr+2	.01%	99.99%
TcO4-	0.00%	100%
EDTA-3 (from .05M EDTA strip solution)	remainder	7.20%
Na+ (from .05M EDTA strip solution)	remainder	0.13 mole/mole Sr+2
Zn+2 (from Zn regeneration soln.)	remainder	0.1 mole/mole Sr+2

Table B10. Basic Cesium Ion Exchange: Relative Flow
Volumes of Streams.

<u>Stream Name</u>	<u>Stream Number*</u>	<u>Column Volumes</u>	<u>Composition</u>
Column Feed	450	2000	---
Regeneration streams			
Feed flush	300	3	2M NaOH
Feed flush	301	6	Water
Cesium Eluant	302	20	Formic acid
Eluant Flush	303	3	Water
Regeneration	304	3	2M NaOH

*Stream identification numbers from Figure B1 CLEAN Option Flowsheet.

Table B11. Basic Strontium Ion Exchange: Relative Flow Volumes of Streams.

<u>Stream Name</u>	<u>Stream Number*</u>	<u>Column Volumes</u>	<u>Composition</u>
Column Feed	305	2000	---
Regeneration streams			
Feed flush	314	3	2M NaOH
Feed flush	315	6	Water
Strontium Eluant	316	20	1M HNO3
Eluant Flush	317	3	Water
Regeneration	318	3	2M NaOH

Table B12. Basic Technetium Ion Exchange: Relative Flow Volumes of Streams.

<u>Stream Name</u>	<u>Stream Number*</u>	<u>Column Volumes</u>	<u>Composition</u>
Column Feed	319	100	---
Regeneration streams			
Feed flush	331	8	2M NaOH
Feed flush	332	12	Water
Na+ displacement	333	6	0.25M HNO3
Technetium Eluant	337	20	6M HNO3
Eluant Flush	335	6	Water
Regeneration	336	8	2M NaOH

*Stream identification numbers from Figure B1 CLEAN Option Flowsheet.

Table B13. Characteristics of Solid Portion of Waste Stream ("Sludge").

Species	Waste Kg	Feed Solids Moles	Mole%	Dissolution Species	%Diss	Undissolved Solids Moles	Mole%
Total	1.79e+07	3.53e+05				4.17e+04	
OH-	2.33e+06	1.37e+05	38.90%	OH-	91.58%	1.16e+04	27.71%
AL+3	1.75e+06	6.49e+04	18.39%	CANCR	0.00%	7.94e+03	19.03%
PO4-3	4.39e+06	4.62e+04	13.10%	AL+3	88.77%	7.28e+03	17.47%
NA+	7.07e+05	3.07e+04	8.72%	PO4-3	90.03%	4.61e+03	11.05%
NO3-	1.02e+06	1.65e+04	4.68%	NA+	92.10%	2.43e+03	5.83%
FE+3	6.97e+05	1.25e+04	3.54%	NO3-	88.34%	1.92e+03	4.61%
CANCR	2.70e+06	7.94e+03	2.25%	NI2FECN6	0.00%	1.51e+03	3.63%
ZRO2	9.63e+05	6.05e+03	1.71%	FE+3	90.47%	1.19e+03	2.85%
UO2+2	1.45e+06	5.37e+03	1.52%	UO2+2	90.16%	5.29e+02	1.27%
CA+2	1.47e+05	3.66e+03	1.04%	ZRO2	92.39%	4.60e+02	1.10%
F-	5.65e+04	2.97e+03	0.84%	CA+2	90.20%	3.59e+02	0.86%
CO3-2	1.75e+05	2.91e+03	0.83%	TOC	90.00%	2.77e+02	0.66%
TOC	3.32e+04	2.77e+03	0.78%	CO3-2	90.83%	2.67e+02	0.64%
MNO2	1.91e+05	2.20e+03	0.62%	SI+4	86.59%	2.22e+02	0.53%
CR+3	9.89e+04	1.90e+03	0.54%	MNO2	90.20%	2.16e+02	0.52%
CE+3	2.34e+05	1.67e+03	0.47%	F-	92.87%	2.12e+02	0.51%
SI+4	4.66e+04	1.66e+03	0.47%	CR+3	90.05%	1.89e+02	0.45%
NI2FECN6	4.98e+05	1.51e+03	0.43%	CE+3	89.96%	1.68e+02	0.40%

APPENDIX C

HANFORD STRATEGIC ANALYSIS MODEL:
ASPEN PLUS¹ IMPLEMENTATION

¹ASPEN PLUS is a trademark of Aspen Technology, Inc.

LIST OF TERMS

HSA	Hanford Strategic Analysis
IDEF	Integrated Computer-Aided Manufacturing (ICAM) Definition (Language)

HANFORD STRATEGIC ANALYSIS MODEL: ASPEN PLUS IMPLEMENTATION

Several process simulation models were developed for the Hanford Strategic Analysis (HSA) Study (Pajunen et al. 1992). The steady-state process simulation program ASPEN PLUS was selected for the modeling of the HSA models to provide mass or material balance calculations for each process flowsheet design. Special material data libraries were created for use with the ASPEN PLUS program to allow modeling the various material waste stream flows. These libraries allowed using radioactive and hazardous materials as components of each stream. However, global level model runs subsequent to those analyses have incorporated component radioactivity data by making a separate model run with curie inventories substituted in the feedstream.

To control the model complexity or abstraction level, waste stream component lumping (i.e., detailed to more general) was used extensively to allow modeling the entire waste processing system, from cradle to grave, with reasonable detail to provide a good assessment of various waste cleanup strategies and options, including sensitivity and parametric studies.

The ASPEN PLUS model implementation started with process flowsheets developed for the various waste cleanup strategies and their respective options. The process flowsheet for the representative Strategy IX, Option 2, is shown in Figure C1. The process flowsheets were subsequently modeled using the Integrated Computer-Aided Manufacturing (ICAM) Definition (Language) (IDEF) software tool (Pajunen et al. 1992) at a higher abstraction or less detailed level showing all major feed and product streams and the main process blocks. The IDEF tool allowed showing the flowsheet description at increasingly decomposed states (i.e., a hierarchical representation). The higher level model allowed good understanding of the overall waste flow in each strategy/option and facilitated the development of the detailed process models. Each main process and stream in the higher level model was further broken down or decomposed to an appropriate detail level for implementation using ASPEN PLUS. Thus, the IDEF representations became the ASPEN PLUS flowsheet specifications. The IDEF flowsheet representation for Strategy IX, Option 2, is shown in Appendix D with the CLEAN Option process strategy appropriately integrated. Figure C2 shows the final ASPEN PLUS implementation model for Strategy IX, Option 2.

The IDEF model flowsheet specifications were used to build the ASPEN PLUS flowsheet model connectivity with all the specified feed and product streams. In place of rigorous chemical and physical process models, the HSA ASPEN PLUS models used simpler mixers and splitter models, referred to as MIXER, FSPLIT, and SEP process unit blocks (Appendix A). The MIXER block combines material streams into one stream. The FSPLIT block combines material streams and divides the resulting stream into two or more streams, with all outlets having the same composition and properties. The SEP block combines streams and separates the resulting stream into two or more streams according to splits or separation factors specified for each component.

The ASPEN PLUS HSA model detail consisted of between 30 and 40 process blocks for each strategy/option, with between 20 and 30 feedstreams and 20 to 30 product streams. Including internal connectivity streams, the ASPEN PLUS models contained between 140 and 170 streams. Each stream contained 14 pseudo (lumped) components as shown below. Figure C3 shows the lumped component attribute tree structure. A more detailed breakdown of each of these components into more specific chemical species is described in Appendix D.

Pseudo-
Component

Name	Long name	Definition
H2O	WATER	Water, including all liquids
TRU2	TRANSU	All elements with atomic number above uranium (92)
ACT2	ACTINIDE	Uranium and thorium and daughters
LAN	LANTH	All lanthanides
CS	CESIUM	All cesium
SR	STRONTIUM	All strontium
TC	TECHNETIUM	Technetium, ⁹⁹ TC
I	IODINE	All iodine
FP2	FISPROD2	All remaining fission products
AP1	ACTPROD1	All Activation Products
NaNO3	NaNO3	Sodium nitrate including NaNO2 and NaNO3
OHAZ1	OHAZ1	Hazardous chemicals
SOI	SOIL	All normal soil (dirt) constituents, excluding water
OTH2	OTHER2	All other solids, except macroscopic dirt constituents

To provide data to run the ASPEN PLUS models, separate spreadsheet tables were created with all the required feedstream mass (kg or curie) inventories. These spreadsheet files are referred to as the Inventory Specifications. These inventory data are shown on the output results for the Strategy IX, Option 2 model (Table C1). Similarly, the separation or stream component split factors needed for the FSPLIT and SEP process blocks were tabulated in spreadsheet files for each process block and its product streams. Thus, there were 14 separation factors per product stream except for the single split factor required by the FSPLIT blocks. These split factors are referred to as the Separation Factor Specifications and are shown in Table C2.

Initially the interactive/graphics model management tool, ModelManager¹, a program provided with ASPEN PLUS, was used to create the ASPEN PLUS models. The graphical user interface within ModelManager allowed relatively fast creation of the flowsheet connectivity while its built-in expert system guided the model development. Menu driven data sheets also facilitated data entry with checking for model completeness and correctness. As the HSA analyses progressed, the model data entry was automated using special spreadsheet script programs. These scripts output the specification data to files in the correct ASPEN PLUS format and, thus, avoided the table entry requirements within ModelManager. A word processor or editor was then used to incorporate each section into a complete ASPEN PLUS input file.

¹ModelManager is a trademark of Aspen Technology, Inc.

The chemical makeup mass inventories were also specified for each base strategy (option 2) model. Special FORTRAN blocks were written using in-line FORTRAN statements to reproduce these base strategy makeup inventories and provide automatic run-time chemical or physical makeup addition calculations for use in the other strategy/option models. These FORTRAN blocks adjusted the makeup stream component mass flows before they were used by the individual process blocks. The makeup mass calculations consisted of applying a makeup-to-input mass ratio for each process block, based on either the total amount of solids flow (defined as the mass flow of all components less H_2O) or the total mass flow of all components, into each process block. These ratios represented the actual makeup inventory modeled in the base strategy runs. When the makeup was determined, three additional ratios split the makeup inventory into three components, H_2O , OHAZ1, and OTH2. A few special cases included the addition of soil through the makeup calculations. These chemical makeup mass ratios are shown for Strategy IX, Option 2, in Table C3.

REFERENCES

Pajunen, A. L., et al., 1992, *Hanford Strategic Analysis Study*, WHC-EP-0549, Westinghouse Hanford Company, Richland, Washington.

Figure C1. Hanford Strategic Analysis Study – Strategy IX, Option 2.

Figure C3. Pseudo Component Attribute Tree.

Table C1. Hanford Strategic Analysis Mass Balance Output Results (kilogram). (sheet 2 of 5)

File: C:\ASPRUN\S0837142.INP (HSA BASE RUN, STRATEGY 09, 37 BLOCKS, 14 COMPONENTS, OPTION 2)

Output Streams	H2O	TRU2	ACT2	LAN	CS	SR	TC	I	FP2	AP1	NANO3	OHAZ1	SOI	OTH2	Totals (Kgs)
1140NRNH	2.60E+03	2.30E-06	1.51E-06	1.51E-06	1.51E-06	1.51E-06	1.51E-06	1.50E-06	1.95E-04	4.21E+00	1.50E-06	1.48E+04	2.97E+06	1.47E+06	4.45E+06
1160NRNH	2.41E+03	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.10E+04	1.36E+07	1.08E+08	1.22E+08
1220SOIL	7.97E+08	1.86E-02	2.19E-01	3.00E-10	2.52E-04	2.26E-05	4.31E-05	3.00E-10	3.00E-10	3.00E-10	3.25E+03	3.41E-01	2.39E+10	3.38E+01	2.47E+10
1300H2O	3.08E+11	2.00E-10	7.96E+00	2.00E-10	7.51E-07	1.89E-08	1.63E-07	2.00E-10	2.00E-10	2.00E-10	8.64E+05	1.00E+03	2.00E-10	9.91E+04	3.08E+11
2120HLWS	3.61E+01	7.04E+03	2.12E+06	3.51E+02	6.73E+02	2.24E+02	1.81E+02	5.15E+01	5.88E+03	1.05E+05	8.00E-10	6.85E-01	4.96E-06	5.31E+05	2.77E+06
2141SNM	1.10E+03	1.00E-04	2.00E-10	2.00E-10	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	2.00E-08	2.00E-10	1.23E+00	3.33E-07	1.21E+02	1.22E+03
2152UO2	7.85E+01	2.00E-10	2.92E+06	2.00E-10	6.67E-07	2.00E-10	1.00E-06	6.67E-07	6.67E-07	6.67E-07	2.00E-10	4.37E+01	6.67E-07	4.33E+03	2.93E+06
2200H2O	2.36E+10	4.11E-05	1.43E+03	7.26E-04	1.65E-04	7.71E-04	4.62E-05	5.82E-06	3.30E-02	1.54E-02	1.26E+04	3.85E+02	3.44E+04	1.16E+04	2.36E+10
2412NRNH	4.99E+01	2.70E-03	1.00E-01	3.00E-10	8.44E-06	4.17E-06	3.00E-10	1.53E-06	3.00E-10	3.00E-10	3.00E-09	2.16E+04	2.35E+07	2.10E+08	2.33E+08
2432SOIL	3.82E+06	1.84E-02	5.17E-01	6.83E-10	1.08E-03	9.66E-05	7.16E-06	1.82E-09	3.89E-08	1.91E-08	3.05E+03	6.85E+00	1.17E+08	2.03E+05	1.21E+08
2452SOIL	7.85E+08	2.95E-04	2.23E+00	1.05E-10	1.46E-03	1.33E-04	4.24E-04	3.96E-09	2.72E-10	2.72E-10	2.95E+05	9.99E+04	2.19E+10	2.99E+07	2.27E+10
3110HLWS	2.07E+04	9.84E+02	6.99E+04	3.58E+04	8.70E+03	3.83E+04	2.10E+03	2.90E+02	2.99E+05	1.71E+02	3.62E+06	2.21E+05	2.52E+03	2.12E+07	2.55E+07
3120TMWS	2.67E+04	4.13E+02	1.29E+05	7.19E-04	4.38E-01	4.07E-02	3.96E-04	1.93E-04	9.65E-02	4.72E-02	1.66E+05	2.10E+06	7.23E+06	2.03E+08	2.13E+08
3120TRUS	2.67E+04	4.13E+02	1.29E+05	7.19E-04	4.38E-01	4.07E-02	3.96E-04	1.93E-04	9.65E-02	4.72E-02	1.66E+05	2.10E+06	7.23E+06	2.03E+08	2.13E+08
3200HLWS	4.44E+07	4.46E+01	7.35E+04	1.99E+03	3.27E+02	2.06E+03	1.16E+02	1.61E+01	1.61E+04	8.21E+03	7.38E+06	1.35E+06	2.77E-08	1.35E+08	4.65E+08
3310LLWL	8.00E+11	2.00E-06	2.00E-06	2.00E-06	2.97E-02	1.15E-02	3.83E-02	2.00E-06	2.00E-06	2.00E-06	7.55E+06	2.84E+04	2.00E-06	2.81E+06	8.00E+11
3320LMWS	1.12E+04	2.70E-01	4.50E+02	2.48E-06	3.80E-02	1.88E-02	1.15E-06	7.66E-04	2.48E-06	2.48E-06	1.02E-06	1.94E+04	2.16E+05	1.92E+06	2.17E+06
3330LLWS	2.00E-06	2.57E+01	8.37E+04	2.00E-06	4.65E+01	6.65E+00	2.00E-06	2.00E-06	2.00E-06	2.00E-06	2.00E-06	8.17E+05	8.18E+06	8.09E+07	9.00E+07
3342LLWS	4.79E+09	4.80E-02	1.90E-06	1.90E-06	2.10E-02	7.80E-03	1.71E-02	6.00E-07	2.00E-07	1.90E-06	1.31E+06	1.70E+05	6.37E+10	2.90E+08	6.87E+10
3400LLWS	7.74E+08	1.54E+01	6.66E+05	5.52E+02	7.98E+00	1.52E+02	8.67E+00	1.18E+00	4.72E+02	7.67E+04	9.03E+07	1.53E+06	3.48E+07	1.56E+08	1.06E+09
3400LMWS	7.74E+08	1.54E+01	6.66E+05	5.52E+02	7.98E+00	1.52E+02	8.67E+00	1.18E+00	4.72E+02	7.67E+04	9.03E+07	1.37E+07	3.14E+08	1.40E+09	2.59E+09
3510LLWS	1.22E+07	1.59E+01	1.54E+05	3.54E-01	1.16E+01	2.12E+00	9.35E-01	2.59E-01	2.97E+01	6.48E+04	1.80E+06	3.53E+06	9.54E+08	8.53E+08	1.82E+09
3520NRHS	3.89E+07	8.21E-01	1.35E+03	7.40E-06	1.71E-02	4.00E-03	7.32E-06	7.14E-06	6.23E-04	4.22E+00	3.33E+04	1.35E+07	6.12E+06	1.61E+08	2.19E+08
3530LMWS	1.22E+07	8.83E+00	1.51E-05	7.26E-01	9.15E+00	2.51E+00	4.27E-02	2.61E-03	2.44E+01	1.14E+01	3.54E+06	8.58E+06	9.54E+08	8.79E+08	1.86E+09
Totals (Kgs)	1.14E+12	8.97E+03	7.16E+06	3.92E+04	9.78E+03	4.09E+04	2.42E+03	3.60E+02	3.23E+05	3.32E+05	2.07E+08	4.79E+07	1.12E+11	4.74E+09	1.26E+12

Table C1. Hanford Strategic Analysis Mass Balance Output Results (kilogram). (sheet 5 of 5)
 File: C:\ASPRUN\S0837142.INP (HSA BASE RUN, STRATEGY 09, 37 BLOCKS, 14 COMPONENTS, OPTION 2)

COENSW	2.07E+08	9.84E-02	6.99E+00	3.58E+00	8.70E-01	3.83E+00	2.10E-01	2.90E-02	3.00E+01	1.71E-02	3.62E+02	2.21E+01	2.52E-01	2.12E+03	2.07E+08
CS-SRCAP	1.00E-06	1.00E-06	1.00E-06	1.00E-06	2.97E+03	5.50E+02	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.10E+02	1.00E-06	1.09E+04	1.45E+04
DSTTNKW	7.52E+07	4.31E+02	2.68E+04	1.08E+04	5.60E+03	4.16E+03	1.30E+03	1.58E+02	3.15E+05	1.61E+05	5.80E+06	4.30E+05	1.00E-06	4.25E+07	1.25E+08
FFTRFUEL	5.00E-01	2.44E+03	6.58E+03	2.80E+02	9.93E+01	1.12E+01	2.23E+01	9.82E+00	5.17E+02	7.64E+03	1.00E-06	3.24E+02	1.00E-06	3.21E+04	5.00E+04
NKRFUEL	1.80E+05	4.50E+03	2.10E+06	7.32E+01	4.70E+02	1.60E+02	1.60E+02	4.20E+01	5.40E+03	1.52E+05	1.00E-06	1.60E+03	1.00E-06	1.58E+05	2.60E+06
NEWNRHSW	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-02	1.00E-06	9.90E-01
NEWRSW	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-02	1.00E-06	9.90E-01
NWDSBW	1.00E-06	1.14E-01	1.00E-06	1.00E-06	6.53E-04	4.68E-04	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	2.21E+06	2.21E+07	2.19E+08	2.43E+08
NWDSGW	3.11E+11	1.00E-06	7.96E+04	1.00E-06	7.51E-03	1.88E-04	1.63E-03	1.00E-06	1.00E-06	1.00E-06	2.47E+06	9.10E+03	1.00E-06	9.01E+05	3.11E+11
NWDSNRFA	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.22E+06	1.36E+07	1.21E+08
NWDSRFAC	2.79E-02	1.61E-01	1.00E-06	2.90E-03	1.18E-02	1.28E-03	1.75E-02	1.00E-06	3.86E+01	1.72E+01	1.00E-06	5.40E+05	6.00E+06	5.35E+07	6.00E+07
NWDSVAD	6.12E+06	1.00E-06	1.00E-06	1.00E-06	9.81E-06	9.93E-06	3.91E-05	1.00E-06	1.00E-06	1.00E-06	1.00E-06	4.20E+00	3.67E+07	4.16E+02	4.28E+07
PC2FUEL	1.00E-06	1.30E+02	1.56E+04	1.73E-03	3.82E-01	1.80E-01	1.00E-06	1.00E-06	4.33E-03	1.08E+04	1.00E-06	1.32E+01	1.00E-06	1.30E+03	2.78E+04
SNM	1.00E-06	1.00E+00	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	8.45E+02	1.00E-06	8.37E+04	8.45E+04
SSTTNKW	4.32E+07	4.40E+02	1.40E+06	2.80E+04	5.60E+02	3.60E+04	9.30E+02	1.50E+02	1.60E+03	4.94E+02	1.33E+08	4.94E+05	1.00E-06	4.89E+07	2.27E+08
STOPRHSW	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	8.53E+03	1.00E-06	8.44E+05	8.53E+05
UGTNKSTR	2.81E+06	2.20E-01	7.00E+02	1.40E+01	1.34E+01	1.80E+01	2.32E+00	3.75E-01	8.00E+00	1.23E+00	3.31E+05	1.31E+06	2.77E+08	1.29E+08	4.11E+08
URAN	7.85E+05	1.00E-06	2.93E+06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	3.74E+03	1.00E-06	3.70E+05	4.09E+06
WDS70TMW	1.00E-06	3.23E+02	4.62E+05	1.00E-06	2.39E-03	6.77E-04	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.59E+05	1.64E+06	1.57E+07	1.80E+07
WDSGW	8.00E+11	1.00E-06	1.00E-06	1.00E-06	2.97E-02	1.15E-02	3.83E-02	1.00E-06	1.00E-06	1.00E-06	7.55E+06	2.84E+04	1.00E-06	2.81E+06	8.00E+11
WDSLLWS	1.00E-06	2.57E+01	8.37E+04	1.00E-06	4.65E+01	6.65E+00	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	8.17E+05	8.18E+06	8.09E+07	9.00E+07
WDSNRFA	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.80E+06	2.00E+07	1.78E+08	2.00E+08
WDSRFAC	1.00E-06	2.70E+01	1.00E+03	1.00E-06	8.44E-02	4.17E-02	1.00E-06	1.53E-02	1.00E-06	1.00E-06	1.00E-06	3.60E+05	4.00E+06	3.56E+07	4.00E+07
WDSRMBRS	1.00E-06	4.68E+02	5.46E+04	1.00E-06	1.70E+01	3.99E+00	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.00E-06	4.54E+05	4.55E+06	4.49E+07	5.00E+07
WDSVAD	1.07E+10	2.40E-01	1.00E-06	1.00E-06	2.10E-01	7.80E-02	5.71E-02	1.00E-06	1.00E-06	1.00E-06	2.62E+07	4.27E+03	6.40E+10	4.23E+05	7.47E+10

Table C2. Hanford Strategic Analysis Separation Specifications. (sheet 1 of 2)

Table C1. SEPARATION SPECIFICATIONS FILE: SEPS_IX_OP2_R6 REV. 18 R.HARMSSEN 14 FEB 92
STRATEGY IX OPTION 2 35 box 14 component PARTIQU SEPS UPDATED TO ACHIEVE PROPER GROUT AND GLASS FEEDS.

PROCESSORS	OUTSTREAMS	COMPONENTS														TOTAL	DENSITY	VOLUME
		H2O	TRU2	ACT2	LAN	CS	SR	TC	I	FP2	AP1	NANO3	CHAZ1	SOI	OTH2			
A111: DEACFAC1:	1110TMWS	.0001	.9800	.0010	.9800	.0010	.0100	.0010	.0010	.0100	.0100	.0010	.0143	.0001	.0143	1.00E+00	2.00E+03	
A111: DEACFAC1:	1110LMWL	.9998	.0100	.9980	.0100	.9980	.9800	.9980	.9980	.9800	.0100	.9980	.0003	.0001	.0003	1.00E+00	1.00E+03	
A111: DEACFAC1:	1110FAC	.0001	.0100	.0010	.0100	.0010	.0100	.0010	.0010	.0100	.9800	.0010	.9854	.9998	.9854	1.00E+00	2.00E+03	
A112: DECONFAC:	1120TMWS	.0002	.9889	.0100	.9889	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.8533	.0001	.8533	1.00E+00	2.00E+03	
A112: DECONFAC:	1120LMWL	.9994	.0100	.9780	.0100	.9979	.9979	.9979	.9979	.9979	.4994	.9979	.0014	.0010	.0014	1.00E+00	1.00E+03	
A112: DECONFAC:	1120FAC	.0002	.0010	.0100	.0010	.0010	.0010	.0010	.0010	.0010	.4995	.0010	.0554	.9889	.0554	1.00E+00	2.00E+03	
A112: DECONFAC:	1120NRHS	.0002	.0001	.0010	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0899	.0100	.0899	1.00E+00	2.00E+03	
A113: DEMOLFAC:	1130FAC	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	1.00E+00	2.00E+03	
A113: DEMOLFAC:	1130NRHS	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	1.00E+00	2.00E+03	
A114: REMOVFAC:	1140NRNH	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.00E+00	2.00E+03	
A115: DEACFAC2:	1150FAC	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.9000	.9990	.9000	1.00E+00	2.00E+03	
A115: DEACFAC2:	1150NRHS	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.1000	.0010	.1000	1.00E+00	2.00E+03	
A116: DEMREM:	1160NRHS	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.9900	.0010	.0100	1.00E+00	2.00E+03	
A116: DEMREM:	1160NRNH	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.0100	.9990	.9900	1.00E+00	2.00E+03	
A121: RETRESM:	1210TMWS	.5000	.9990	.9990	.0010	.0010	.0010	.0010	.0010	.0010	.5000	.5000	.5000	.5000	.5000	1.00E+00	2.00E+03	
A121: RETRESM:	1210LLWS	.5000	.0010	.0010	.9990	.9990	.9990	.9990	.9990	.9990	.5000	.5000	.5000	.5000	.5000	1.00E+00	2.00E+03	
A122: EXCAQLAS:	1220SOIL	.1667	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.5000	.0001	2.50E+10	1.55E+03	
A122: EXCAQLAS:	1220TRUS	.0042	.9840	.0002	.9840	.4278	.4278	.0166	.0166	.4278	.4278	.0940	.0910	.0025	.0910	1.40E+08	1.75E+03	
A122: EXCAQLAS:	1220LMWS	.8291	.0159	.9997	.0159	.5721	.5721	.9833	.9833	.5721	.5721	.9059	.9089	.4975	.9089	2.80E+10	1.75E+03	
A13: PUMTREAT:	1300LLWS	.0001	.4999	.4900	.4999	.4995	.4995	.4995	.4995	.4995	.4995	.0500	.0500	.3000	.9700	3.10E+09	2.00E+03	
A13: PUMTREAT:	1300LMWL	.0100	.4999	.4999	.4999	.4994	.4994	.4994	.4994	.4994	.4994	.5990	.0500	.0010	.0099	9.90E+08	1.00E+03	
A13: PUMTREAT:	1300NRHS	.0001	.0001	.0100	.0001	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.8999	.8989	.0200	6.10E+07	2.00E+03	
A13: PUMTREAT:	1300H2O	.9898	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.3500	.0001	.0001	.0001	3.08E+11	1.00E+03	
A211: CLEANNA:	2110FFTF	.0010	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.0001	.9999	.5000	.9999	5.80E+04	6.00E+03	
A211: CLEANNA:	2110LMWL	.9990	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.9999	.0001	.5000	.0001	6.30E+05	1.00E+03	
A212: PROFEMOT:	2120LLWS	.0010	.0010	.0010	.0010	.0007	.0001	.0050	.0050	.0050	.3800	.0010	.0001	.0039	.2148	2.90E+05	2.45E+03	
A212: PROFEMOT:	2120CSSR	.0002	.0001	.0010	.0001	.8092	.8698	.0001	.0001	.0001	.0001	.0002	.9988	.0001	.0002	1.70E+04	6.00E+03	
A212: PROFEMOT:	2120TMWL	.9986	.0039	.0010	.0039	.0001	.0001	.0010	.0010	.0010	.0039	.9986	.0010	.0039	.0010	2.80E+06	1.00E+03	
A212: PROFEMOT:	2120HLWS	.0002	.9950	.9970	.9950	.1900	.3100	.9939	.9939	.9939	.6160	.0002	.0001	.9921	.7840	1.80E+05	1.48E+03	
A213: DISSCSSR:	2130HLWL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3.10E+04	1.21E+03	
A214: PROCSNM:	2141SNM	.0001	.0001	.0001	.0001	.1666	.1666	.1666	.1666	.1666	.0100	.0001	.0001	.1666	.0001	1.00E+04	1.00E+04	
A214: PROCSNM:	21412LML	.9602	.0001	.2499	.0010	.1666	.1666	.1666	.1666	.1666	.0100	.0001	.0100	.1666	.0100	1.10E+07	1.00E+03	
A214: PROCSNM:	2141NRHS	.0001	.0001	.0003	.0003	.1667	.1667	.1667	.1667	.1667	.0010	.0001	.0001	.1667	.0001	1.00E+00	1.00E+03	
A214: PROCSNM:	2141TMWS	.0010	.0010	.2499	.4943	.1667	.1667	.1667	.1667	.1667	.4890	.0001	.7198	.1667	.7198	9.70E+05	5.00E+02	
A214: PROCSNM:	2141LMWS	.0001	.0001	.2499	.0100	.1667	.1667	.1667	.1667	.1667	.4890	.0001	.2100	.1667	.2100	9.50E+04	2.00E+03	
A214: PROCSNM:	2141TMWL	.0385	.9986	.2499	.4943	.1667	.1667	.1667	.1667	.1667	.0010	.9995	.0600	.1667	.0600	7.90E+05	1.00E+03	
A215: PROCURAN:	2151LML	.9989	.0001	.0010	.0001	.3334	.0001	.4999	.3334	.3334	.3334	.0001	.9900	.3334	.9900	3.30E+05	1.00E+03	
A215: PROCURAN:	2151LLWS	.0010	.9998	.0010	.9998	.3333	.9998	.0001	.3333	.3333	.3333	.9998	.0050	.3333	.0050	9.60E+08	1.57E+03	
A215: PROCURAN:	2152UO2	.0001	.0001	.9980	.0001	.3333	.0001	.5000	.3333	.3333	.3333	.0001	.0050	.3333	.0050	3.30E+06	4.00E+03	
A22: TREATWAT:	2200H2O	.97998	.0001	.0333	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0003	.0001	.0001	.0001	1.80E+10	1.00E+03	
A22: TREATWAT:	2200LLWS	.02000	.9000	.9000	.9000	.9584	.9400	.9584	.9584	.9262	.9262	.9582	.0011	.9989	.9989	8.00E+08	1.33E+03	
A22: TREATWAT:	2200LMWS	.00001	.0999	.0667	.0999	.0415	.0599	.0415	.0415	.0737	.0737	.0415	.9988	.0010	.0010	1.00E+06	1.33E+03	
A2311: RETRSST:	2311EQPT	.0003	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.5000	.0100	1.10E+07	1.80E+03	
A2311: RETRSST:	2311HLWL	.9997	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.5000	.9900	6.10E+08	1.14E+03	
A2312: RETRDOT:	2312EQPT	.0117	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.5000	.0100	7.10E+06	1.80E+03	
A2312: RETRDOT:	2312HLWL	.9883	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.9990	.5000	.9900	3.90E+08	1.14E+03	
A2313: XFRSST:	2313HEEL	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	7.10E+06	2.00E+03	
A2313: XFRSST:	2313HLWL	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	3.90E+08	1.14E+03	
A2314: XFRDST:	2314HEEL	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	7.10E+06	2.00E+03	
A2314: XFRDST:	2314HLWL	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	.9500	3.90E+08	1.14E+03	

C-14

WHC-EP-0791

Table C2. Hanford Strategic Analysis Separation Specifications. (sheet 2 of 2)

Table C1. SEPARATION SPECIFICATIONS FILE: SEPS_IX_OP2_R6 REV. 18 R.HARMSEN 14 FEB 92
STRATEGY IX OPTION 2 35 box 14 component PARTIQU SEPS UPDATED TO ACHIEVE PROPER GROUT AND GLASS FEEDS.

PROCESSORS	OUTSTREAMS	COMPONENTS														TOTAL	DENSITY	VOLUME
		H2O	TRU2	ACT2	LAN	CS	SR	TC	I	FP2	AP1	NANO3	OHAZ1	SOI	OTH2			
A2321: PARTIQU1	2321LLWL	.0734	.1000	.9500	.9923	.9866	.9939	.9866	.9866	.9939	.9939	.9990	.9992	.5000	.9992	1.00E+00	1.00E+03	
A2321: PARTIQU1	2321TMWL	.9266	.9000	.0500	.0077	.0134	.0061	.0134	.0134	.0061	.0061	.0010	.0008	.5000	.0008	1.00E+00	1.00E+03	
A2322: PARTIQU2	2322COND	.7000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0010	.0010	.0004	.0004	.0010	.0004	1.00E+00	1.00E+03	
A2322: PARTIQU2	2322HLWL	.0272	.9701	.0499	.9701	.9975	.9921	.9921	.9921	.9970	.0010	.0270	.0320	.0010	.0320	1.00E+00	1.50E+03	
A2322: PARTIQU2	2322LLWL	.1364	.0149	.4750	.0149	.0012	.0039	.0039	.0039	.0010	.4990	.4863	.4838	.4990	.4838	1.00E+00	1.50E+03	
A2322: PARTIQU2	2322LMWL	.1364	.0149	.4750	.0149	.0012	.0039	.0039	.0039	.0010	.4990	.4863	.4838	.4990	.4838	1.00E+00	1.00E+03	
A241: DACTDCON	2411LMWL	.9960	.0100	.4499	.0100	.4499	.4499	.8998	.8998	.0100	.0100	.9880	.0001	.0001	.0001	1.00E+00	1.00E+03	
A241: DACTDCON	2411LMWS	.0010	.0100	.4499	.4949	.4499	.4499	.0500	.0500	.4949	.4949	.0050	.0090	.0090	.0090	1.00E+00	2.00E+03	
A241: DACTDCON	2411TMWS	.0010	.9798	.1000	.4949	.1000	.1000	.0500	.0500	.4949	.4949	.0050	.0010	.0010	.0010	1.00E+00	2.00E+03	
A241: DACTDCON	2412NRHS	.0010	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0010	.9799	.0100	.0100	1.00E+00	2.00E+03	
A241: DACTDCON	2412NRHL	.0010	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0010	.0100	.9799	.9799	1.00E+00	2.00E+03	
A242: SRTSAMP1	2420LLWS	.0500	.0100	.2495	.2495	.2495	.2495	.2495	.2495	.2495	.2495	.1667	.0010	.0200	.0500	1.00E+04	2.00E+03	
A242: SRTSAMP1	2420LMWS	.0500	.0100	.2495	.2495	.2495	.2495	.2495	.2495	.2495	.2495	.1667	.0010	.0200	.0500	1.00E+04	2.00E+03	
A242: SRTSAMP1	2420NRHS	.1000	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.1667	.1000	.1000	.0500	1.00E+04	2.00E+03	
A242: SRTSAMP1	2420SOIL	.0500	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.1667	.0010	.7600	.0010	1.00E+04	2.00E+03	
A242: SRTSAMP1	2420TMWS	.3750	.4890	.2495	.2495	.2495	.2495	.2495	.2495	.2495	.2495	.1666	.4480	.0500	.4245	8.00E+04	2.00E+03	
A242: SRTSAMP1	2420TRUS	.3750	.4890	.2495	.2495	.2495	.2495	.2495	.2495	.2495	.2495	.1666	.4490	.0500	.4245	8.00E+04	2.00E+03	
A243: TRTSOIL1	2432SOIL	.1000	.0001	.0010	.0001	.0010	.0010	.0010	.0010	.0001	.0001	.0010	.0010	.8980	.3000	1.00E+00	2.00E+03	
A243: TRTSOIL1	2432TRUS	.0010	.1499	.0010	.1499	.8000	.8000	.1090	.5000	.5000	.5000	.1090	.2000	.1000	.2000	1.00E+00	3.00E+03	
A243: TRTSOIL1	2435COND	.8970	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0010	.4700	1.00E+00	1.00E+03	
A243: TRTSOIL1	2435TMWL	.0020	.8499	.9979	.8499	.1989	.1989	.8899	.4999	.4998	.4998	.8899	.7989	.0010	.0300	1.00E+00	1.00E+03	
A244: SRTSAMP2	2440LLWS	.2500	.4990	.4990	.4990	.4990	.4990	.4990	.4990	.4990	.4990	.2500	.0010	.0200	.4490	1.00E+00	1.00E+03	
A244: SRTSAMP2	2440LMWS	.2500	.4990	.4990	.4990	.4990	.4990	.4990	.4990	.4990	.4990	.2500	.4990	.0200	.4500	1.00E+00	1.00E+03	
A244: SRTSAMP2	2440NRHS	.2500	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.2500	.4990	.1000	.1000	1.00E+00	2.00E+03	
A244: SRTSAMP2	2440SOIL	.2500	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.0010	.2500	.0010	.8600	.0010	1.00E+00	2.00E+03	
A245: TRTSOIL2	2452LLWS	.0005	.0750	.0005	.0750	.4000	.4000	.0545	.2500	.2500	.2500	.0600	.0010	.0400	.0010	9.00E+08	2.00E+03	
A245: TRTSOIL2	2452LMWS	.0005	.0749	.0005	.0749	.4000	.4000	.0545	.2500	.2500	.2500	.0600	.1990	.0400	.1990	9.00E+08	2.00E+03	
A245: TRTSOIL2	2452SOIL	.1000	.0001	.0010	.0001	.0010	.0010	.0010	.0010	.0001	.0001	.0100	.1000	.9188	.3000	2.20E+10	2.00E+03	
A245: TRTSOIL2	2455COND	.8970	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.5300	.0001	.0010	.4700	7.80E+09	1.00E+03	
A245: TRTSOIL2	2455LMWL	.0020	.8499	.9979	.8499	.1989	.1989	.8899	.4999	.4998	.4998	.3400	.6999	.0002	.0300	3.30E+07	1.00E+03	
A311: VITRW	CDENSW	.9999	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	1.00E+00	1.00E+03	
A311: VITRW	3110HLWS	.0001	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999	1.00E+00	2.00E+03	
A312: STABTRU	3120TRUS	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	1.00E+00	3.00E+03	
A312: STABTRU	3120TMWS	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	1.00E+00	3.00E+03	
A32: IMMOBIL2	3200HLWS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.00E+00	2.00E+03	
A331: RSTRICGW	3310LLWL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	8.20E+09	1.00E+03	
A332: ENTOMIFA	3320LMWS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.00E+00	2.00E+03	
A333: STABSUR	3330LLWS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.00E+00	2.00E+03	
A334: INSTACAP	3341LMWL	.7000	.8000	.0500	.0500	.9000	.9000	.7000	.7000	.9000	.0500	.9500	.9500	.0050	.1400	3.00E+08	1.00E+03	
A334: INSTACAP	3342LLWS	.3000	.2000	.9500	.9500	.1000	.1000	.3000	.3000	.1000	.9500	.0500	.0500	.9950	.8600	1.20E+09	2.00E+03	
A34: GROUTW	3400LLWS	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.1000	.1000	.1000	1.00E+00	2.00E+03	
A34: GROUTW	3400LMWS	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.9000	.9000	.9000	1.00E+00	2.00E+03	
A351: STABLLW1	3510LLWS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.00E+00	2.00E+03	
A352: PKGNPH	3520NRHS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.00E+00	2.00E+03	
A353: STABLLM2	3530LMWS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.00E+00	2.00E+03	

Table C3. Ratios of Chemical Makeup Mass to Process Block Input Mass
Along With Makeup Component Ratios.

Strategy IX Option 2
(S0937142)

MAKEUP STREAM	CM/INP	H2O/CM	OHAZ1/CM	OTH2/CM
111CM	8.305E-02	9.915E-01	8.526E-05	8.441E-03
112CM	4.425E-01	9.916E-01	8.390E-05	8.306E-03
113CM	1.574E-12	7.143E-02	7.143E-02	7.143E-02
114CM	3.148E-12	7.143E-02	7.143E-02	7.143E-02
115CM	7.164E-05	9.915E-01	8.526E-05	8.441E-03
116CM	1.130E-13	7.143E-02	7.143E-02	7.143E-02
121CM	4.500E-14	7.143E-02	7.143E-02	7.143E-02
122CM	2.922E-16	7.143E-02	7.143E-02	7.143E-02
13CM	3.213E-03	1.000E-15	1.000E-02	9.900E-01
211CM	1.260E+01	1.000E+00	1.587E-12	1.587E-12
212CM	1.908E-01	2.083E-12	1.000E-02	9.900E-01
213CM	2.004E+00	1.000E+00	4.000E-11	4.000E-11
214CM	1.436E+02	9.061E-01	9.394E-04	9.301E-02
215CM	1.514E-01	2.000E-12	1.000E-02	9.900E-01
22CM	4.435E-04	9.200E-14	1.000E-02	9.900E-01
2311CM	8.000E-14	7.143E-02	7.143E-02	7.143E-02
2312CM	2.990E-13	7.143E-02	7.143E-02	7.143E-02
2313CM	2.182E+00	1.000E+00	2.000E-15	2.000E-15
2314CM	4.867E+00	1.000E+00	4.000E-15	4.000E-15
2321CM	6.396E+01	1.000E+00	8.406E-16	8.406E-16
2322CM	7.589E+00	1.000E+00	5.846E-16	5.846E-16
241CM	2.098E-04	9.915E-01	8.526E-05	8.441E-03
242CM	6.900E-14	7.143E-02	7.143E-02	7.143E-02
243CM	1.388E-01	9.750E-01	2.505E-04	2.480E-02
244CM	1.300E-14	7.143E-02	7.143E-02	7.143E-02
245CM	1.668E-01	9.750E-01	2.498E-04	2.473E-02
311CM	1.873E+01	8.554E-01	1.446E-03	1.432E-01
312CM	1.419E+00	4.000E-15	1.000E-02	9.900E-01
32CM	3.300E-14	7.143E-02	7.143E-02	7.143E-02
331CM	1.348E-12	7.143E-02	7.143E-02	7.143E-02
332CM	5.138E-03	1.000E+00	9.009E-11	9.009E-11
333CM	1.560E-13	7.143E-02	7.143E-02	7.143E-02
334CM	8.812E-02	9.397E-01	6.028E-04	5.968E-02
34CM	6.004E-01	7.300E-16	1.000E-02	9.900E-01
351CM	2.418E-01	1.336E-03	9.987E-03	9.887E-01
352CM	7.800E-14	7.143E-02	7.143E-02	7.143E-02
353CM	2.407E-01	1.336E-03	9.986E-03	9.887E-01

NOTE: RATIOS FOR 13CM (PUMTREAT), 22CM (TREATWAT),
AND 34CM (GROUTW) ARE BASED ON TOTAL MASS
INPUT INTO BLOCK WITHOUT SUBTRACTING H2O OUT

APPENDIX D

GLOBAL LEVEL MODEL: ASPEN PLUS¹ IMPLEMENTATION

¹ASPEN PLUS is a trademark of Aspen Technology, Inc.

LIST OF TERMS

IDEF	Integrated Computer-Aided Manufacturing (ICAM) Definition (Language)
TRUEX-C	Transuranic Extraction Option C

GLOBAL LEVEL MODEL: ASPEN PLUS IMPLEMENTATION

The ASPEN PLUS global model development began with a process flowsheet modeled using the Integrated Computer-Aided Manufacturing (ICAM) Definition (Language) (IDEF) software tool (Pajunen et al. 1992) at a higher abstraction or less detailed level showing all major feed and product streams and the main process blocks. The IDEF tool allowed showing the flowsheet description at increasingly decomposed states (i.e., a hierarchical representation) as shown in Figure D1. The higher level model allowed good understanding of the overall waste flow in each process and facilitated the development of a more detailed process model. Each main process and stream in the higher level model was further broken down or decomposed to an appropriate detail level for implementation using ASPEN PLUS. Thus, the IDEF representations became the ASPEN PLUS flowsheet specifications. The IDEF flowsheet representation for the CLEAN Option process strategies is shown in Figure D2.

The IDEF model flowsheet specifications were used to build the ASPEN PLUS flowsheet model connectivity with all the specified feed and product streams. In place of rigorous chemical and physical process models, the ASPEN PLUS models used simpler mixers and splitter models, referred to as MIXER, FSPLIT, and SEP process unit blocks (see Appendix A). The MIXER block combines material streams into one stream. The FSPLIT block combines material streams and divides the resulting stream into two or more streams, with all outlets having the same composition and properties. The SEP block combines streams and separates the resulting stream into two or more streams according to splits or separation factors specified for each component. The last process type modeled is a "reactor" (RYIELD). The reactor is used to simulate chemical reactions. The RYIELD reactor process simulates a reactor with specified reaction yields of each component.

A global (or intermediate) level model was developed to represent the CLEAN Option (CLEAN) process strategy described in Appendix B. This global model represented these process strategies with 63 blocks (23 reactors, 33 seps, 4 mixers, and 3 fsplits) and was self-contained in modeling the tank waste retrieval, treatment, and disposal processes, along with the tertiary nonprocess waste generation. The global model was created to run with either 25 pseudo (or lumped) or 168 specie components. Calculations of stream component masses, stream separation factors, and reactor yield factors using the detailed model data, were automated using spreadsheet script programs. This automation allows using any component lumping scheme desired in processing the detailed model results for implementation in the global model.

A detailed oxidation model was included in the detailed CLEAN Option model to accurately account for oxide creation during the high-level waste vitrification process. The resulting oxide product stream was used in a glass composition optimization routine, described in Appendix G, to find the maximum waste oxide loading in the glass along with the glass former composition. This optimization routine accounts for high-level waste glass property constraints (viscosity, electrical conductivity, durability-boron release), heat loading constraints, critical solubility constraints, and single- and multiple-component constraints (Appendix G). Because specifications for low-level waste glass have not yet been determined, the low-level waste mass was converted to glass using the same high-level waste constraints. However,

for further model comparison purposes, a previously developed grout calculation module used in the Transuranic Extraction Option C (TRUEX-C) and Sludge Wash C models was also added to the detailed CLEAN Option model to provide a similar grout mass calculation. FORTRAN blocks were developed and used in the global ASPEN PLUS models to account for chemical makeup additions, tertiary nonprocess waste generation (Appendix E), process block cost calculations (Appendix F), and output stream file creation.

The actual global ASPEN PLUS flowsheet model for the CLEAN Option process strategy is shown in Figure D3. Because the CLEAN Option model will be compared to the previously developed TRUEX-C and Sludge Wash C process strategies (Knutson et al. 1993), their global flowsheet model is shown in Figure D4. In Figure D4, the FSPLIT blocks allowed routing the waste streams to the appropriate processes to represent a particular process strategy (e.g., TRUEX-C and Sludge Wash C).

Table D1 describes stream-naming conventions and provides a brief description of the CLEAN Option global model blocks. Table D2 describes stream-naming conventions and provides a brief description of the TRUEX-C and Sludge Wash C global model blocks. Table D3 shows the relationship between the CLEAN Option global model streams and the detailed model streams. Table D4 provides the component lumping scheme used for the CLEAN Option global model streams. This table shows the global model stream components and the detailed model stream species that are included in those global components.

Table D5 provides the separation factor and reactor component yield data used in the CLEAN Option global model blocks. Table D6 provides the separation factor and reactor component yield data used in the TRUEX-C global model blocks. Table D7 provides the separation factor and reactor component yield data used in the Sludge Wash C global model blocks. The separation factors were based on rolling up (or lumping) the detailed model stream and component data for individual output streams and comparing the component distributions between streams to the total output stream. The reactor yield factors were based on comparing the distribution of component masses in the total output stream compared to the total input stream for a particular process block. Note that accurate representation of the detailed models was achieved in the global model by representing a group of detailed process blocks with a reactor and a separation block together. The reactor blocks accounted for component mass changes resulting from chemical reactions within the group of detailed model process blocks while the separation blocks separated those components into their appropriate output streams.

REFERENCES

- Knutson, B. J., et al., 1993, "Advanced Chemical Separation Study: TRUEX Strategy Compared To Sludge Wash Ion Exchange," Letter report, Westinghouse Hanford Company, Richland, Washington.
- Pajunen, A. L., et al., 1992, *Hanford Strategic Analysis Study*, WHC-EP-0549, Westinghouse Hanford Company, Richland, Washington.

Figure D1. IDEF Structured Flowsheet.

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 1 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option - Global Level.
(sheet 2 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option - Global Level.
(Sheet 3 of 27)

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

3 of 6

Figure D2. Hanford Strategic Analysis with CLEAN Option — Global Level.
(sheet 4 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 5 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 6 of 27)

D-11

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 8 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 9 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option -- Global Level.
(sheet 10 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 11 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option - Global Level.
(sheet 13 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option -- Global Level.
(sheet 14 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 15 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 16 of 27)

Figure D2. Hanford Strategic Analysis with CLEAN Option - Global Level.
(sheet 17 of 27)

Figure D2. Hanford Strategic Analysis with CLEAN Option — Global Level.
(sheet 18 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 19 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 20 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option - Global Level.
(sheet 21 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 22 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 24 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 25 of 27)

D-30

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 26 of 27)

Figure D2. Hanford Strategic Analysis With CLEAN Option — Global Level.
(sheet 27 of 27)

Figure D3. CLEAN Option Global Model.

Figure D4. Transuranic Extraction (TRUEX)/Sludge Wash Global Model.

Table D1. ASPEN PLUS Intermediate CLEAN Option Model Stream Naming and Process Block Descriptions. (sheet 1 of 8)

CLEAN OPTION STREAM NAMING CONVENTIONS:

AL	=	Aluminum
ALK	=	Alkaline Waste
ALRED	=	Reduced Aluminum
ALS	=	Aluminum Solid
AM	=	Americium
AQUE	=	Aqueous
BA	=	Barium
DST	=	Double-Shell Tank
CBUST	=	Combustible
CDENS	=	Condensate
CHEM	=	Chemicals
CONC	=	Concentrate
COND	=	Condensate
CM	=	Chemical Makeup used in process
CR	=	Chromium
CS	=	Cesium
COST	=	Stream used in process cost calculations
EQPT	=	Equipment
G	=	Offgas from process
GAS	=	Offgas from process
H2O	=	Water
HEEL	=	Non-retrievable residual waste
HLL	=	High Level Waste Liquid
HLS	=	High Level Waste Solid
HLW	=	High Level Waste (L = liquid, S = solid)
HNO3	=	Nitric Acid
LEACH	=	Leachate
LLW	=	Low Level Waste (L = liquid, S = solid)
LML	=	Low Level Waste Liquid
LMW	=	Low level Mixed (hazardous and radioactive) Waste (L = liquid, S = solid)
LN	=	Lanthanides
MTL	=	Metals
NA	=	Sodium
NAL	=	Sodium liquid
NAOH	=	Sodium Hydroxide
NCBUST	=	Non-Combustible
RCY	=	Recycle

Table D1. ASPEN PLUS Intermediate CLEAN Option Model Stream Naming and Process Block Descriptions. (sheet 2 of 8)

CLEAN OPTION STREAM NAMING CONVENTIONS (continued):

SLAG	=	Fused Solids after separation of a specific metal
SOL	=	Solids
SR	=	Strontium
SS	=	Stainless Steel
SST	=	Single-Shell Tank
STR	=	Stream
TC	=	Technetium
TH	=	Thorium
TML	=	Transuranic Mixed Waste Liquid
TMWS	=	Transuranic Mixed Waste Solid
TRUS	=	Transuranic Solid Waste
TNK	=	Tank
TRU	=	Transuranic
U	=	Uranium
V	=	Variable or process facility throughput dependent

Table D1. ASPEN PLUS Intermediate CLEAN Option Model Stream Naming and Process Block Descriptions. (sheet 3 of 8)

CLEAN OPTION BLOCK DESCRIPTIONS:

XFRSST	=	Transfer SST waste from tanks using additional H ₂ O, producing a HLW liquid stream and a residual or heel HLW stream.
XFRDST	=	Transfer DST waste from tanks using additional H ₂ O producing a HLW liquid stream and a residual or heel HLW stream.
RETRSST	=	Retrieve SST waste from interim storage tanks producing a HLW liquid stream and a residual contaminated equipment HLW waste stream.
RETRDST	=	Retrieve DST waste from interim storage tanks producing a HLW liquid stream and a residual contaminated equipment HLW waste stream.
WSPLIT	=	A stream splitter for routing the primary waste streams along optional processing steps (if needed).
SEPSOLIQ	=	Wash the SST and DST waste sludge streams with H ₂ O and Polyelectrolyte and separate the solid and liquid using either filtration or centrifugation to produce a HLW liquid (HLL) supernate stream and a HLW solids (HLS) stream.
DESTORG	=	Perform organic complexant destruction using Super Critical Water Oxidation (SCWO) to precipitate TRU, fission products, and cations in the alkaline solution.
CAUSLEAC	=	Dissolve selected solids by caustic leaching and separate the solid and liquid using either filtration or centrifugation to produce HLL and HLS waste streams.
CSIX	=	Perform Cs Ion Exchange and evaporation of the HLW liquid supernate to produce a LML concentrated supernate stream, a HLW stream containing mostly Cs and a condensate stream.
SRIX	=	Perform Sr Ion Exchange and evaporation of the HLW liquid supernate to produce a LML concentrated supernate stream, a HLW stream containing mostly Sr and a condensate stream.
TCIX	=	Perform Tc Ion Exchange of the LML stream from the SRIX process to produce a LML stream and a concentrated HLW stream containing mostly Tc.

Table D1. ASPEN PLUS Intermediate CLEAN Option Model Stream Naming and Process Block Descriptions. (sheet 4 of 8)

CLEAN OPTION BLOCK DESCRIPTIONS Continued:

DISOLVA	=	Dissolve the HLW solids using mixed nitric-oxalic acids to produce a dissolved HLW solids stream, an undissolved HLW solids stream, and an offgas stream.
DISOLVF	=	Dissolve the HLW solids using mixed nitric-hydrofluoric acids to produce a dissolved HLW solids stream, an undissolved HLW solids stream, an offgas stream, and a sludge waste recycle stream returning to CAUSLEAC.
EXTRUPU	=	Perform Actinide Extraction using TBP to extract tetravalent and hexavalent actinide and lanthanide elements from acidic waste streams to produce an actinide stream, an offgas stream, a U rich stream, and a LML stream.
PURIFYU	=	Perform concentration of U rich stream from EXTRUPU to produce a U product stream, a LML stream, an acid recycle stream, an organic recycle stream, and a condensate stream.
EXTRAMLN	=	Perform Actinide Extraction using CMPO to extract trivalent actinide and lanthanide elements and separate them from Bismuth in the acidic waste streams to produce an actinide/lanthanide stream, a HLW stream, and a LML stream.
AMLANIX	=	Perform Americium/Lanthanide Ion Exchange on the respective EXTRAMLN actinide/lanthanide stream to produce two LML streams, one directly calcinable and the other requiring denitration, and a concentrated HLW actinide/lanthanide stream.
SREX	=	Perform Strontium Extraction using crown ether solvent to extract Sr and Tc from acidic waste streams to produce a concentrated Sr/Tc stream, a HLW stream, and a LML stream.
SRBAIX	=	Perform band displacement cation exchange to extract the Sr and Ba to produce a concentrated Sr/Ba and Tc stream and a LML stream.
APMCSIX	=	Perform Cs Ion Exchange of the concentrated Sr/Tc stream from the SREX process to produce a Cs rich stream and a LML stream.

Table D1. ASPEN PLUS Intermediate CLEAN Option Model Stream Naming and Process Block Descriptions. (sheet 5 of 8)

CLEAN OPTION BLOCK DESCRIPTIONS Continued:

RCOVACID	=	Recover nitric acid from evaporator overheads and process gaseous NO _x streams from denitration to produce a HNO ₃ product stream, an offgas stream, and water recycle stream.
EVAPORH	=	Evaporation of various HLW streams produced from acidic and alkaline side processing to produce a HLW liquid stream and an HNO ₃ stream.
DNITRH	=	Perform denitration of HLW waste streams to produce a HLW solid stream and a gaseous NO _x stream.
DNITRL	=	Perform denitration of LML waste streams to produce a LML stream and a gaseous NO _x stream.
CALCINE	=	Perform calcination of LML waste streams to destroy nitrates and nitrites and produce a caustic slurry stream, an offgas stream, and a water recycle stream.
REMCr	=	Remove Cr from LML waste streams to produce a NaOH recycle stream, a LML stream, and a Cr rich LML stream.
MIXLLW	=	Separate LLW streams into HSA higher level model streams.
MIXHLW	=	Combine HLW streams into HSA higher level model stream.
MIXH2O	=	Combine condensate streams into HSA higher level model stream.
MIXOGAS	=	Combine offgas streams into HSA higher level model stream.
IMMOBILZ	=	Immobilize the HLW contaminated tank and equipment using a dome filling technique.
STABTRU	=	Stabilize the TMW and TRU solids in waste packages for shipment to a TRU waste isolation repository.
STABLLM2	=	Stabilize the LMW solids using an in-situ grouting technique.
TREATWAT	=	Treat condensate waste liquid to produce a recycle H ₂ O stream and LLW and LMW streams for grouting.
GROUTW	=	Combine LLW solids in a salt grout for vault storage.
VITRW	=	Combine HLW solids with glass formers and vitrify mixture into glass logs for storage in an offsite HLW repository.

Table D1. ASPEN PLUS Intermediate CLEAN Option Model Stream Naming and Process Block Descriptions. (sheet 6 of 8)

CLEAN OPTION BLOCK DESCRIPTIONS Continued:

INCIN	-	Incinerate combustible secondary wastes produced from SST waste treatment processes to produce a waste ash stream and an offgas stream requiring scrub treatment.
TRTSSOL	-	Treat noncombustible secondary waste solids to produce a groutable waste stream, a landfill qualified solid waste stream for burial, and a leachate stream.
OGASTRT	-	Treat waste-processing and cell-air offgasses producing contaminated filters, releasable offgases, and a condensate stream.
EVAPIX	-	Use evaporation and ion exchange processes on secondary waste aqueous streams to remove excess liquid and selected waste elements, respectively.
RSEPSOLI	-	Account for waste stream component reactions or mass transfer between components within the SEPSOLIQ process.
RDESTORG	-	Account for waste stream component reactions or mass transfer between components within the DESTORG process.
RCAUSLEA	-	Account for waste stream component reactions or mass transfer between components within the CAUSLEAC process.
RCSIX	-	Account for waste stream component reactions or mass transfer between components within the CSIX process.
RSRIX	-	Account for waste stream component reactions or mass transfer between components within the SRIX process.
RTCIX	-	Account for waste stream component reactions or mass transfer between components within the TCIX process.
RDISOLVA	-	Account for waste stream component reactions or mass transfer between components within the DISOLVA process.
RDISOLVF	-	Account for waste stream component reactions or mass transfer between components within the DISOLVF process.
REXTRUPU	-	Account for waste stream component reactions or mass transfer between components within the EXTRUPU process.

Table D1. ASPEN PLUS Intermediate CLEAN Option Model Stream Naming and Process Block Descriptions. (sheet 7 of 8)

CLEAN OPTION BLOCK DESCRIPTIONS Continued:

RPURIFYU	=	Account for waste stream component reactions or mass transfer between components within the PURIFYU process.
REXTRAML	=	Account for waste stream component reactions or mass transfer between components within the EXTRAMLN process.
RAMLANIX	=	Account for waste stream component reactions or mass transfer between components within the AMLANIX process.
RSREX	=	Account for waste stream component reactions or mass transfer between components within the SREX process.
RSRBAIX	=	Account for waste stream component reactions or mass transfer between components within the SRBAIX process.
RAPMCSIX	=	Account for waste stream component reactions or mass transfer between components within the APMCSIX process.
RRCOVACID	=	Account for waste stream component reactions or mass transfer between components within the RCOVACID process.
RNEUTRAL	=	Account for waste stream component reactions or mass transfer between components within the NEUTRAL process.
RDNITRH	=	Account for waste stream component reactions or mass transfer between components within the DNITRH process.
RDNITRL	=	Account for waste stream component reactions or mass transfer between components within the DNITRL process.
RCALCINE	=	Account for waste stream component reactions or mass transfer between components within the CALCINE process.
RREMCR	=	Account for waste stream component reactions or mass transfer between components within the REMCR process.
RMIXLLW	=	Account for waste stream component reactions or mass transfer between components within the LLW stream mixing process.
RMIXHLW	=	Account for waste stream component reactions or mass transfer between components within the HLW stream mixing process.

Table D1. ASPEN PLUS Intermediate CLEAN Option Model Stream Naming and Process Block Descriptions. (sheet 8 of 8)

CLEAN OPTION BLOCK DESCRIPTIONS Continued:

RMIXH2O	-	Account for waste stream component reactions or mass transfer between components within the H2O stream mixing process.
RGROUTW	-	Account for waste stream component reactions or mass transfer between components within the GROUTW process.
RMAKEOX	-	Account for waste stream component reactions or mass transfer between components within the HLW vitrification process.
SEPOX	-	Separate the oxide stream from the offgas stream.

Table D2. ASPEN PLUS Intermediate TRUEX-C/Sludge Wash C Model Stream Naming and Process Block Descriptions. (sheet 1 of 6)

TRUEX-C/SLUDGE WASH C STREAM NAMING CONVENTIONS:

AL	=	Aluminum
ALK	=	Alkaline Waste
ALRED	=	Reduced Aluminum
ALS	=	Aluminum Solid
AQUE	=	Aqueous
DST	=	Double-Shell Tank
CBUST	=	Combustible
CDENS	=	Condensate
CHEM	=	Chemicals
CONC	=	Concentrate
COND	=	Condensate
CM	=	Chemical Makeup used in process
CS	=	Cesium
EQPT	=	Equipment
G	=	Offgas from process
GAS	=	Offgas from process
H2O	=	Water
HEEL	=	Nonretrievable residual waste
HLL	=	High Level Waste Liquid
HLS	=	High Level Waste Solid
HLW	=	High Level Waste (L = liquid, S = solid)
LEACH	=	Leachate
LLW	=	Low Level Waste (L = liquid, S = solid)
LML	=	Low Level Waste Liquid
LMW	=	Low level Mixed (hazardous and radioactive) Waste (L = liquid, S = solid)
MTL	=	Metals
NA	=	Sodium
NAL	=	Sodium liquid
NCBUST	=	Noncombustible
RCY	=	Recycle
SLAG	=	Fused Solids after separation of a specific metal
SOL	=	Solids
SR	=	Strontium
SS	=	Stainless Steel
SST	=	Single-Shell Tank
TC	=	Technetium
TML	=	Transuranic Mixed Waste Liquid
TMWS	=	Transuranic Mixed Waste Solid
TRUS	=	Transuranic Solid Waste
TNK	=	Tank
TRU	=	Transuranic
U	=	Uranium
V	=	Variable or process facility throughput dependent

Table D2. ASPEN PLUS Intermediate TRUEX-C/Sludge Wash C Model Stream Naming and Process Block Descriptions. (sheet 2 of 6)

TRUEX-C/SLUDGE WASH C BLOCK DESCRIPTIONS:

XFRSST	-	Transfer SST waste from tanks using additional H ₂ O, producing a HLW liquid stream and a residual or heel HLW stream.
XFRDST	-	Transfer DST waste from tanks using additional H ₂ O producing producing a HLW liquid stream and a residual or heel HLW stream.
RETRSST	-	Retrieve SST waste from interim storage tanks producing a HLW liquid stream and a residual contaminated equipment HLW waste stream.
RETRDST	-	Retrieve DST waste from interim storage tanks producing a HLW liquid stream and a residual contaminated equipment HLW waste stream.
WASHSLUD	-	Wash the SST waste sludge stream with H ₂ O and Polyelectrolyte to produce a HLW liquid supernate stream and a HLW solids stream.
DESTORG	-	Perform organic complexant destruction using Super Critical Water Oxidation (SCWO) to precipitate TRU, fission products, and cations in the alkaline solution.
FILTADSB	-	Perform sodium titanate sorption to adsorb residual Sr and TRU from the SCWO effluent.
CSIX	-	Perform Cs Ion Exchange and evaporation of the HLW liquid supernate from the FILTADSB process to produce a LML concentrated supernate stream, a HLW stream containing mostly Cs, an offgas stream, and a condensate stream.
TCIX1	-	Perform Tc Ion Exchange of the LML stream from the CSIX process to produce a LML stream, a condensate stream, and a concentrated HLW stream containing mostly Tc.
DISSOLVA	-	Dissolve the HLW solids from the WASHSLUD process using additional H ₂ O, HNO ₃ , and Polyelectrolyte, to produce a dissolved HLW solids stream, an undissolved HLW solids stream, and an offgas stream.
TRUEX	-	Perform Transuranic Extraction to extract actinide and lanthanide elements from acidic waste streams to produce a U/Tc concentrated stream, a TRU stream, an offgas stream, and a condensate stream.

Table D2. ASPEN PLUS Intermediate TRUEX-C/Sludge Wash C Model Stream Naming and Process Block Descriptions. (sheet 3 of 6)

TRUEX-C/SLUDGE WASH C BLOCK DESCRIPTIONS Continued:

SREX	-	Perform Strontium Extraction to extract Sr from acidic waste streams to produce a concentrated Sr stream, a recycle HLW stream, an LML stream, an offgas stream, and a condensate stream.
UTCSTRIP	-	Perform strip of U/Tc from HLW stream to produce a concentrated U/Tc stream and an organic solvent recycle stream.
TCIX2	-	Perform Tc Ion Exchange of the U/Tc rich stream from the UTCSTRIP process to produce concentrated U and Tc streams, a condensate stream, and an offgas stream.
PURIFYU	-	Perform concentration of U rich stream from TCIX2 to produce a U product stream, a LML stream, a Tc recycle stream, and an offgas stream.
NEUTRAL	-	Neutralize the concentrated Cs and Tc HLW streams produced from alkaline side processing to produce a HLW liquid stream.
NEUTDCAN	-	Neutralize and Decant the HLW streams resulting from acid side processing to produce a HLW liquid stream.
CALCINE	-	Perform calcination of acidic HLW waste streams to produce a HLW solid (oxide) stream and an offgas stream.
SSPLIT#	-	A stream splitter for routing the solid waste streams along optional processing steps.
LSPLIT#	-	A stream splitter for routing the liquid waste streams along optional processing steps.
WSPLIT	-	A stream splitter for routing the primary waste streams along optional processing steps.
USPLIT	-	A stream splitter for routing the U/Tc waste stream from process UTCSTRIP along optional processing steps.
HLWSPLT1	-	A stream splitter for routing the HLW streams from acid side processing to neutralization or calcination process steps.
HLWSPLT2	-	A stream splitter for routing the HLW streams from alkaline side processing to neutralization or calcination process steps.

Table D2. ASPEN PLUS Intermediate TRUEX-C/Sludge Wash C Model Stream Naming and Process Block Descriptions. (sheet 4 of 6)

TRUEX-C/SLUDGE WASH C BLOCK DESCRIPTIONS Continued:

MIXLLW	-	Separate LLW streams into HSA higher level model streams.
MIXHLW	-	Combine HLW streams into HSA higher level model stream.
MIXH2O	-	Combine condensate streams into HSA higher level model stream.
IMMOBILZ	-	Immobilize the HLW contaminated tank and equipment using a dome filling technique.
STABTRU	-	Stabilize the TMW and TRU solids in waste packages for shipment to a TRU waste isolation repository.
STABLLM2	-	Stabilize the LMW solids using an in-situ grouting technique.
TREATWAT	-	Treat condensate waste liquid to produce a recycle H2O stream and LLW and LMW streams for grouting.
GROUTW	-	Combine LLW solids in a salt grout for vault storage.
VITRW	-	Combine HLW solids with glass formers and vitrify mixture into glass logs for storage in an offsite HLW repository.
INCIN	-	Incinerate combustible secondary wastes produced from SST waste treatment processes to produce a waste ash stream and an offgas stream requiring scrub treatment.
TRTSSOL	-	Treat noncombustible secondary waste solids to produce a groutable waste stream, a landfill qualified solid waste stream for burial, and a leachate stream.
OGASTRT	-	Treat waste-processing and cell-air offgasses producing contaminated filters, releasable offgases, and a condensate stream.
EVAPIX	-	Use evaporation and ion exchange processes on secondary waste aqueous streams to remove excess liquid and selected waste elements, respectively.
RWASHSLU	-	Account for waste stream component reactions or mass transfer between components within the WASHSLUD process.

Table D2. ASPEN PLUS Intermediate TRUEX-C/Sludge Wash C Model Stream Naming and Process Block Descriptions. (sheet 5 of 6)

TRUEX-C/SLUDGE WASH C BLOCK DESCRIPTIONS Continued:

RDESTORG	-	Account for waste stream component reactions or mass transfer between components within the DESTORG process.
RFILTADS	-	Account for waste stream component reactions or mass transfer between components within the FILTADSB process.
RCSIX	-	Account for waste stream component reactions or mass transfer between components within the CSIX process.
RTCIX1	-	Account for waste stream component reactions or mass transfer between components within the TCIX1 process.
RDISSOLV	-	Account for waste stream component reactions or mass transfer between components within the DISSOLVA process.
RTRUEX	-	Account for waste stream component reactions or mass transfer between components within the TRUEX process.
RSREX	-	Account for waste stream component reactions or mass transfer between components within the SREX process.
RUTCSTRI	-	Account for waste stream component reactions or mass transfer between components within the UTCSTRIP process.
RTCIX2	-	Account for waste stream component reactions or mass transfer between components within the TCIX2 process.
RPURIFYU	-	Account for waste stream component reactions or mass transfer between components within the PURIFYU process.
RNEUTRAL	-	Account for waste stream component reactions or mass transfer between components within the NEUTRAL process.
RNEUTDCAN	-	Account for waste stream component reactions or mass transfer between components within the NEUTDCAN process.
RPURIFYU	-	Account for waste stream component reactions or mass transfer between components within the PURIFYU process.
RMIXLLW	-	Account for waste stream component reactions or mass transfer between components within the LLW stream mixing process.
RMIXHLW	-	Account for waste stream component reactions or mass transfer between components within the HLW stream mixing process.

Table D2. ASPEN PLUS Intermediate TRUEX-C/Sludge Wash C Model Stream Naming and Process Block Descriptions. (sheet 6 of 6)

TRUEX-C/SLUDGE WASH C BLOCK DESCRIPTIONS Continued:

RMIXH2O	=	Account for waste stream component reactions or mass transfer between components within the H2O stream mixing process.
RGROUTW	=	Account for waste stream component reactions or mass transfer between components within the GROUTW process.
RCALCINE	=	Account for waste stream component reactions or mass transfer between components within the CALCINE process.
RMAKEOX	=	Account for waste stream component reactions or mass transfer between components within the HLW vitrification process.
SEPOX	=	Separate the oxide stream from the offgas stream.

Table D3. Stream Relationships: Global Versus Detailed
Clean Option Models. (sheet 1 of 6)

<u>GLOBAL MODEL</u>	<u>DETAILED MODEL</u>				
RSEPSOLI/SEPSOLIQ:	(SLUDGE WASH AND SOLIDS AND LIQUID SEPARATION)				
<u>FEEDS:</u> SSTTNKW	400				
<u>FEEDS:</u> DSTTNKW	401				
<u>FEEDS:</u> B111CM	402	405	408		
<u>PRODUCTS:</u> B111HLL	403	406			
<u>PRODUCTS:</u> B111HLS	409				
RDESTORG/DESTORG:	(ORGANIC DESTRUCTION WITH SCWO AND SOLIDS SEPARATION)				
<u>FEEDS:</u> B111HLL	403	406			
<u>FEEDS:</u> B112CM	422	425	428		
<u>PRODUCTS:</u> B112HLL	423	426			
<u>PRODUCTS:</u> B112HLS	429				
<u>PRODUCTS:</u> B112GAS	411				
RCAUSLEA/CAUSLEAC:	(CAUSTIC LEACH)				
<u>FEEDS:</u> B132SRCY	280				
<u>FEEDS:</u> B24CS	101				
<u>FEEDS:</u> B42NAOH	530				
<u>FEEDS:</u> B111HLS	409				
<u>FEEDS:</u> B112HLS	429				
<u>FEEDS:</u> B12CM	442	445	448		
<u>PRODUCTS:</u> B12HLL	443	446			
<u>PRODUCTS:</u> B12HLS	449				
RCSIX/CSIX:	(CESIUM ION EXCHANGE)				
<u>FEEDS:</u> B3HRCY	548				
<u>FEEDS:</u> B112HLL	423	426			
<u>FEEDS:</u> B12HLL	443	446			
<u>FEEDS:</u> B211LML	18				
<u>FEEDS:</u> B31CM	300	301	302	303	304
<u>PRODUCTS:</u> B31CS	310				
<u>PRODUCTS:</u> B31HLL	305				
<u>PRODUCTS:</u> B31COND	451				
RSRIX/SRIX:	(STRONTIUM ION EXCHANGE)				
<u>FEEDS:</u> B31HLL	305				
<u>FEEDS:</u> B32CM	314	315	316	317	318
<u>PRODUCTS:</u> B32SR	220				
<u>PRODUCTS:</u> B32LML	319				
<u>PRODUCTS:</u> B32COND	326				

Table D3. Stream Relationships: Global Versus Detailed Clean Option Models. (sheet 2 of 6)

STREAM RELATIONSHIPS: GLOBAL VS. DETAILED CLEAN OPTION MODELS CONTINUED**RTCIX/TCIX: (TECHNETIUM ION EXCHANGE)**

<u>FEEDS:</u>	B32LML	319					
<u>FEEDS:</u>	B33CM	331	332	333	334	335	336
<u>PRODUCTS:</u>	B33TC	343					
<u>PRODUCTS:</u>	B33LML	350					

RDISOLVA/DISOLVA: (ACID (OXALIC+HNO₃) DISSOLUTION OF SOLIDS)

<u>FEEDS:</u>	B32SR	220					
<u>FEEDS:</u>	B12HLS	449					
<u>FEEDS:</u>	B131CM	210	211	215	216	232	235 238
<u>PRODUCTS:</u>	B131HLL	233	236				
<u>PRODUCTS:</u>	B131HLS	239					
<u>PRODUCTS:</u>	B131GAS	218					

RDISOLVF/DISOLVF: (ACID (HF+HNO₃) DISSOLUTION OF SOLIDS)

<u>FEEDS:</u>	B131HLS	239					
<u>FEEDS:</u>	B132CM	250	251	255	256	272	275 278
<u>PRODUCTS:</u>	B132SRCY	280					
<u>PRODUCTS:</u>	B132HLL	273	276				
<u>PRODUCTS:</u>	B132HLS	281					
<u>PRODUCTS:</u>	B132GAS	258					

REXTRUPU/EXTRUPU: (ACTINIDE EXTRACTION USING TBP)

<u>FEEDS:</u>	B131HLL	233	236				
<u>FEEDS:</u>	B132HLL	273	276				
<u>FEEDS:</u>	B212ORCY	3					
<u>FEEDS:</u>	B211CM	2	4	5	9	13	14 17 6A
<u>PRODUCTS:</u>	B211THPU	11					
<u>PRODUCTS:</u>	B211U	15					
<u>PRODUCTS:</u>	B211LML	18					
<u>PRODUCTS:</u>	B211HLL	7					

RPURIFYU/PURIFYU: (URANIUM PURIFICATION)

<u>FEEDS:</u>	B211U	15				
<u>FEEDS:</u>	B212CM	22	23	24	28	33
<u>PRODUCTS:</u>	B212LML	34				
<u>PRODUCTS:</u>	B212ORCY	3				
<u>PRODUCTS:</u>	B212ARCY	38				
<u>PRODUCTS:</u>	B212COND	37	26	20	31	
<u>PRODUCTS:</u>	B212U	36				

Table D3. Stream Relationships: Global Versus Detailed
Clean Option Models. (sheet 3 of 6)**STREAM RELATIONSHIPS: GLOBAL VS. DETAILED CLEAN OPTION MODELS CONTINUED****GLOBAL MODEL****DETAILED MODEL****REXTRAML/EXTRAMLN: (AMERICIUM AND LANTHANIDES EXTRACTION USING CMPO)**

<u>FEEDS:</u>	B211HLL	7				
<u>FEEDS:</u>	B221CM	39	40	41	44	49
<u>PRODUCTS:</u>	B221AMLN	45				
<u>PRODUCTS:</u>	B221HLL	42				
<u>PRODUCTS:</u>	B221LML	51				

RAMLANIX/AMLANIX: (AMERICIUM AND LANTHANIDES ION EXCHANGE)

<u>FEEDS:</u>	B221AMLN	45					
<u>FEEDS:</u>	B222CM	53	54	55	56	57	58 59
<u>PRODUCTS:</u>	B222AMLN	62					
<u>PRODUCTS:</u>	B222ALML	61					
<u>PRODUCTS:</u>	B222BLML	60					

RSREX/SREX: (STRONTIUM AND TECHNETIUM EXTRACTION)

<u>FEEDS:</u>	B221HLL	42			
<u>FEEDS:</u>	B231CM	70	71	74	77
<u>PRODUCTS:</u>	B231SRTC	75			
<u>PRODUCTS:</u>	B231HLL	72			
<u>PRODUCTS:</u>	B231LML	78			

RSRBAIX/SRBAIX: (STRONTIUM, BARIUM, AND TECHNETIUM ION EXCHANGE)

<u>FEEDS:</u>	B231SRTC	75				
<u>FEEDS:</u>	B232CM	80	81	82	83	84 85
<u>PRODUCTS:</u>	B232SRTC	94				
<u>PRODUCTS:</u>	B232LML	95				

RAPMCSIX/APMCSIX: (CESIUM ION EXCHANGE USING APM)

<u>FEEDS:</u>	B231HLL	72	
<u>FEEDS:</u>	B24CM	96	99
<u>PRODUCTS:</u>	B24CS	101	
<u>PRODUCTS:</u>	B24LML	102	

Table D3. Stream Relationships: Global Versus Detailed
Clean Option Models. (sheet 4 of 6)**STREAM RELATIONSHIPS: GLOBAL VS. DETAILED CLEAN OPTION MODELS CONTINUED****GLOBAL MODEL DETAILED MODEL****RCALCINE/CALCINE: (WASTE CALCINING)**

<u>FEEDS:</u>	B33LML	350		
<u>FEEDS:</u>	B212LML	34		
<u>FEEDS:</u>	B221LML	51		
<u>FEEDS:</u>	B222ALML	61		
<u>FEEDS:</u>	B231LML	78		
<u>FEEDS:</u>	B232LML	95		
<u>FEEDS:</u>	B45LML	512		
<u>FEEDS:</u>	B41CM	506	507	
<u>PRODUCTS:</u>	B41COND	501		
<u>PRODUCTS:</u>	B41NACR	514		
<u>PRODUCTS:</u>	B41GAS	515		

RREMCr/REMCr: (CHROMIUM REMOVAL)

<u>FEEDS:</u>	B41NACR	514		
<u>FEEDS:</u>	B42CM	516	522	525
<u>PRODUCTS:</u>	B42NAOH	530		
<u>PRODUCTS:</u>	B42LML	518	524	527

RDNITRL/DNITRL: (LLW DENITRATION)

<u>FEEDS:</u>	B222BLML	60		
<u>FEEDS:</u>	B24LML	102		
<u>FEEDS:</u>	B45CM	508	509	
<u>PRODUCTS:</u>	B45LML	512		
<u>PRODUCTS:</u>	B45COND	504	511	

REVAPORH/EVAPORH: (HLW EVAPORATION)

<u>FEEDS:</u>	B211THPU	11		
<u>FEEDS:</u>	B33TC	343		
<u>FEEDS:</u>	B232SRTC	94		
<u>FEEDS:</u>	B222AMLN	62		
<u>PRODUCTS:</u>	B46HLL	539		
<u>PRODUCTS:</u>	B46COND	538		

Table D3. Stream Relationships: Global Versus Detailed
Clean Option Models. (sheet 5 of 6)

STREAM RELATIONSHIPS: GLOBAL VS. DETAILED CLEAN OPTION MODELS CONTINUED

GLOBAL MODEL DETAILED MODEL
 RRCOVACI/RCOVACID: (HNO₃ ACID RECOVERY)

<u>FEEDS:</u>	B45COND	504	511
<u>FEEDS:</u>	B32COND	326	
<u>FEEDS:</u>	B212ARCY	38	
<u>FEEDS:</u>	B44COND	542	
<u>FEEDS:</u>	B46COND	538	
<u>FEEDS:</u>	B43CM	550	558
<u>PRODUCTS:</u>	B43HRCY	557	
<u>PRODUCTS:</u>	B43HNO ₃	556	
<u>PRODUCTS:</u>	B43GAS	554	

RDNITRH/DNITRH: (HLW DENITRATION)

<u>FEEDS:</u>	B31CS	310
<u>FEEDS:</u>	B46HLL	539
<u>FEEDS:</u>	B44CM	540
<u>PRODUCTS:</u>	B44HLS	543
<u>PRODUCTS:</u>	B44COND	542

MIXHLW: (COMBINE HLW WASTE STREAMS)

<u>FEEDS:</u>	B44HLS	543
<u>FEEDS:</u>	B132HLS	281
<u>FEEDS:</u>	B3CM	546
<u>PRODUCTS:</u>	2322HLWL	544
<u>PRODUCTS:</u>	B3HRCY	548
<u>PRODUCTS:</u>	B3GAS	547

MIXLLW: (COMBINE LLW WASTE STREAMS)

<u>FEEDS:</u>	B42LML	518	524	527
<u>FEEDS:</u>	B4CM	528		
<u>PRODUCTS:</u>	2322LLWL	529		

MIXOGAS: (COMBINE OFFGAS WASTE STREAMS)

<u>FEEDS:</u>	B111GAS	411
<u>FEEDS:</u>	B131GAS	218
<u>FEEDS:</u>	B132GAS	258
<u>FEEDS:</u>	B41GAS	515
<u>FEEDS:</u>	B43GAS	554
<u>FEEDS:</u>	B3GAS	547
<u>PRODUCTS:</u>	ALLGAS	570

Table D3. Stream Relationships: Global Versus Detailed
Clean Option Models. (sheet 6 of 6)

STREAM RELATIONSHIPS: GLOBAL VS. DETAILED CLEAN OPTION MODELS CONTINUED

GLOBAL MODEL

DETAILED MODEL

MIXH20: (COMBINE PDT WATER STREAMS)

<u>FEEDS:</u>	B31COND	451			
<u>FEEDS:</u>	B212COND	37	26	20	31
<u>FEEDS:</u>	B43HNO3	556			
<u>FEEDS:</u>	B41COND	501			
<u>PRODUCTS:</u>	2322COND	560			

RMAKEOX: (MAKE OXIDES FROM NEUTRALIZED HLW)

<u>FEEDS:</u>	2322HLWL	544
<u>FEEDS:</u>	C12CM	HYDROX
<u>PRODUCTS:</u>	C12HLS	TCOX

SEPOX: (OXIDE STREAM SEPARATION)

<u>FEEDS:</u>	C12HLS	TCOX
<u>PRODUCTS:</u>	C13HLS	HLWOXS
<u>PRODUCTS:</u>	311OGAS	REST

VITRW: (VITRIFICATION)

<u>FEEDS:</u>	C13HLS	HLWOXS
<u>FEEDS:</u>	C11CM	FRIT (GLASS FORMERS)
<u>PRODUCTS:</u>	311OHLWS	GLASS

RGROUTW/GROUTW: (GROUTING OF LLW)

<u>FEEDS:</u>	2322LLWL	529			
<u>FEEDS:</u>	34CM	H2OFIX	DRYMIX	AIRIN	AIRLK
<u>PRODUCTS:</u>	3400LMWS	GRLMWS			
<u>PRODUCTS:</u>	3400LLWS	GRLLS			
<u>PRODUCTS:</u>	3400GAS	GRGAS			

COST: (COSTING)

<u>FEEDS:</u>	STR304A	304A
<u>FEEDS:</u>	STR450	450
<u>FEEDS:</u>	STR318A	318A
<u>FEEDS:</u>	STR336A	336A
<u>FEEDS:</u>	STR59A	59A
<u>FEEDS:</u>	STR85A	85A
<u>PRODUCTS:</u>	COST304A	304A
<u>PRODUCTS:</u>	COST450	450
<u>PRODUCTS:</u>	COST318A	318A
<u>PRODUCTS:</u>	COST336A	336A
<u>PRODUCTS:</u>	COST59A	59A
<u>PRODUCTS:</u>	COST85A	85A

Table D4. Component Lumping Scheme Used for CLEAN Option Global Models.

Lumped Component	Detailed Model Species			
01) H2O	H2O	H2O2		
02) PU	PUO2	PU+4		
03) U	U3O8	UO2+2	UO3	
04) LANL	CE2O3	CE+3	LA2O3	LA+3
05) CS	CS2O	CS+		
06) SR	SRO	SR+2		
07) TC	TC2O7	TCO2	TCO4-	
08) I	H	I2	I-	
09) FP2	RU2O3	RU+3	SEO3	SE+6
09) FP2	SNO2	SN+4	ZNO	ZN+2
09) FP2	ZRO2	ZRO2:2H2	ZR+4	
10) AP1	C14			
11) NANO3	NA2C2O4	NA2O	NATITAN	NA+
11) NANO3	NO2	NO2-	NO3-	
12) OHAZ2	AG2O	AG+	AS2O5	AS+5
12) OHAZ2	BEO	BE+2	CDO	CD+2
12) OHAZ2	CL-	CUO	CU+2	FECN6-3
12) OHAZ2	F-	HCOO-	HF	HGO
12) OHAZ2	HG+2	K2O	K+	LI2O
12) OHAZ2	LI+	MGO	MG+2	NI2FECN6
12) OHAZ2	PBO2	PB+4	TEO3	TE+6
12) OHAZ2	THFTCA	DTPA	EDTA	
13) SOI	SOI			
14) OTH3	AA	B2O3	BI2O3	BI+3
14) OTH3	BLAST-SL	B+3	C2H2O4	C2O4-2
14) OTH3	C6H8O6	CANCRINI	CAO	CASO4
14) OTH3	CA+2	FE2O3	FEO	FESA
14) OTH3	FE+2	FE+3	FLY-ASH	LIMESTON
14) OTH3	MNO	MNO2	MN+2	MN+4
14) OTH3	MOO3	MO+6	NB2O5	NB+5
14) OTH3	NI2O3	NIO	NI+3	ORGS
14) OTH3	ORGT	ORGU	P2O5	P2O5:24W
14) OTH3	PO4-3	POLY	PORTLAND	PTA-3
14) OTH3	RB2O	RB+	RE2O7	RE+7
14) OTH3	RH2O3	RH+3	SB2O5	SB+5
14) OTH3	SO3	SO4-2	TIO2	TI+4
14) OTH3	TL2O3	TL+3	V2O5	V+5
14) OTH3	WO2	WO3	W+6	
14) OTH3	APM-	NH2OH	SUCROSE	CO+3
15) CR2O3	CR2O3	CR+3		
16) AM	AM2O3	AM+3	CM2O3	CM+3
17) TH	THO2	TH+4		
18) NP	NPO2	NP+4		
19) LANH	SM2O3	SM+3		
20) NAOH	NAOH	OH-		
21) BA	BAO	BA+2		
22) HNO3	HNO3	H+		
23) AL2O3	AL2O3	AL+3		
24) SIO2	SIO2	SI+4		
25) NOX	OO	CO2	CO2O3	CO3-2
25) NOX	H2	N2	NO	
25) NOX	O2	TOC	NH3	NH4+

D-57

Table D5. Separation Factors and Reactor Component Yield Data for Model CLEAN31. (sheet 3 of 4)

BLOCK	H2O	FU	U	LANL	CS	SR	TC	I	FP2	AP1	NANO3	CHAZ2	SCI	OTHS	CR203
RSEPSOL	7.2387E-01	6.1822E-07	1.8751E-03	3.1548E-04	2.1557E-06	5.4178E-05	4.4651E-06	1.4295E-06	1.1342E-03	1.4824E-09	2.1770E-01	5.1481E-03	1.0000E-14	1.7449E-02	2.1063E-04
RDESTORG	7.2745E-01	1.8814E-08	1.1637E-04	3.2805E-06	2.0476E-06	5.7840E-07	3.6528E-06	1.5050E-06	2.9908E-05	1.5650E-09	2.2599E-01	4.2206E-03	1.0000E-14	9.5715E-03	5.3164E-05
RICALUSLEA	7.8855E-01	1.6598E-06	4.8421E-03	1.0198E-03	1.2325E-06	1.3991E-04	2.7346E-06	9.7162E-07	4.3617E-03	5.2587E-11	6.7502E-02	1.3253E-02	1.0000E-14	4.4485E-02	5.6410E-04
RCSIX	7.6083E-01	5.4777E-10	3.2918E-08	5.9614E-05	1.8260E-06	4.3642E-08	2.9934E-06	1.3456E-06	4.3237E-04	1.1190E-09	1.7978E-01	6.7818E-03	1.0000E-14	1.6218E-02	5.8659E-07
RFBIX	7.6197E-01	5.4489E-10	3.2733E-06	5.9280E-05	1.8158E-10	4.3397E-08	2.9786E-06	1.3381E-06	4.2994E-04	1.1127E-09	1.7931E-01	6.3721E-03	1.0000E-14	1.6127E-02	5.9324E-07
RTOX	8.2438E-01	3.7822E-10	2.2729E-06	4.1162E-05	1.2608E-10	1.1752E-10	2.0669E-06	9.2913E-07	2.9854E-04	7.7266E-10	1.3080E-01	4.4246E-03	1.0000E-14	1.1178E-02	4.1193E-07
RDISOLVA	6.8780E-01	1.9539E-06	5.6964E-03	9.6821E-04	7.2144E-07	1.6487E-04	3.1606E-06	6.3532E-08	2.1727E-03	4.4682E-11	2.5588E-01	2.1708E-03	1.0000E-14	3.5484E-02	6.6382E-04
RDISOLVF	7.5813E-01	1.2292E-06	3.5837E-03	6.0673E-04	4.5034E-07	1.0362E-04	1.9881E-06	3.4738E-08	1.7265E-03	2.8019E-11	1.5858E-01	1.2836E-02	1.0000E-14	5.4849E-02	4.1762E-04
REXTRIFU	7.9583E-01	1.1169E-06	4.0332E-03	5.7194E-04	4.2958E-07	9.8164E-05	1.9826E-06	3.7882E-08	1.1575E-03	2.6604E-11	1.7414E-01	2.1875E-03	1.0000E-14	1.7098E-02	3.7942E-04
RFURIFU	9.7528E-01	3.3983E-10	1.2869E-02	1.7402E-11	1.0000E-14	1.0000E-14	2.5780E-09	1.0000E-14	1.0000E-14	1.0000E-14	1.0688E-02	3.2631E-06	1.0000E-14	2.2603E-05	1.0000E-14
REXTRAML	8.5377E-01	8.1408E-11	2.9401E-07	4.1689E-04	3.1315E-07	7.1559E-05	1.3710E-06	2.7815E-08	8.4294E-04	1.9394E-11	1.2504E-01	3.3390E-03	1.0000E-14	1.1984E-02	2.7859E-04
RAMLANDX	9.6280E-01	2.1678E-10	7.8282E-07	1.1100E-03	1.0000E-14	1.0000E-14	1.8258E-09	1.0000E-14	2.9099E-04	1.0000E-14	3.0198E-02	4.9832E-03	1.0000E-14	3.4395E-04	1.0000E-14
RFBIX	9.1425E-01	1.0000E-14	1.6637E-11	2.3590E-08	1.7720E-07	4.0493E-05	7.7504E-07	1.5826E-08	4.7652E-04	1.0974E-11	7.5229E-02	9.0059E-04	1.0000E-14	6.4908E-03	1.5851E-04
RFBIX	9.8455E-01	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	3.9308E-05	7.4492E-07	1.0000E-14	1.0478E-03	1.0000E-14	7.3142E-03	6.4717E-03	1.0000E-14	1.0000E-14	1.0000E-14
RAPMCSIX	8.1583E-01	1.0000E-14	3.7808E-11	5.3807E-08	4.0267E-07	9.2018E-09	1.7812E-08	3.5510E-08	1.0828E-03	2.4938E-11	1.6291E-01	2.0485E-03	1.0000E-14	1.4750E-02	3.5585E-04
RFCOVACI	8.7988E-01	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	8.6600E-02	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14
RNEUTRAL	9.8690E-01	7.2906E-07	2.6330E-06	3.5811E-07	1.0000E-14	6.4086E-05	5.8389E-06	1.0000E-14	5.5298E-06	1.0000E-14	1.1588E-02	7.7561E-04	1.0000E-14	4.2842E-04	1.0000E-14
RDNTRH	8.5383E-01	2.3967E-05	6.6556E-05	1.1772E-05	9.3177E-05	2.1067E-03	1.9194E-04	1.0000E-14	1.8178E-04	1.0000E-14	7.1253E-02	2.5497E-02	1.0000E-14	1.4083E-02	1.0000E-14
RDNTRL	8.4209E-01	5.8208E-11	2.1022E-07	4.1980E-05	2.2393E-10	5.1171E-09	1.0285E-08	1.9747E-08	6.0278E-04	1.3868E-11	1.0972E-01	1.1392E-03	1.0000E-14	8.2908E-03	1.9778E-04
RICALONE	8.6564E-01	2.6784E-10	1.6230E-08	1.3507E-04	1.6360E-10	1.9359E-09	1.0655E-08	6.1319E-07	9.3607E-04	1.0000E-14	4.0239E-02	7.0784E-03	1.0000E-14	1.0403E-02	7.2133E-05
RFBIX	6.8864E-01	8.8524E-10	5.3642E-06	4.4841E-04	5.4089E-10	6.3982E-09	3.5218E-08	2.0266E-06	3.0937E-03	1.0000E-14	1.3299E-01	2.3387E-02	1.0000E-14	3.4836E-02	2.3940E-04
RMAKECK	1.4471E-04	6.8071E-07	3.1975E-06	8.3028E-07	2.1560E-06	6.0445E-05	3.9837E-06	9.5210E-12	7.6880E-06	7.0000E-15	3.4666E-05	6.1897E-04	1.0000E-14	2.5821E-04	7.6802E-07
RGROUTW	6.6262E-01	1.3771E-10	8.3446E-07	6.9445E-05	8.4110E-11	9.9532E-10	5.4782E-09	3.1526E-07	4.8126E-04	1.0000E-14	2.0688E-02	3.6312E-03	1.0000E-14	2.8707E-01	4.6329E-05

Table D5. Separation Factors and Reactor Component Yield Data for Model CLEAN31. (sheet 4 of 4)

BLOCK	AM	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX
RSEPSOL	4.9082E-08	1.5888E-05	1.2571E-07	5.8949E-07	2.2339E-02	5.7857E-04	7.5000E-14	5.0581E-03	6.8946E-05	4.1770E-03
RDESTORG	2.4381E-09	2.0003E-07	5.5552E-09	5.9861E-09	2.1674E-02	3.7819E-07	8.0000E-14	3.2581E-03	1.6448E-05	7.8088E-03
RCALUSLEA	1.3177E-07	4.2754E-05	3.3822E-07	1.5228E-08	5.4111E-02	1.8354E-03	3.4052E-08	1.5387E-02	1.8228E-04	3.7301E-03
RCSIX	5.7588E-11	4.0181E-08	3.6552E-10	8.1007E-10	2.8824E-02	1.0282E-04	7.7709E-06	5.9186E-03	2.4793E-05	3.2530E-03
RSPKX	5.7245E-11	3.9955E-08	3.6347E-10	8.0864E-10	2.8503E-02	1.0235E-04	4.2385E-06	5.8834E-03	2.4654E-05	3.2092E-03
RTOKX	3.9749E-11	2.7744E-08	2.5238E-10	4.2124E-10	2.2527E-02	1.0000E-14	1.8548E-05	4.0853E-03	1.7119E-05	2.2284E-03
RDISOLVA	1.5511E-07	5.0224E-05	3.9724E-07	1.7920E-06	1.4739E-03	2.1627E-03	3.5560E-03	1.1539E-03	1.8313E-04	8.7567E-04
RDISOLVF	9.7582E-08	3.1596E-05	2.4991E-07	1.1274E-06	9.1288E-04	1.1073E-03	2.5285E-03	3.5476E-03	1.0238E-04	5.2977E-04
REXTRIPIU	8.8657E-08	2.8709E-05	2.2707E-07	1.0670E-06	1.0000E-14	1.2903E-03	2.4646E-03	4.8432E-04	9.7127E-05	1.3457E-04
RFURIPYU	1.0000E-14	8.6490E-09	6.8409E-11	1.0000E-14	1.0000E-14	1.0000E-14	1.0225E-04	1.0000E-14	1.0000E-14	7.3287E-04
REXTRAML	8.4622E-08	2.0928E-07	1.6553E-09	7.7771E-07	1.0000E-14	9.4083E-04	1.7633E-03	3.5306E-04	7.0803E-05	1.1271E-03
RAMLANDX	1.7208E-07	5.5723E-07	2.2039E-09	2.0707E-08	1.0000E-14	1.0000E-14	4.8630E-04	1.0000E-14	1.0000E-14	1.0000E-14
RSPKX	3.6550E-12	1.1843E-11	4.6834E-10	4.4008E-11	1.0000E-14	5.3227E-04	1.0927E-03	1.9978E-04	4.0085E-05	5.9231E-04
RSPBAX	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	5.1670E-04	6.0837E-05	1.0000E-14	1.0000E-14	1.0000E-14
RAPMCSIX	8.3080E-12	2.6911E-11	1.0643E-09	1.0000E-10	1.0000E-14	1.2095E-07	2.3410E-03	5.2647E-04	9.1044E-05	6.5141E-05
RRCOVACI	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	8.8600E-04	1.0000E-14	1.0000E-14	3.2653E-02
RNEUTRAL	5.7862E-08	1.8555E-05	1.4678E-07	6.8643E-07	1.0000E-14	3.8554E-05	1.7701E-04	1.0000E-14	1.0000E-14	1.0000E-14
RDNTRH	1.9021E-06	6.0997E-04	4.8245E-06	2.2894E-05	1.0000E-14	1.2674E-03	4.1883E-04	1.0000E-14	1.0000E-14	3.0319E-02
RDNTRL	9.2370E-12	1.4984E-07	1.1836E-09	1.1122E-10	1.0000E-14	6.7284E-08	5.9282E-04	6.6546E-03	5.0631E-05	3.0613E-02
RCALONE	3.2638E-11	7.2472E-08	5.9470E-10	3.3538E-10	2.7883E-02	2.3321E-04	1.0000E-14	5.0825E-03	2.9582E-05	4.2267E-02
RREMOX	1.0788E-10	2.3951E-07	1.9654E-09	1.1083E-09	9.1919E-02	7.7077E-04	1.0000E-14	1.6797E-02	9.7701E-05	6.7799E-03
RMAKSOX	5.0813E-08	1.8875E-05	1.3314E-07	6.4409E-07	4.7526E-01	3.4648E-05	4.7528E-02	4.3122E-05	4.0703E-05	4.7594E-01
RGRROUTW	1.6777E-11	3.7259E-08	3.0574E-10	1.7241E-10	1.4299E-02	1.1990E-04	1.0000E-14	2.6130E-03	1.5199E-05	8.3455E-03

Table D6. Separation Factors and Reactor Component Yield Data for Model TRUG31. (sheet 2 of 4)

PROCESSORS	OUTSTREAMS	CPRO3	AM	TH	NP	LANH	NACH	BA	HN03	AL2O3	SiO2	NOX
WASHSLUD	B111HLL	.236031	.046446	.011775	.041325	.009465	.862281	.000613	.000000	.802571	.223091	.937385
DESTORG	B112HSL	.009996	.009996	.009996	.009996	.009996	.904720	.999604	.000000	.899728	.999604	.414109
DESTORG	B112HLS	.990004	.990004	.990004	.990004	.990004	.095280	.000396	.000000	.000000	.000396	.000164
DESTORG	B112CONO	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
FLTAUSB	B113HLL	.902500	.902500	.902500	.902500	.902500	.000000	.000000	.000000	.000000	.000000	.000000
CSK	B31CS	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
CSK	B311LML	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
CSK	B311CONO	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
TOX1	B311TC	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
TOX1	B312LML	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
TOX1	B312GAS	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
DESSOLVA	B13HLL	.897157	.828169	.890715	.856858	.914921	.000000	.922589	.986208	.884715	.862748	.074131
DESSOLVA	B13HLL	.102843	.171831	.109285	.143142	.085078	.000000	.077411	.003792	.115285	.137252	.046808
TRLEX	B21TRU	.000000	.990025	.990025	.990025	.990025	.000000	.000000	.084087	.000000	.000000	.000000
TRLEX	B211UTC	.000000	.004975	.004975	.004975	.004975	.000000	.000000	.000283	.000000	.000000	.000000
TRLEX	B21HLL	.000000	.005000	.005000	.005000	.005000	.000000	.000000	.871836	.000000	.000000	.037884
TRLEX	B211CONO	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
TRLEX	B212UTC	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
UTCSHPP	B23U	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
TOX2	B23U	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
TOX2	B23GAS	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
PLUPYU	B24UTCY	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
PLUPYU	B24U	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
PLUPYU	B24LML	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
SPFX	B22SR	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
SPFX	B22HLL	.000000	.999987	.000000	.000000	.000000	.189343	.000000	.000000	.997422	.000000	.992926
SPFX	B22LML	.000000	.003013	.000000	.000000	.000000	.810657	.000000	.009052	.002578	.000000	.307074
SPFX	B22CONO	.000500	.000500	.000500	.000500	.000500	.000000	.000500	.000000	.000500	.000500	.000000
NEUTOCAN	T31LML	.000500	.000500	.000500	.000500	.000500	.224583	.000500	.000000	.000500	.000500	.005977
MOXLLW	2322LML	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
MOXPD	2322CONO	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
GFOUTW	3400LLWS	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
GFOUTW	3400LMLS	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
CALCNE	C14HLS	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
SEPOX	C13HLS	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
VITRW	3110HLWS	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
COST	COST102	.497488	.342919	.025217	.081134	.019954	.467003	.497488	.035103	.497487	.497488	.493488
COST	COST304	.000000	.310700	.940311	.836913	.959891	.000000	.000000	.964887	.000000	.000000	.000000
TRTSOL	S10BUR	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
TRTSOL	S10GRT	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
TRTSOL	S10LEACH	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
INON	S20ASH	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
INON	S20GAS	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
EVAPX	S30CONO	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
EVAPX	S30CONC	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
OGASTRT	S40FLT	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
OGASTRT	S40GAS	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
OGASTRT	S40LIQ	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
RETRST	2312EOP	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
RETRST	2311EOP	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
RETRST	2311EOP	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
TREATWAT	2200H2O	.000000	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001

Table D6. Separation Factors and Reactor Component Yield Data for Model TRUG31. (sheet 3 of 4)

BLOCK	H2O	FU	"	LANL	CS	SR	TC	I	FP2	AP1	NANO3	CHAZZ	SCI	OTH3	CR203
RWASHSLU	7.2433E-01	6.1710E-07	1.8717E-03	3.1489E-04	2.1521E-06	5.4079E-05	4.4575E-06	1.4271E-08	1.1322E-03	1.4799E-09	2.1734E-01	5.1393E-03	1.0000E-14	1.7425E-02	2.1026E-04
RDESTORG	7.3121E-01	1.8679E-08	1.1554E-04	3.2571E-06	2.0330E-06	5.7227E-07	3.6268E-06	1.4942E-06	2.9695E-05	1.5539E-09	2.2342E-01	4.1948E-03	1.0000E-14	9.5043E-03	5.2783E-05
RFLTADS	7.3438E-01	1.8980E-10	1.1728E-06	3.3081E-08	2.0636E-06	5.8089E-09	3.6813E-06	1.5167E-06	2.9042E-05	1.5772E-09	2.2742E-01	4.2550E-03	1.0000E-14	9.5405E-03	5.3579E-07
RCSIX	8.7199E-01	4.9681E-11	4.0138E-07	1.1315E-08	7.8631E-07	1.7942E-09	1.2882E-06	5.2712E-07	9.9392E-06	5.4659E-10	1.0921E-01	1.4938E-03	1.0000E-14	6.2772E-03	1.8337E-07
RTCDX1	8.6970E-01	4.9918E-11	4.0329E-07	1.1369E-08	9.8196E-09	1.8028E-09	1.6120E-06	5.2964E-07	9.9866E-06	5.4920E-10	1.1093E-01	1.5010E-03	1.0000E-14	6.3071E-03	1.8424E-07
RDISSOLV	7.4095E-01	2.0759E-06	6.2940E-03	1.0594E-03	8.1236E-07	1.8195E-04	3.5297E-06	7.6794E-08	2.2576E-03	6.5808E-11	1.8885E-01	4.0365E-03	1.0000E-14	3.8878E-02	7.0579E-04
RTRUEX	4.2705E-01	4.0550E-07	1.2569E-03	2.1040E-04	1.6245E-07	3.6229E-05	7.0887E-07	1.6335E-08	4.3710E-04	1.3806E-11	4.2007E-02	3.8787E-04	1.0000E-14	5.2495E-01	1.4078E-04
RUTCSTRI	1.7990E-01	6.3300E-09	3.7240E-03	3.2843E-06	1.0000E-14	1.0000E-14	2.0279E-06	1.0000E-14	1.0000E-14	1.0000E-14	4.2230E-03	1.4550E-09	1.0000E-14	8.0948E-01	1.0000E-14
RTCDX2	9.5135E-01	1.5189E-08	8.9356E-03	7.8807E-06	1.0000E-14	1.0000E-14	4.8660E-06	1.0000E-14	1.0000E-14	1.0000E-14	3.0666E-02	3.4912E-09	1.0000E-14	3.9987E-03	1.0000E-14
RPURIFYU	5.7533E-01	3.4605E-09	2.0359E-03	1.7955E-06	1.0000E-14	1.0000E-14	1.1087E-08	1.0000E-14	1.0000E-14	1.0000E-14	1.1250E-02	7.9542E-10	1.0000E-14	4.1121E-01	1.0000E-14
RSPRX	6.3518E-01	3.9891E-09	1.2365E-05	2.0698E-06	3.1974E-07	7.1305E-05	1.1301E-07	3.2151E-08	1.4894E-03	2.7172E-11	1.0001E-01	7.6303E-04	1.0000E-14	2.5483E-01	2.7700E-04
RNEUTDCA	8.8014E-01	5.7004E-06	2.5697E-03	2.9087E-03	2.2629E-07	4.9952E-04	1.0097E-06	9.2004E-09	8.7055E-04	1.0289E-11	7.7949E-02	6.3505E-03	1.0000E-14	3.7274E-02	2.0108E-04
RNEUTRAL	6.3303E-01	1.0000E-14	1.0000E-14	1.0000E-14	1.0510E-03	1.0000E-14	2.1590E-03	1.0000E-14	1.0000E-14	1.0000E-14	3.4830E-01	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14
RMDXLLW	7.2050E-01	2.0452E-05	9.2196E-03	1.0436E-02	7.1079E-05	1.7922E-03	1.4770E-04	3.0454E-08	3.1234E-03	3.4755E-11	7.0562E-02	2.2768E-02	1.0000E-14	1.2513E-01	7.2143E-04
RMDXLLW	7.5505E-01	3.8711E-09	7.4218E-06	1.9809E-06	1.8389E-08	3.4154E-07	2.8627E-08	9.4439E-07	6.8767E-04	9.7925E-10	2.0706E-01	2.9524E-03	1.0000E-14	1.2708E-02	1.2491E-04
RMDXHZO	9.9962E-01	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	3.8087E-04	1.0000E-14	1.0000E-14	9.8801E-07	1.0000E-14
RGRROUTW	6.9973E-01	1.0388E-09	1.9912E-06	5.3147E-07	4.9337E-09	9.1632E-08	7.6804E-09	2.5337E-07	1.8450E-04	2.6273E-10	5.5552E-02	7.9211E-04	2.3571E-03	2.2974E-01	3.3512E-05
RCALONE	1.3300E-13	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14
RMAKECK	2.0916E-02	6.3849E-07	2.6389E-04	3.3660E-04	2.0748E-06	5.8353E-05	3.8669E-06	8.4513E-10	6.6943E-05	9.5700E-13	1.2552E-03	1.1884E-04	1.0000E-14	9.4940E-04	2.9031E-05

Table D6. Separation Factors and Reactor Component Yield Data for Model TRUG31. (sheet 4 of 4)

BLOCK	AM	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX
RWASHSLU	4.9002E-08	1.5859E-05	1.2548E-07	5.8842E-07	2.2301E-02	5.7553E-04	6.3228E-16	5.0474E-03	6.8823E-05	4.1700E-03
RDESTORG	2.4206E-09	1.9860E-07	5.5154E-09	5.9234E-09	2.0453E-02	3.7550E-07	1.0000E-14	3.2349E-03	1.6331E-05	7.7635E-03
RFLTADS	2.4586E-11	2.0160E-09	5.5985E-11	6.0127E-11	1.8790E-02	3.8115E-07	1.0000E-14	2.2985E-03	1.6578E-05	3.2646E-03
RCSX	8.2330E-11	6.8994E-10	1.9160E-11	2.0578E-11	8.1095E-03	1.3044E-07	2.7595E-05	1.7400E-03	5.6730E-06	1.1309E-03
RTCDX1	8.2723E-11	6.9323E-10	1.9252E-11	2.0676E-11	8.8788E-03	1.3106E-07	2.3257E-06	1.7483E-03	5.7001E-06	9.1904E-04
RDISSOLV	1.6481E-07	5.3354E-05	4.2204E-07	1.9797E-06	1.3710E-03	1.9353E-03	1.7440E-03	9.8224E-03	1.7993E-04	1.6772E-03
RTRUEX	3.0346E-08	1.0566E-05	8.0403E-08	4.0270E-07	1.0000E-14	3.9697E-04	4.2128E-04	1.9344E-03	3.4514E-05	7.2971E-04
RUTCSTRI	4.7371E-10	1.6494E-07	1.2551E-09	6.2863E-09	1.0000E-14	1.0000E-14	3.7423E-07	1.0000E-14	1.0000E-14	2.6902E-03
RTCDX2	1.1367E-09	3.9577E-07	3.0116E-09	1.5084E-08	1.0000E-14	1.0000E-14	1.2026E-04	1.0000E-14	1.0000E-14	4.9197E-03
RPURIFYU	2.5897E-10	9.0170E-08	6.8616E-10	3.4366E-09	9.2842E-05	1.0000E-14	4.3916E-05	1.0000E-14	1.0000E-14	4.0672E-05
RSREX	2.9863E-10	1.0395E-07	7.9095E-10	3.9615E-09	2.5830E-03	7.8108E-04	4.4391E-05	3.8073E-03	6.7908E-05	7.8317E-05
RNEUTDCA	4.5279E-07	1.4649E-04	1.1592E-06	5.4341E-06	7.2382E-03	4.1502E-04	1.0000E-14	3.1369E-03	6.8413E-05	2.1975E-04
RNEUTRAL	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.5456E-02	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	3.2592E-06
RMD04LW	1.6245E-06	5.2558E-04	4.1589E-06	1.9497E-05	2.1181E-02	1.4890E-03	1.0000E-14	1.1255E-02	2.4545E-04	7.8433E-04
RMD0LLW	2.9761E-10	9.9715E-08	7.8527E-10	3.7848E-09	1.6760E-02	3.5152E-04	1.0000E-14	3.1215E-03	4.0705E-05	1.1366E-03
RMD0420	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14
RGRDUTW	7.9837E-11	2.6753E-08	2.1068E-10	1.0154E-09	4.4966E-03	9.4310E-05	1.0000E-14	8.3748E-04	1.0921E-05	6.1685E-03
RCALONE	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	4.7619E-01	1.0000E-14	4.7619E-02	1.0000E-14	1.0000E-14	4.7619E-01
RMAKEOX	4.9144E-08	1.6466E-05	1.2996E-07	6.2247E-07	4.6263E-01	4.5772E-05	4.6298E-02	1.4393E-03	1.0207E-03	4.6455E-01

D-64

WMC-EP-0791

Table D7. Separation Factors and Reactor Component Yield Data for Model SLUG31. (sheet 2 of 4)

PROCESSORS	OUTSTREAMS	CR203	AM	TH	NP	LANH	NACH	BA	HNO3	AL2O3	SiO2	NOX
WASHSLD	B111HLL	.238163	.046477	.011783	.041354	.009472	.862371	.000614	.991556	.602746	.223216	.937432
DESTORG	B112HSL	.010005	.010005	.010005	.010005	.989895	.094794	.999603	.999603	.300089	.999603	.414106
DESTORG	B112HLS	.989895	.989895	.989895	.989895	.989895	.095206	.000397	.000397	.000000	.000000	.000184
DESTORG	B112CONC	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
FLTAUSEB	B113HLL	1.000000	.902500	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
CBK	B31CS	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.002168	.000000	.000000	.000000
CBK	B311LML	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	.482924	1.000000	1.000000	1.000000
CBK	B31CONC	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.504907	.000000	.000000	.000000
TCX1	B312LML	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.852724	.000000	.000000	.000000
TCX1	B312GAS	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	1.000000	1.000000	.000000
TCX1	T311LML	.000500	.000664	.000500	.000500	.000500	.017834	.000500	.000500	.003518	.000500	.044028
NEUTDCAN	2322LMWL	0.500000	0.500000	0.500000	0.500000	0.500000	0.500000	0.500000	.000000	.000000	.000000	.000000
MOU20	2322CONC	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.042134
GROUTW	3400LLWS	0.500000	0.500000	0.500000	0.500000	0.500000	0.500000	0.500000	.000000	.000000	.000000	.042133
GROUTW	3400LLWS	0.500000	0.500000	0.500000	0.500000	0.500000	.000000	0.500000	.000000	.000000	.000000	.000000
CAZONE	C14HLS	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000002
SEPOX	C13HLS	1.000000	1.000000	1.000000	1.000000	1.000000	.000000	1.000000	.000000	1.000000	1.000000	1.000000
VITRW	3110HLLWS	1.000000	1.000000	1.000000	1.000000	1.000000	.000000	1.000000	.000000	1.000000	1.000000	.487488
COBT	COBT102	.497487	.497487	.497487	.497488	.497488	.473274	.497488	.000000	.497487	.497487	.0.00
COBT	COBT304	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000	.000000
TRISSOL	S10BFR	0.3333	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	.00001	.4500	.4500	0.0001
TRISSOL	S10GRT	0.3333	0.0001	0.0001	0.0001	0.9998	0.9998	0.9998	.00001	0.1000	0.1000	0.9998
TRISSOL	S10LEACH	0.3334	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	.00001	.00001	.00001	0.9999
INON	S20ASH	0.5000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	.00001	.00001	.00001	0.0001
INON	S20GAS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	.00001	.00001	.00001	0.0001
EVAPX	S30CONC	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	.00001	.00001	.00001	0.9999
EVAPX	S30CONC	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	.00001	.00001	.00001	0.9999
CGASTRT	S40FLT	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	.00001	.00001	.00001	0.9999
CGASTRT	S40GAS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	.00001	.00001	.00001	0.0001
CGASTRT	S40LIQ	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	.00001	.00001	.00001	0.0010
PGASTRT	2312ECPT	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14
PGASTRT	2311ECPT	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14	1.000E-14
PGASTRT	2200H2O	1.000E-04	1.000E-04	0.03330	1.000E-04	1.000E-04	1.000E-04	1.000E-04	1.000E-04	1.000E-04	1.000E-04	1.000E-04
TREATWAT												

Table D7. Separation Factors and Reactor Component Yield Data for Model SLUG31. (sheet 3 of 4)

BLOCK	H2O	FU	U	LANL	CS	SR	TC	I	FP2	AP1	NANO3	CHAZ2	SCI	OTH3	CF2O3
FWASHSLU	7.5548E-01	5.4710E-07	1.6594E-03	2.7916E-04	1.9092E-06	4.7944E-05	3.9540E-06	1.2661E-06	1.0037E-03	1.3129E-09	1.9282E-01	4.5586E-03	1.0000E-14	1.5419E-02	1.8643E-04
ROESTORG	7.3389E-01	1.8477E-08	1.1429E-04	3.2218E-06	2.0128E-06	5.6608E-07	3.5907E-06	1.4794E-06	2.9398E-05	1.5384E-09	2.2119E-01	4.1530E-03	1.0000E-14	9.4042E-03	5.2213E-05
RFLTADS	7.3145E-01	1.9170E-10	1.1858E-06	3.3427E-08	2.0854E-06	5.8732E-09	3.7221E-06	1.5335E-06	2.9363E-05	1.5947E-09	2.2993E-01	4.3021E-03	1.0000E-14	9.6439E-03	5.4171E-07
RCSX	8.7470E-01	6.4011E-11	5.1715E-07	1.4578E-08	9.0995E-07	2.3117E-09	1.6233E-06	6.6879E-07	1.2806E-05	6.9548E-10	1.0723E-01	1.8763E-03	1.0000E-14	4.2059E-03	2.3625E-07
FTCDX1	8.7195E-01	6.4542E-11	5.2144E-07	1.4699E-08	1.1404E-08	2.3309E-09	1.6363E-06	6.7435E-07	1.2912E-05	7.0126E-10	1.0928E-01	1.8918E-03	1.0000E-14	4.2409E-03	2.3822E-07
RNEUTDCA	9.1453E-01	2.0676E-06	6.2688E-03	1.0552E-03	8.0910E-07	1.8122E-04	3.5155E-06	7.6470E-08	3.7041E-03	6.5529E-11	1.1495E-02	4.0204E-03	1.0000E-14	2.8668E-02	7.0294E-04
RNEUTRAL	6.3340E-01	1.0000E-14	1.0000E-14	1.0000E-14	1.2254E-03	1.0000E-14	2.2004E-03	1.0000E-14	1.0000E-14	1.0000E-14	3.4771E-01	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14
RMDXHLW	7.4717E-01	6.1799E-06	1.8737E-02	3.1538E-03	2.1284E-05	5.4164E-04	4.4384E-05	1.8628E-07	1.1070E-02	1.5190E-10	3.2894E-02	1.1898E-02	1.0000E-14	8.5418E-02	2.1010E-03
RMDXLLW	7.6503E-01	3.8817E-10	1.7717E-06	1.6479E-07	2.5959E-08	2.7948E-08	2.6440E-08	1.2351E-06	2.4133E-05	1.2844E-09	2.0055E-01	3.4655E-03	1.0000E-14	7.7710E-03	5.2690E-07
RMDXHZO	9.9950E-01	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	5.0215E-04	1.0000E-14	1.0000E-14	7.0313E-08	1.0000E-14
RGRDUTW	7.0108E-01	1.0933E-10	4.9907E-07	4.6418E-08	7.3123E-09	7.8725E-09	7.4477E-09	3.4791E-07	6.7979E-06	3.6180E-10	5.6493E-02	9.7583E-04	2.3150E-03	2.2447E-01	1.4842E-07
RCALONE	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14
RMAKECK	6.9858E-02	6.0476E-07	1.6811E-03	3.1887E-04	1.9475E-06	5.5262E-05	3.6425E-06	1.6205E-08	7.4164E-04	1.3109E-11	1.8122E-03	6.1338E-04	1.0000E-14	4.6548E-03	2.6502E-04

Table D7. Separation Factors and Reactor Component Yield Data for Model SLUG31. (sheet 4 of 4)

BLOCK	AM	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX
RWASHSLU	4.3445E-08	1.4080E-05	1.1125E-07	5.2168E-07	1.9783E-02	5.1023E-04	6.7000E-14	4.4767E-03	6.1025E-05	3.6994E-03
RDESTORG	2.3945E-09	1.9646E-07	5.4558E-09	5.8593E-09	2.0248E-02	3.7178E-07	7.9000E-14	3.2018E-03	1.6168E-05	7.6862E-03
RFLTADS	2.4838E-11	2.0383E-09	5.6604E-11	6.0792E-11	1.8998E-02	3.8536E-07	8.2000E-14	2.3239E-03	1.6760E-05	3.3007E-03
RCSX	9.7760E-12	8.8893E-10	2.4687E-11	2.6513E-11	9.5040E-03	1.6807E-07	7.9024E-08	1.0135E-03	7.3093E-06	1.4395E-03
RTCDX1	9.8580E-12	8.9632E-10	2.4892E-11	2.6733E-11	1.0146E-02	1.6946E-07	2.3313E-06	1.0219E-03	7.3700E-06	1.4515E-03
RNEUTDCA	1.6415E-07	5.3141E-05	4.2036E-07	1.9718E-06	1.6540E-02	1.9276E-03	1.0000E-15	9.7827E-03	1.7921E-04	8.7959E-04
RNEUTRAL	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.5463E-02	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	2.2268E-06
RMDHLW	4.9055E-07	1.5883E-04	1.2564E-06	5.8934E-06	4.8818E-02	5.7613E-03	4.0000E-15	2.9151E-02	5.3564E-04	2.5145E-03
RMDLLW	4.6471E-11	8.5840E-09	1.0041E-10	3.0659E-10	1.8604E-02	5.6145E-07	1.0000E-14	1.8751E-03	1.3482E-05	2.6606E-03
RMDH2O	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14
RGRDUTW	1.3089E-11	2.4180E-09	2.8281E-11	8.6361E-11	5.2405E-03	1.5815E-07	1.0000E-14	5.2820E-04	3.7976E-06	8.8938E-03
RCALONE	1.0000E-14	1.0000E-14	1.0000E-14	1.0000E-14	4.7619E-01	1.0000E-14	4.7619E-02	1.0000E-14	1.0000E-14	4.7619E-01
RMAKEOX	4.6518E-08	1.5598E-05	1.2307E-07	5.8981E-07	4.3232E-01	5.5516E-04	4.3388E-02	5.5552E-03	1.0436E-03	4.3711E-01

This page intentionally left blank.

APPENDIX F
COST ESTIMATION MODELS

LIST OF TERMS

CMPO	N-diisobutylcarbamoylmethylphosphine oxide
CPU	compact processing unit
D&D	decontamination and decommissioning
DST	double-shell tank
HLW	high-level waste
HSA	Hanford Strategic Analysis
HWVP	Hanford Waste Vitrification Plant
ICF	Consolidated Incinerator Facility
ISV	in situ vitrification
LLW	low-level waste
SCWO	supercritical water oxidation
SST	single-shell tank
SWA	Sludge Wash A
SWB	Sludge Wash B
SWC	Sludge Wash D
TBP	tributyl phosphate
TRU	transuranic
TRUEX-C	Transuranic Extraction Option C
TWRS	Tank Waste Remediation System
WIPP	Waste Isolation Pilot Plant

COST ESTIMATION MODELS

This appendix discusses the development of the cost estimation models and the results from using these models. The cost models are based on cost data taken from a library of cost data compiled to support Hanford Site tank waste retrieval systems engineering efforts. In most cases, the data exist in the form of cost functions, though some data may be in the form of point estimates.

F1.0 DEVELOPMENT OF THE COST ESTIMATION MODELS

F1.1 COST FUNCTIONS

Cost functions predict the cost of some facility or activity based on input parameters, such as design throughput capacity, degree of chemical separation, amount of material treated or disposed, or other parameters as needed. Consequently, cost functions predict costs over a wide range of possible system configurations, rather than for just one specific configuration.

F1.1.1 Throughput Capacity

Cost function terms depending on design throughput capacity are based on the well known exponent scaling method. That is, terms such as the following:

$$(\text{actual capacity}/\text{reference capacity})^{**\text{Exp}}$$

are used, where the ratio of the desired capacity to a reference capacity is raised to an exponent between 0.0 and 1.0. One of these terms is multiplied times a reference capital cost to obtain a capacity-scaled capital cost. A similar term (generally with a different exponent) is multiplied times a reference operating cost to obtain a capacity-scaled operating cost. Many published tables of suggested exponents exist for specific chemical processes and processing facilities. Where no process-specific exponent can be found, a generic value of 0.7 is often used for the capital cost component. A value of 0.75 is usually used for the operating cost component.

F1.1.2 Chemical Separation

Cost function terms, depending on the degree of chemical separation, are based on the estimation that precipitation processes tend to have costs that increase linearly with increasing separation, solvent extraction processes tend to have costs that increase as the logarithm of separation, and ion exchange processes tend to have costs that increase as the logarithm of separation raised to the 0.55 power. These functional dependencies are semiquantitative estimates based on first principles considerations.

F1.1.3 Other

Other cost function terms have been derived from specific available data. For example, the cost function describing the cost for high-level waste disposal in the Nevada Repository is a curve fit based on cost estimates for specific volumes of material disposed.

F2.1 FUNCTION CREATION

In fully general form, a cost function should be independent of a particular process or particular facility. This is accomplished, in principle, in the following manner.

1. Cost functions are developed for several processes or facilities that perform a similar waste processing operation. Often these process/facility functions have different volume or separation performance ranges of applicability, but not always.
2. Overall process/facility-independent cost functions are developed by combining the individual functions in a way that seems most cost-advantageous or reasonable.

In practice, funding has not been available to develop and cost a wide enough range of process and facility alternatives to produce more than a few process/facility-independent cost functions using the two-step process described above. More typically, only Step 1 above is performed. That is, only a single process or facility is assumed available. The way in which this single process/facility cost varies with capacity or separation (or other appropriate parameter) is then estimated to produce a cost function based on that one process/facility.

Typically, individual cost functions are developed by multiplying together terms that correct for throughput capacity and terms that account for desired separation (if applicable). In instances where no separation is involved, an appropriate cost term is often simply multiplied times the total volume of waste involved in the process or facility. In other, unusual cases, some other scheme for developing the final cost function may be employed, but in all cases the end result is some combination of curve fitting, exponent scaling, and assumed functional forms for the process or activity under consideration.

Typically, capital and operating cost terms are represented separately in the cost functions.

F3.1 POINT ESTIMATES

In a few instances, information has not been located to allow development of even a "one process" cost function (using only Step 1 above). Where functions are not available, "point estimates" have been made for the cost of processes or facilities of a specific size and with specific, fixed parameters.

F4.1 COST FUNCTIONS AND POINT ESTIMATES USED

The previous report on the Transuranic Extraction Option C (TRUEX-C) and Sludge Wash C evaluation (Knutson et al. 1993) contained process cost function derivations based largely on the detailed cost estimates contained in the *Tank Waste Technical Options Report* (Boomer et al. 1993) work. These cost estimates were based on using a central processing facility. However, the CLEAN Option work did not include such detailed process cost estimations. Therefore, to provide a similar process cost breakdown for the CLEAN Option strategy based on the central facility concept, process cost function estimates were made based on matching the CLEAN Option processes with similar type processes in the TRUEX-C and Sludge Wash C process strategies for which cost functions were available. Because most of the available cost functions were related to process flows and separation factor performance, these function matches were considered adequate to provide reasonable cost estimates for the anticipated CLEAN Option processes. These CLEAN Option process matching assumptions are shown below.

Other CLEAN Option cost estimates have been made based on using some combination of compact processing units (CPUs) for processing supernate and salt cake and a central facility for processing sludge. A discussion of cost estimates for this concept is given in an individual writeup for CLEAN that follows.

CLEAN Option process matching assumptions for central facility concept:

1. Cesium Ion Exchange--same as before

$$CSIX = CSIX \text{ (TRUEX-C).}$$

2. Strontium Ion Exchange--same as technetium ion exchange

$$SRIX = TCIX1 \text{ (TRUEX-C).}$$

3. Technetium Ion Exchange--same as before

$$TCIX = TCIX1 \text{ (TRUEX-C).}$$

4. Acid (HNO_3 +Oxalic) Dissolution--set to 15% of previous TRUEX/SREX/technetium recovery cost

$$DISOLVA = 0.15 * (\text{TRUEX} + \text{SREX} + \text{DISSOLVA} + \dots) \text{ (TRUEX-C).}$$

5. Acid ($\text{HF} + \text{HNO}_3$) Dissolution--same as 4; Acid Dissolution

$$\text{DISOLVF} = \text{DISOLVA.}$$

6. Actinide Extraction (TBP)--set to 1.33 times the purify uranium cost below

$$\text{EXTRUPU} = 1.33 * (\text{PURIFYU}) \text{ (TRUEX-C).}$$

7. Purify Uranium--same as previous UREX process
PURIFYU = PURIFYU (TRUEX-C).
8. AM and Lanth Extraction (CMPO)--set to 50% of previous
TRUEX/SREX/technetium recovery cost
EXTRAMLN = 0.50*(TRUEX+SREX+DISSOLVA+...) (TRUEX-C).
9. Americium and Lanth Ion Exchange--use general IX module
AMLANIX = TCIX1 (TRUEX-C).
10. Strontium and Technetium Extraction--set to 35% of previous
TRUEX/SREX/technetium recovery cost
SREX = 0.35*(TRUEX+SREX+DISSOLVA+...) (TRUEX-C).
11. Strontium/Barium/Technetium Band Ion Exchange--use general IX module
SRBAIX = TCIX1 (TRUEX-C).
12. Cesium Ion Exchange (APM)--use general IX module
APMCSIX = TCIX1 (TRUEX-C).
13. Recover Acid From Evap Overheads--assume 50% dissolver
(evaporation+distillation)
RCOVACID = 0.50*DISOLVA.
14. Evaporation (HLW)--assumed to be small compared to other processes
EVAPORH = none.
15. Denitration (HLW)--(sugar denitration) dissolver in reverse
DNITRH = DISOLVA.
16. Denitration (LLW)--(sugar denitration) dissolver in reverse
DNITRL = DNITRH.
17. Calcination--calcining of LLW
CALCINE = CALCINE (TRUEX-C).
18. Remove Chromium--(probably a precipitation and centrifuge process)
REMCR = SEPSOLIQ.

19. **Separate Solid/Liquid--water wash and centrifuge**

SEPSOLIQ = Sludge Wash A strategy.

20. **Caustic Leaching--caustic wash and centrifuge**

CAUSLEAC = SEPSOLIQ.

21. **Organic Destruction with SCWO**

DESTORG = (DESTORG+FILTADSB) (TRUEX-C)
(Assume FILTADSB contribution small compared to DESTORG).

Following the summary results section and its associated figures and tables are individual writeups for the functions and point estimates used to develop costs for this report. The functions/estimates may be sorted into the following categories:

- Retrieval
 - Retrieval (10-27-92)
- Pretreatment
 - Sludge Wash A (3-27-93)
 - Uranium Recovery (3-29-93)
 - Cesium Separation To HLW (3-26-93)
 - Plasma Torch Calcine (6-14-93)
 - Strontium Cost Equation For Use With TRUEX and Sludge Wash Type Processes (3-27-93)
 - TRUEX, SREX, Technetium Recovery (3-30-93)
 - Technetium Ion Exchange (6-14-93)
- Low-Level Waste (LLW) Disposal
 - Salt Grout Plant (4-5-94)
 - Transportation and Disposal Cost For Class A LLW (1-4-93)
 - Mixed Waste Incineration (4-6-93)
 - Glass-in-Sulfur Plant (3-3-94)
- Waste Water Treatment
 - Water Treatment Plant - Facility No. 8 (3-17-93)
- High-Level Waste Disposal
 - HLW Disposal To Glass (5-11-93)
 - Volume Scaleup For HLW Glass Production Plant (1-24-93)
- Transuranic Disposal
 - WIPP Disposal (1-27-93)

- In Situ Disposal
 - In Situ Grout (3-23-93)
- Empty Tank and Past-Practice Unit Disposal
 - Immobilization and Dome Filling (3-24-93)
- CLEAN Option
 - Clean (9-1-93)
- CPU COST
 - Generic CPU Cost (8-30-93).

It may be noted that throughput capacity is often quoted in terms of "dry" throughput. This refers to flow with the free water subtracted out.

F2.0 SUMMARY OF RESULTS

Figures F1 and F2 show cost summary plots for the CLEAN Option and TRUEX-C and Sludge Wash C process strategies, respectively, with the primary LLW going to a salt grout product. Figures F3 and F4 show similar cost summary plots with the primary LLW going to a glass-in-sulfur product. These same cost data are given in a more detailed breakdown between capital and expense costs in Tables F1 through F4. The cost estimates in Tables F1 through F3 reflect the use of a central processing facility that processes all single- and double-shell tank waste with a 13-year campaign. Table F4 shows a cost estimate for the CLEAN Option process strategy based on using a combination of CPUs for processing supernate and salt cake and a central facility for processing sludge. Table F5 gives a summary of the total primary waste and tertiary waste (i.e., on process waste streams or wastes that did not result directly from splitting or partitioning of the main process streams; see Appendix E for a more detailed description) processing costs associated with each process strategy along with comparison ratios.

To further show the basis of the cost differences between the process strategies, the costs were combined into major process categories. These process categories are listed in Table F6 with their corresponding process block distribution (from Tables F1 through F4) for each process strategy. Table F7 presents a summary of the cost data for these major process categories by process strategy and primary LLW disposal option (i.e., salt grout or glass-in-sulfur products). Figures F5 and F6 show these same process category cost data for the primary LLW disposal to glass-in-sulfur and salt grout products, respectively. Table F8 presents differential process category costs compared to the CLEAN31 model (i.e., CLEAN Option without CPUs in Table F7).

Note from Table F5 that the CLEAN Option total primary and tertiary waste processing costs and, hence, the overall cost are reduced by approximately 24% when the CLEAN Option uses CPUs along with a central processing facility. Similar cost reductions could potentially apply to the TRUEX-C and Sludge Wash C process strategies if similar CPU use is included.

Note that costs for both primary LLW salt grout and glass-in-sulfur product options are included for each process strategy. Because no LLW glass composition specifications have yet been formulated (Appendix G), high-level waste (HLW) glass composition specifications were also applied to primary LLW glass. Note from Tables F1 through F5 that total LLW processing and disposal costs for the primary LLW to glass and to grout product options were essentially the same. Small increases in the tertiary salt grout costs occur for the primary LLW to glass product option because previously shared primary and tertiary LLW grout plant costs are now borne only by the tertiary LLW for this option.

Note that the costs associated with the HLW and LLW glass products can vary dramatically, depending on which glass optimization models and associated composition constraints are used (Appendix G). For example, the P_2O_5 constraint was relaxed for all process strategy glass product results. If this constraint were included, the HLW glass canister count would increase by factors of 1.7 and 3.6 (Appendix G, Table G7) for the TRUEX-C and Sludge Wash C process strategies, respectively, while the LLW glass vault count would increase by a factor of 1.2 for the CLEAN Option process strategy. The corresponding cost increases would be \$1.6B, \$17.5B, and \$0.085B for the TRUEX-C, Sludge Wash C, and CLEAN Option process strategies, respectively.

From Table F5 note the magnitudes of the costs associated with processing the primary waste stream and those associated with processing the tertiary nonprocess waste streams. These "primary" and "tertiary" costs are calculated separately. The tertiary waste processing costs were approximately 31, 27, 16, and 30% of the total costs for the CLEAN Option without CPUs, TRUEX-C, Sludge Wash C, and CLEAN Option with CPUs process strategies, respectively. These percentages essentially apply to either the primary LLW to grout or glass product options. The ratios of tertiary to primary costs were approximately 45, 37, 19, and 44% for these same process strategies, respectively.

Because the CLEAN Option and TRUEX-C process strategies produce less HLW than the Sludge Wash C process strategy, the associated HLW glass-related costs are lower, especially for the CLEAN Option process strategy. The LLW grout-related costs are lowest for the CLEAN Option strategy because less LLW reports to grout than either the TRUEX-C strategy or Sludge Wash C process strategies. However, when the LLW is converted to oxides during vitrification, the CLEAN Option and TRUEX-C process strategies have nearly similar oxide stream mass inventories, while the Sludge Wash C oxide stream is 25 and 22% less in inventory than the CLEAN Option and TRUEX-C process strategies, respectively (Appendix G).

For the primary LLW glass product option, results in Table F5 show the CLEAN Option process strategy without CPUs had primary waste processing costs approximately 20% greater than those for the TRUEX-C process strategy, approximately 7% less than those for Sludge Wash C, and approximately 31% greater than those for the CLEAN Option with CPUs. However, the tertiary

waste process costs for the CLEAN Option without CPUs were approximately 45% greater than those for the TRUEX-C process strategy, approximately 117% greater than those for the Sludge Wash C process strategy, and approximately 35% greater than for the CLEAN Option with CPUs.

Overall, the CLEAN Option without CPUs had total costs of \$41.2B, which were approximately 27% greater than those for the TRUEX-C process strategy (\$32.5B), approximately 13% greater than those for the Sludge Wash C process strategy (\$36.4B), and approximately 32% greater than the CLEAN Option with CPUs (\$31.1B). Cost comparison ratios for the primary LLW to grout option were comparable to those for the primary LLW to glass option stated above.

Note that all process strategy costs assume that a 0% heel was left in the waste tanks. Generally, if a 5% heel was assumed, the process strategy costs would be reduced by approximately 5 to 6% because of the reduced process stream flows (Knutson et al. 1993).

From Table F7 note that the costs associated with tank waste retrieval and liquid waste partitioning are substantial (approximately \$8.1B) and are assumed to be the same for each process strategy. Costs associated with waste tank immobilization were estimated to be \$0.43B, again, assumed to be the same for each process strategy. Note that the LLW treatment and disposal costs for the salt grout and glass-in-sulfur products were essentially the same. Therefore, the following discussion will relate the costs associated with the primary LLW to glass product option because the results for the primary LLW to grout option were comparable.

Table F8 shows that the costs for separation of solids and liquids along with solids dissolution for the CLEAN Option process strategy without CPUs required approximately 1.3 and \$0.99B more than the TRUEX-C and Sludge Wash C process strategies, respectively. The costs for nuclide removal from alkaline liquids for the CLEAN Option process strategy without CPUs required approximately 1.0 and \$1.2B more than the TRUEX-C and Sludge Wash C process strategies, respectively. The costs for nuclide removal from acidic liquids for the CLEAN Option process strategy without CPUs required approximately 2.6 and \$4.2B more than the TRUEX-C and Sludge Wash C process strategies, respectively. The costs for removal and purification of bulk chemicals for the CLEAN Option process strategy without CPUs required approximately \$4.2B more than the TRUEX-C and Sludge Wash C process strategies.

Combining these four processing categories together (item C1 in Tables F7 and F8 and Figures F5 and F6) showed that the CLEAN Option process strategy without CPUs required approximately 9.1, 10.6, and \$6.7B more than the TRUEX-C, Sludge Wash C, and CLEAN Option with CPUs process strategies, respectively. The trade-off for these higher processing costs for the CLEAN Option process strategy is seen in the reduced HLW and LLW processing and disposal costs as compared to the TRUEX-C and Sludge Wash C process strategies. Items C2 and C3 in Tables F7 and F8 show how the combined processing differential cost C1 is impacted by including the HLW and LLW processing and disposal costs. As shown in Table F8, the CLEAN Option process strategy without CPUs required approximately 4.6 and \$6.7B more than the TRUEX-C and CLEAN Option with CPUs process strategies, respectively, but \$2.4B less than the Sludge Wash C process strategy for the primary LLW-to-glass option.

However, the increased processing in the CLEAN Option process strategy generated more tertiary waste than the other process strategies. Thus, the tertiary waste treatment and disposal costs for the CLEAN Option process strategy without CPUs required approximately 4.0, 6.9, and \$3.3B more than the TRUEX-C, Sludge Wash C, and CLEAN Option with CPUs process strategies, respectively (see item C4 in Table F8). Consequently, reductions in the HLW and LLW treatment and disposal costs for the CLEAN Option process strategy compared to the other process strategies were offset by the increased cost of tertiary waste treatment and disposal.

In summary, the cost savings associated with CPU use was significant and should be incorporated into any process strategy. The large tertiary waste costs could be decreased significantly if process design is also focused on reducing the amount of tertiary waste produced. More glass composition constraint evaluation and experimentation on key waste oxide stream components could allow relaxing the current constraints, resulting in significantly reduced HLW glass canister and LLW glass vault counts (i.e., higher waste oxide loadings in glass) and their associated costs. The trade-off for the higher processing costs for the CLEAN Option process strategy without CPUs is seen in the reduced HLW and LLW processing and disposal costs as compared to the TRUEX-C and Sludge Wash C process strategies. However, the increased processing in the CLEAN Option process strategy generated more tertiary waste and higher associated treatment and disposal costs, offsetting the reductions in the HLW and LLW treatment and disposal costs.

F3.0 REFERENCES

- Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, pp. 7-51, Westinghouse Hanford Company, Richland, Washington.
- Knutson, B. J., et al., 1993, "Advanced Chemical Separation Study: TRUEX Strategy Compared to Sludge Wash Ion Exchange," DRAFT letter report, July 1993, Westinghouse Hanford Company, Richland, Washington.

RETRIEVAL 10-27-92

Estimates of this cost can be obtained from both the Hanford Strategic Analysis (HSA) project work⁽¹⁾ and from data contained in the decision analysis computer model developed for the Tank Waste Remediation System (TWRS) program.

HANFORD STRATEGIC ANALYSIS

The equation developed to support HSA⁽¹⁾ is as follows:

$$\text{Total cost} = \$5.7\text{e}9(1 - \text{SF_HEEL_TC}) - \$3.47\text{e}8 \ln(\text{SF_HEEL_TC}),$$

where SF HEEL TC is the separation factor (fraction) of technetium left in the "heel" of waste remaining in the tank after retrieval. This equation was originally based on information from Bob Parazin⁽²⁾ and included cost for both single-shell tanks (SSTs) and double-shell tanks (DSTs).

This equation produces the following values:

<u>Separation factor</u>	<u>Cost</u>
1.0	\$0
0.01	\$7.3B
0.001	\$8.2B

There is no data to support use of this equation outside these ranges.

TWRS DECISION ANALYSIS SPREADSHEET MODEL

The TWRS spreadsheet includes the following cost data for tank retrieval. (The spreadsheet provides best estimate values, pessimistic values, and optimistic values.)

	Estimated HEEL			
	RT1	RT2	RT3	RT4
Pessimistic	15%	5%	1%	1%
Best estimate	10%	1%	0.1%	0.1%
Optimistic	5%	0.1%	0.05%	0.05%

	Estimated DST Per Tank Cost ⁽³⁾			
	RT1	RT2	RT3	RT4
Pessimistic	\$40M	-	\$250M	-
Best estimate	\$20M	-	\$100M	-
Optimistic	\$10M	-	\$50M	-

	Estimated SST Per Tank Cost ⁽³⁾			
	RT1	RT2	RT3	RT4
Pessimistic	-	\$35M	\$15M	\$25M
Best estimate	-	\$30M	\$10M	\$20M
Optimistic	-	\$25M	\$5M	\$15M

where: RT1 = Mixer pump retrieval system.
 RT2 = Mechanical retrieval system.
 RT3 = High-volume sluice retrieval system.
 RT4 = Hydraulic or pneumatic retrieval system.
 SST = Single-shell tank.
 DST = Double-shell tank.

Because high-volume sluice is the only system currently considered feasible for both SSTs and DSTs ("-" indicates not currently considered feasible), that option is focused on, and best estimate separation factors are used.

Assuming 28 DSTs and 149 SSTs are retrieved:

Cost (pessimistic) = \$250M(28) + \$15M(149) = \$9.2B (dtTc = 0.001)
 Cost (best estimate) = \$100M(28) + \$10M(149) = \$4.3B (")
 Cost (optimistic) = \$50M(28) + \$5M(149) = \$2.1B (")

Note that the spreadsheet recognizes the existence of aluminum, chromium, sodium, nickel, NO₂, cesium, strontium, technetium, and transuranic in the tanks. However, the retrieval separation factors are treated as the same for all isotopes.

ANALYSIS

The range of costs for SF_HEEL_TC derived from the spreadsheet data (\$2.1B to \$9.2B) is consistent with the HSA equation estimate of \$8.2B for this separation factor. Therefore, there is no reason not to continue using this equation.

Consistent with the spreadsheet assumption, the SF_Heel separation factor value is considered to be the same for all isotopes.

REFERENCES

1. Tank Retrieval, Bruce Zimmerman, personal notes for HSA cost functions, February 26, 1992, Westinghouse Hanford Company, Richland, Washington.
2. "SST Closure Estimate for Sensitivity Study," Bob Parazin, personal communication, January 24, 1992, Stabilization and Retrieval Engineering, Westinghouse Hanford Company, Richland, Washington.
3. Reick, C. A., WHC-SD-W211-CDR-011, Rev. 0, *Conceptual Design Report, Initial Tank Retrieval System, Project W-211*, Westinghouse Hanford Company, Richland, Washington.

SLUDGE WASH A
3-27-93

The relevant data are as follows:

<u>Capital</u>	<u>Expense</u>	<u>Dry throughput</u>
\$0.96B ⁽¹⁾	\$1.13B ⁽¹⁾	5.4 E+4 kg/day*

*The total flow into Sludge Wash A (SWA) per operating day is 2.7 E+5 kg/OD (kilograms per operating day), the water portion is 1.8 E+5 kg/OD, so the "dry" flow is 9 E+4 kg/OD. Because the operating efficiency is assumed to be 60%, the dry flow per 24-hour day is 5.4 E+4 kg/day. Note that these flows correspond to processing a homogeneous mixture of single- and double-shell tank waste in 13 years⁽²⁾.

These cost values correspond to the following separations:

SF_HLW_Tc	0.23 ⁽³⁾
SF_HLW-Cs	0.11 ⁽³⁾
SF_HLW-Sr	0.99 ⁽³⁾
SF_HLW_Na	0.02 ⁽⁴⁾
SF_HLW_A1	0.47 ⁽⁴⁾

where, for example, SF_HLW_tc refers to the separation factor (fraction) of technetium into the high-level waste stream.

The capacity scaling is done using a standard 0.7 exponent for capital equipment⁽⁵⁾ and 0.75 for expense costs⁽⁶⁾.

$$\text{\$cap}(B) = \$0.96B(\text{actual daily dry throughput}/5.4 \text{ E}+4 \text{ kg/day})^{**0.7}$$

$$\text{\$exp}(B) = \$1.13B(\text{actual daily dry throughput}/5.4 \text{ E}+4 \text{ kg/day})^{**0.75}$$

REFERENCES

1. Boomer, et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, p. 7-51, Westinghouse Hanford Company, Richland, Washington.
2. "Separations Data," personal communication (cc:mail) from Eric Slaathaug to Bruce Zimmerman, dated March 30, 1993, Westinghouse Hanford Company, Richland, Washington.
3. Ibid. 1, p. 7-11.
4. Ibid. 1, p. 7-12.

5. Remer, D. S., and L. H. Chai, August 1990, "Design Cost Factors For Scaling-Up Engineering Equipment," *Chemical Engineering Progress*, American Institute of Chemical Engineers, New York, New York, p. 82.
6. Black, J. H., "Scaling Operating Costs By Cost-Capacity Factors," 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30, 1982, Houston, Texas, H.3.1.

URANIUM RECOVERY
3-29-93

The TRUEX-C and TRUEX-D chemical separation processes have previously been costed in detail. TRUEX-C is approximately the same as TRUEX-D, except that TRUEX-C contains a uranium recovery module and an organic destruction/titinate (SCWO) module that TRUEX-D does not. Consequently, the cost of the uranium recovery module (UREX) can be estimated as:

$$\text{UREX} = (\text{TRUEX-C}) - (\text{SCWO}) - (\text{TRUEX-D}).$$

The relevant data are⁽¹⁾ as follows:

	<u>TRUEX-C</u>	<u>SCWO</u>	<u>TRUEX-D</u>
Capital cost	\$2.69B	\$0.44B	\$2.10B
Expense cost	\$2.66B	\$0.13B	\$2.48B

(SCWO = supercritical water oxidation)

So, for UREX:

Capital cost	\$0.15B
Expense cost	\$0.05B

It was assumed that the uranium separation fraction to LLW is 1% for TRUEX-C⁽²⁾.

The total flow rate into the UREX module of TRUEX-C is 2.73 E+4 kg/OD (kilograms per operating day), the water flow is 2.51 E+4 kg/OD⁽³⁾, so the "dry" flow is 2.2 E+3 kg/OD. Because the assumed operating efficiency is 60%, the dry flow per 24-hour day is 1.32 E+3 kg/day. This flow assumes that the homogenized single- and double-shell tank waste is processed in 13 years. These flows are expected to be approximately the same as the flows for processing only single-shell tank waste in 10 years.

The capacity scaling is done using the standard 0.7 exponent for capital equipment⁽⁴⁾ and 0.75 for expense costs⁽⁵⁾:

$$\text{\$cap(B)} = \$0.15 \text{ (actual daily dry feed into the UREX module / } 1.32 \text{ E+3 kg/day)}^{**0.7}$$

$$\text{\$exp(B)} = \$0.05 \text{ (actual daily dry feed into the UREX module / } 1.32 \text{ E+3 kg/day)}^{**0.75}$$

REFERENCES

1. Boomer, et al., 1993, *Tank Waste Technical Report Options*, WHC-EP-0616, p. 7-51, Westinghouse Hanford Company, Richland, Washington.
2. Ibid., 1 p. 7-11.

3. "Separations Data," personal communication (cc:mail) from Eric Slaathaug to Bruce Zimmerman, dated March 30, 1993, Westinghouse Hanford Company, Richland, Washington.
4. Remer, D. S., and L. H. Chai, August 1990, "Design Cost Factors For Scaling-Up Engineering Equipment," *Chemical Engineering Progress*, American Institute of Chemical Engineers, New York, New York, p. 82.
5. Black, J. H., "Scaling Operating Costs By Cost-Capacity Factors," 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30, 1982, Houston, Texas, H.3.1.

CS SEPARATION TO HLW 3-26-93

The Sludge Wash A (SWA) and Sludge Wash B (SWB) processes have previously been costed in detail. Sludge Wash A and Sludge Wash B are the same, except that Sludge Wash B includes a cesium ion exchanger. Consequently, the difference in these costs represents the cost of the ion exchanger.

BASIC DATA

	SWA	SWB
SF CS LLW ⁽¹⁾	89%	1%
cap. cost ⁽²⁾	\$0.96B	\$1.33B
exp. cost ⁽²⁾	\$1.13B	\$1.47B
capacity*	4.6 E+4 kg/day	4.6 E+4 kg/day
operation duration ⁽³⁾	10 yr (SST waste)	10 yr (SST waste)

*Assumed capacity for this stream is 2.89 E+5 kg/OD (kilograms per operation day), 2.13 E+5 kg/OD is water, so the dry design capacity is 7.6 E+4 kg/OD⁽⁴⁾. However, at 60% assumed efficiency, the actual dry throughput per day, is 4.6 E+4 kg/day. The process is sized to treat all single-shell tank waste in 10 years⁽³⁾⁽⁴⁾, which is approximately the same as processing all single- and double-shell tank waste in 13 years.

SF CS LLW = the separation factor (fraction) of cesium that goes to the low-level waste stream.

The costs to be assigned to the cesium ion exchanger are then:

Capital cost = \$0.37B
Expense cost = \$0.34B

ION EXCHANGER FUNCTIONAL FORM

Based on the derivation in Reference 5, the generic functional form for ion exchanger cost versus separation factor is as follows:

$$\$ = A \cdot (1 - \ln(SF))^{**0.55} - A$$

where: SF=0 means perfect separation. In the context here, SF is SF_CS_LLW.

Normally, SF=1 (no separation) would correspond to \$0. In the present instance, however, SF=0.89 corresponds to \$0 ion exchanger cost, because no ion exchanger is needed to get SF=0.89. The equation's offset must be something different than "A":

$$\$ = A \cdot (1 - \ln(SF))^{**0.55} + B.$$

Determining the constants "A" and "B" for both capital cost and expense cost (assuming that capital and expense costs would scale similarly with separation factor), gives the following:

$$\text{Capital cost}(\$B): \quad \$ = \$0.244(1-\ln(\text{SF_CS_LLW}))^{**0.55} - \$0.259$$

$$\text{Expense cost}(\$B): \quad \$ = \$0.224(1-\ln(\text{SF_CS_LLW}))^{**0.55} - \$0.238$$

Including a capacity scaling term of 0.55 for the capital cost (assumes throughput is proportional to resin bed size^[5]) and 0.75 for the expense cost^[6]:

$$\text{Capital cost:} \quad \$ = \{ \$0.244(1-\ln(\text{SF_CS_LLW}))^{**0.55} - \$0.259 \} * \{ \text{actual daily dry throughput} / 4.6 \text{ E+4 kg/day} \}^{**0.55}$$

$$\text{Expense cost:} \quad \$ = \{ \$0.224(1-\ln(\text{SF_CS_LLW}))^{**0.55} - \$0.238 \} * \{ \text{actual daily dry throughput} / 4.6 \text{ E+4 kg/day} \}^{**0.75}$$

REFERENCES

1. Boomer, K. D., et al., 1993, *Tank Waste Engineering Study*, WHC-EP-0616, p. 7-11, Westinghouse Hanford Company, Richland, Washington.
2. Ibid. ref.1, p. 7-51.
3. Ibid. ref.1, p. 7-22, 7-24.
4. "Sludge Wash B," personal communication (cc:mail) from Eric Slaathaug to Bruce Zimmerman, dated March 26, 1993, Westinghouse Hanford Company, Richland, Washington.
5. "Ion Exchanger Generic Function Derivation," B. Zimmerman personal notes, December 29, 1992, Westinghouse Hanford Company, Richland, Washington.
6. Black, J. H., "Scaling Operating Costs By Cost-Capacity Factors", 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30, 1982, Houston, Texas, H.3.1.

PLASMA TORCH CALCINE 6-14-93

As suggested in references 1 and 2, this process can be thought of as decomposable into the following separate steps: calcine, offgas treatment, dissolution, technetium ion exchange, cesium ion exchange.

Recognizing that the dissolution, technetium ion exchange, and cesium ion exchange steps are collectively similar to the previously costed Sludge Wash C process⁽²⁾, and that the overall plasma torch calcine facility may be comparable to the previously costed TRUEX-D facility⁽²⁾, the following rough cost estimates can be made.

	<u>calcine/offgas#</u>	<u>dissolution*</u>	<u>TcIx**</u>	<u>CsIx***</u>
Capital	\$0.7B ⁽²⁾	\$1.4B	\$0.07B	\$0.37B
Expense	\$0.54B ⁽²⁾	\$1.26B	\$0.34B	\$0.34B

(Including allowance for D&D)

0.54 value determined as $2.48 - 1.26 - 0.34 - 0.34^{(3)}$; the 2.48 number is for TRUEX-D

* values determined as (Sludge Wash C) - (TcIx) - (CsIx)(2)(3)

** values determined as (Sludge Wash D) - (Sludge Wash B)(3)

*** values determined as (Sludge Wash B) - (Sludge Wash A)(3)

Based on inspection of ASPEN PLUS flow sheet results⁽⁴⁾, it appears that essentially all the sodium and aluminum separation occurs in the dissolution step. For sodium and aluminum, the separation is estimated to be about 5% to high-level waste (HLW) and 95% to the low-level waste (LLW) stream, while the technetium and cesium are mostly passed through to the ion exchangers⁽⁴⁾⁽⁵⁾.

DISSOLUTION

Developing a functional form for wash dissolution as a function of sodium separation gives:

Input data: \$0 capital, \$0 expense implies 1.0 of Na to HLW
\$1.4B capital, \$1.26B expense implies 0.05 of Na to HLW

(actually applies to both aluminum and sodium)

Sodium

Resulting equations:

$$\text{Capital \$B} = - \$1.47\text{B}(\text{SF_CALC_HLW_NA}) + \$1.47\text{B}$$

$$\text{Expense \$B} = - \$1.33\text{B}(\text{SF_CALC_HLW_NA}) + \$1.33\text{B}$$

The linear form was suggested by George Jansen⁽⁶⁾, along with the restriction that SF_CALC_HLW_NA should be restricted to the range 0.01 to 0.1.

Note that the expense costs include an allowance for D&D⁽²⁾.

Ion Exchange

For technetium and cesium ion exchange the previously derived equations⁽⁷⁾⁽⁸⁾ were used:

Tc

$$\begin{aligned} \text{capital \$B} &= \{ 0.048\text{B}(1 - \ln(1 - \text{SF_HLW_TC}))^{**0.55} - \$0.055 \} * \\ &\quad \{ \text{actual daily dry throughput} / 0.486 \text{ E+5 kg/day} \}^{**0.55} \\ \text{expense \$B} &= \{ \$0.235(1 - \ln(1 - \text{SF_HLW_TC}))^{**0.55} - \$0.267 \} * \\ &\quad \{ \text{actual daily dry throughput} / 0.486 \text{ E+5 kg/day} \}^{**0.75} \end{aligned}$$

Cs

$$\begin{aligned} \text{Capital \$B} &= \{ \$0.244(1 - \ln(1 - \text{SF_HLW_CS}))^{**0.55} - \$0.259 \} \\ &\quad \{ \text{actual daily dry throughput} / 4.6 \text{ E+4 kg/day} \}^{**0.55} \\ \text{Expense \$B} &= \{ \$0.224(1 - \ln(1 - \text{SF_HLW_CS}))^{**0.55} - \$0.238 \} * \\ &\quad \{ \text{actual daily dry throughput} / 4.6 \text{ E+4 kg/day} \}^{**0.75} \end{aligned}$$

VOLUME CORRECTION TERMS

It is assumed that the reference case throughput for the ion exchange terms of 4.6 E+4 kg/day dry feed = 1.68 E+7 dry kg/yr, as specified above. For the calcine, offgas, and dissolution steps, the throughput for the reference case was calculated as follows:

$$\begin{aligned} &233 \text{ Mkg of original total "dry" waste (salt cake and sludge)}^{(9)} \\ &\text{divided by 13 years assumed total processing time}^{(2)} \\ &\hline &1.79 \text{ E+7 kg/yr} \end{aligned}$$

The following scaling exponents were used to scale for throughput⁽¹⁰⁾⁽¹¹⁾:

All expense terms	0.75 (personnel)
Calcine step capital term	0.8 (furnaces)
Dissolution step capital term	0.8 (centrifuges)
Ion exchange capital terms	0.55 (ion exchangers)

RESULT

Putting all the above components together produces the final equation:

$$\begin{aligned}
 \$B = & \$0.7B * (\text{actual annual dry throughput} / 1.79 \text{ E}+7 \text{ kg/yr})^{**0.8} \\
 & + \$0.54B * (\text{actual annual dry throughput} / 1.79 \text{ E}+7 \text{ kg/yr})^{**0.75} \\
 & + [-\$1.47B * (\text{SF_CALC_HLW_NA}) + \$1.47B] (\text{actual annual dry throughput} / 1.79 \text{ E}+7 \text{ kg/yr})^{**0.8} \\
 & + [-\$1.26B * (\text{SF_CALC_HLW_NA}) + \$1.26B] (\text{actual annual dry throughput} / 1.79 \text{ E}+7 \text{ kg/yr})^{**0.75} \\
 & + \{ 0.048B(1 - \ln(1 - \text{SF_HLW_TC}))^{**0.55} - \$0.055 \} * \\
 & \quad \{ \text{actual daily dry throughput} / 0.486 \text{ E}+5 \text{ kg/day} \}^{**0.55} \\
 & + \{ \$0.235(1 - \ln(1 - \text{SF_HLW_TC}))^{**0.55} - \$0.267 \} * \\
 & \quad \{ \text{actual daily dry throughput} / 0.486 \text{ E}+5 \text{ kg/day} \}^{**0.75} \\
 & + \{ \$0.244(1 - \ln(1 - \text{SF_HLW_CS}))^{**0.55} - \$0.259 \} * \\
 & \quad \{ \text{actual daily dry throughput} / 4.6 \text{ E}+4 \text{ kg/day} \}^{**0.55} \\
 & + \{ \$0.224(1 - \ln(1 - \text{SF_HLW_CS}))^{**0.55} - \$0.238 \} * \\
 & \quad \{ \text{actual daily dry throughput} / 4.6 \text{ E}+4 \text{ kg/day} \}^{**0.75}
 \end{aligned}$$

And: $\text{SF_CALC_HLW_NA} = \text{SF_CALC_HLW_AL}$

where: SF_CALC_HLW_NA should be restricted to the range 0.01 to 0.1.

It is assumed that annual dry throughput = daily dry throughput X 365.

REFERENCES

1. *Evaluation of Hanford Tank Waste Treatment Alternatives: Calcination/Dissolution Compared To TRUEX-A and Sludge Wash C*, Figure B1, September 1992, Systems Technology, Westinghouse Hanford Company, Richland, Washington.
2. "Cost Estimate For Calcine Facility," meeting notes, December 11-15, 1992, Zimmerman, B. D., Westinghouse Hanford Company, Richland, Washington.
3. Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, p. 7-51, Westinghouse Hanford Company, Richland, Washington.
4. Ibid ref. 1., Table B2.

5. George Jansen, personal computer database printout for ASPEN PLUS blocks A23221111 and A23221112, Dec. 16, 1992, Westinghouse Hanford Company, Richland, Washington.
6. Personal communication, G. Jansen to B. Zimmerman, Dec. 15, 1992, Westinghouse Hanford Company, Richland, Washington.
7. "Tc Ion Exchange," personal notes, B. Zimmerman, June 14, 1993, Westinghouse Hanford Company, Richland, Washington.
8. "Cs Separation To HLW," personal notes, B. Zimmerman, March 26, 1993, Westinghouse Hanford Company, Richland, Washington.
9. "Table 1. Tank Waste Inventory For TWRS Parametrics," personal communication, R. Harmsen to B. Zimmerman, June 1993, Westinghouse Hanford Company, Richland, Washington.
10. Remer, D. S., and L. H. Chai, August 1990, "Design Cost Factors For Scaling-Up Engineering Equipment," *Chemical Engineering Progress*, American Institute of Chemical Engineers, New York, New York, pp. 77-82.
11. Black, J. H., "Scaling Operating Costs By Cost-Capacity Factors," 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30, 1982, Houston, Texas, H.3.1.

**STRONTIUM COST EQUATION FOR USE WITH
SLUDGE WASH AND TRUEX TYPE PROCESSES
3-27-93**

In the typical Sludge Wash and transuranic solvent extraction process (TRUEX) separation processing trains, the first process is a sludge wash (followed by ion exchanges, solvent extractions for specific isotopes, etc.). A Sludge Wash alone will typically produce a strontium separation to the low-level waste (LLW) stream (SF SR LLW) of approximately 1%⁽¹⁾. When the TRUEX step is added into the high-level waste (HLW) stream to separate the transuranics (TRUs) from the HLW, a so-called strontium extraction (SREX) (a solvent extraction) is also added into the HLW stream to prevent the transuranic extraction from returning large amounts of strontium to the LLW stream.

For the analysis here, it is assumed that an SREX module is always bundled with the transuranic extraction process in the HLW stream and is costed as part of the transuranic extraction. Variations in the overall strontium separation (of which TRUEX-SREX are one part) are, therefore, achieved by adding strontium separation modules to the LLW stream. These strontium separation modules are expected to be of either the supercritical water oxidation (plus titanate bed) type or the ion exchange type.

Supercritical water oxidation (SCWO) is primarily a precipitation process. Precipitation processes tend to exhibit a linear relationship between cost and separation factor, at least over a limited range⁽²⁾.

Because the sludge wash step alone produces a strontium separation to LLW (SF SR LLW) of 1%, the 1% is considered to be obtained "for free." The cost function derived below deals with separations beyond this 1%.

Assume, as is typical of the processes described in reference 1, that SCWO would be employed to reduce SF SR LLW from 1% to approximately 0.1%. The cost for an SCWO module can be estimated as follows.

	<u>SWC</u>	<u>SWD</u>
components:	Sludge Wash CsIx SCWO TcIx	Sludge Wash CsIx TxIx
Capital cost	\$1.84B	\$1.40B
Expense cost	\$1.94B	\$1.81B

All of these cost figures are from reference 3.

Then, the cost of an SCWO module must be about:

Capital cost	\$0.44B
Expense cost	\$0.13B

Using the linear form for SCWO with the values:

	SF_SR_LLW	
separation factor	0.01	0.001
Capital cost	\$0	\$0.44B
Expense cost	\$0	\$0.13B

produces the following two equations:

$$\begin{aligned}\text{Capital cost (\$B)} &= -\$48.9\text{B} \cdot \text{SF_SR_LLW} + \$0.489\text{B} \\ \text{Expense cost (\$B)} &= -\$14.4\text{B} \cdot \text{SF_SR_LLW} + \$0.144\text{B}\end{aligned}$$

These equations are good for SF_SR_LLW in the range 0.01 to 0.001.

It is reasonable to assume that separation better than 0.001 would be achieved by adding a Sr ion exchanger into the LLW stream⁽⁴⁾. This possibility is not considered here at this time.

CAPACITY

The design capacity for the SCWO system is 2.78 E+5 kg/OD (kilograms per operating day)⁽⁵⁾. 2.02 E+5 kg of this is water, so the "dry" flow rate is 7.6 E+4 kg/OD. Because the plant is only expected to have an operating efficiency of 60%, the actual average throughput in a 24-hour period would be 7.6 E+4 kg * 0.6 = 4.6 E+4 dry kg/day.

For capital cost scaling a capacity scaling factor of 0.7 is appropriate⁽⁶⁾. This is a typical value because a more specific value for this process is not available. For expense cost scaling a scaling factor of 0.75 will be assumed⁽⁷⁾.

Employing these factors gives:

$$\begin{aligned}\text{Total cost (\$B)} &= \{-\$48.9 \cdot \text{SF_SR_LLW} + \$0.489\} \{ \text{actual daily dry} \\ &\quad \text{throughput} / 4.6 \text{ E+4 dry kg/day} \}^{**0.7} \\ &\quad + \{-\$14.4 \cdot \text{SF_SR_LLW} + \$0.144\} \{ \text{actual daily dry} \\ &\quad \text{throughput} / 4.6 \text{ E+4 dry kg/day} \}^{**0.75}\end{aligned}$$

where: SF_SR_LLW is restricted to be ≤ 0.01, and where there is no design data to support SF_SR_LLW < 0.001.

Note that these flow values are based on the assumption that homogeneously mixed single-shell and double-shell tank waste is processed in 13 years⁽⁵⁾. This is expected to be approximately the same flow as required to process only single-shell tank waste in 10 years.

REFERENCES

1. Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, p. 7-11, Westinghouse Hanford Company, Richland, Washington.
2. Personal communication, G. Jansen to B. Zimmerman, Jan. 15, 1993, Westinghouse Hanford Company, Richland, Washington.
3. Ibid. ref.1, p. 7-51.
4. "How Would One Extend The Strontium Separation For Sludge Wash Type Processes?," meeting notes, Jan. 18, 1993, B. D. Zimmerman, Westinghouse Hanford Company, Richland, Washington.
5. "Separations Data," personal communication (cc:mail) from Eric Slaathaug to Bruce Zimmerman, dated March 30, 1993, Westinghouse Hanford Company, Richland, Washington.
6. Remer, D. S., and L. H. Chai, August 1990, "Design Cost Factors For Scaling-Up Engineering Equipment," *Chemical Engineering Progress*, American Institute of Chemical Engineers, New York, New York, p. 82.
7. Black, J. H., "Scaling Operating Costs By Cost-Capacity Factors," 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30, 1982, Houston, Texas, H.3.1.

TRUEX, SREX, TECHNETIUM RECOVERY
3-30-93

The primary difference between TRUEX-D and Sludge Wash D is the TRUEX, SREX, and technetium recovery modules. Consequently, these two previously costed waste processing configurations can be used to estimate the cost of these modules.

The relevant data are as follows:

	<u>TRUEX-D</u>	<u>Sludge Wash D</u>
	Sludge wash	Sludge wash
	Cesium ion exchange	Cesium ion exchange
	Technetium Ion exchange	Technetium Ion Exchange
	TRUEX	
	SREX	
	Technetium Recovery	
capital cost ⁽¹⁾	\$2.1B	\$1.4B
expense cost ⁽¹⁾	\$2.48B	\$1.81B
Sr sep. to on-site ⁽²⁾	0.02	0.01
U sep. to on-site ⁽²⁾	0.86	0.06
Pu sep. to on-site ⁽²⁾	0.04	0.03

"Sep. to onsite" refers to the fraction of the isotope that remains in the low-level waste stream that is currently assumed to be disposed of on site.

From reference 3, the total flow rate into the TRUEX module of TRUEX-D is 5.83 E+4 kg/OD (kilograms per operating day), the water flow is 4.15 E+4 kg/OD. Therefore, the "dry" flow is 1.68 E+4 kg/OD. Because the assumed operating efficiency is 60%, the dry flow per 24-hour day is 1.01 E+4 kg/day. These flows are based on the assumption that all single- and double-shell tank waste is processed in 13 years. These flows are expected to be approximately the same as the flows for processing single-shell tank waste only in 10 years.

The cost to be assigned to the TRUEX/SREX/Technetium recovery modules is then:

Capital cost = \$0.7B
Expense cost = \$0.67B

The capacity scaling is obtained using a standard 0.7 exponent for capital equipment⁽⁴⁾ and 0.75 for expense costs⁽⁵⁾:

$$\text{\$Capital(B)} = \text{\$0.7B (actual daily dry feed into TRUEX module/1.01 E+4 kg/day)**0.7}$$

$$\text{\$Expense(B)} = \text{\$0.67B(actual daily dry feed into TRUEX module/1.01 E+4 kg/day)**0.75}$$

REFERENCES

1. Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, p. 7-51, Westinghouse Hanford Company, Richland, Washington.
2. Ibid., p. 7-11.
3. "Separations Data," personal communication (cc:mail) from Eric Slaathaug to Bruce Zimmerman, dated March 30, 1993, Westinghouse Hanford Company, Richland, Washington.
4. Remer, D. S., and L. H. Chai, August 1990, "Design Cost Factors For Scaling-Up Engineering Equipment," *Chemical Engineering Progress*, American Institute of Chemical Engineers, New York, New York, p. 82.
5. Black, J. H., "Scaling Operating Costs By Cost-Capacity Factors," 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30, 1982, Houston, Texas, H.3.1.

TECHNETIUM ION EXCHANGE
6-14-93

Sludge Wash D (SWD) and Sludge Wash B (SWB) are the same, except that Sludge Wash D includes a technetium ion exchanger. Consequently, the difference in these previously costed configurations represents the cost of the ion exchanger.

<u>Basic Data</u>	<u>SWD</u>	<u>SWB</u>
SF HLW Tc ⁽¹⁾	99%	23%
Capital cost ⁽²⁾	\$1.40B	\$1.33B
Expense cost ⁽²⁾	\$1.81B	\$1.47B
Capacity*	0.486 E+5 kg/day for Tc ion exchanger	
oper. duration ⁽³⁾	10 years	10 years

*Assumed operating capacity for this stream is 4.03 E+5 kg/OD (kilograms per operating day) total, of which 3.22 E+5 kg/OD is water and 0.81 E+5 kg/OD is "dry." Because the assumed operating efficiency is 60%, the dry flow in this stream per 24-hour day is $0.81 \text{ E}+5 \times 0.6 = 0.486 \text{ E}+5 \text{ kg/day}$. This flow rate is designed to handle all single-shell tank waste in 10 years⁽⁴⁾.

SF_HLW_Tc = separation factor (fraction) of technetium to the high-level waste stream.

The costs to be assigned to the technetium ion exchanger are then:

Capital cost = \$0.07B
Expense cost = \$0.34B

ION EXCHANGER FUNCTIONAL FORM

Based on internal analysis, the generic functional form for ion exchanger cost versus separation factor has been estimated to be:

$$\$ = A \cdot (1 - \ln(1 - \text{SF_HLW_Tc}))^{**0.55} + B.$$

where: SF=1 means perfect separation for SF_HLW_Tc. In the present instance, SF_HLW_Tc = 0.23 corresponds to \$0, because a technetium exchanger is not needed to obtain this separation value. (Sludge wash alone produces 0.23.)

Fitting this functional form to the capital and expense cost data produces the following equations:

$$\text{Capital cost}(\$B) = \$0.048(1 - \ln(1 - \text{SF_HLW_Tc}))^{**0.55} - \$0.055.$$

$$\text{Expense cost}(\$B) = \$0.235(1 - \ln(1 - \text{SF_HLW_Tc}))^{**0.55} - \$0.267.$$

Including a capacity scaling term of 0.55 for the capital cost (assumes throughput is proportional to resin bed size) and 0.75 for the expense cost⁽⁵⁾:

$$\text{Capital cost}(\$B) = \{ \$0.048(1-\ln(1-SF \text{ HLW } Tc))^{**0.55} - \$0.055 \} * \{ \text{actual daily dry throughput} / 0.486 \text{ E}+5 \text{ kg/day} \}^{**0.55}$$

$$\text{Expense cost}(\$B) = \{ \$0.235(1-\ln(1-SF \text{ HLW } Tc))^{**0.55} - \$0.267 \} * \{ \text{actual daily dry throughput} / 0.486 \text{ E}+5 \text{ kg/day} \}^{**0.75}$$

REFERENCES

1. Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, p. 7-11, Westinghouse Hanford Company, Richland, Washington.
2. Ibid. p. 7-51.
3. Ibid. p. 7-29.
4. Ibid. p. G7-74.
5. Black, J. H., "Scaling Operating Costs By Cost-Capacity Factors", 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30, 1982, Houston, Texas, H.3.1.

SALT GROUT PLANT
4-5-94

The following data are applicable for a salt grout plant:

<u>Capital</u>	<u>Operating</u>	<u>Assumed capacity</u>	<u>Dry feed capacity</u>
\$0.605B ⁽¹⁾	\$3.29B ⁽¹⁾	3.83 E+5 kg/OD ⁽²⁾	1.04 E+5 kg/OD ⁽²⁾

B = \$Billions; OD = operating day = 2,847 days (see calculation below)

The operating cost includes an allowance for decontamination and decommissioning (D&D) and the capital cost includes required double-shell tanks (DSTs) to support the facility. The plant operating costs are based on a 13-year operating period with a 50% plant efficiency. The capacity numbers are for waste flowing into the salt grout plant and do not include added grout cement binding material. Using the assumed 50% plant efficiency, this implies a 24-hour day capacity of 5.21 E+4 dry kg/day.

The \$3.29B breaks down as follows⁽³⁾:

Staff cost:	\$49.9M/yr for 15 years = \$749M
Essential mat'ls:	\$16.9M/yr for 13 years = \$220M
Vaults:	\$7.65M per vault (with diffusion barriers and liners) + \$2M per acre for closure barriers = \$2074M

{ Two vaults require approximately 1 acre of land.⁽³⁾
Each vault holds 1.4 E+6 gallons or 5.3 E+3 m³ of waste.⁽⁴⁾
The salt grout product flow = 7.18 E+5 kg/OD,
yielding a total of 241 vaults⁽²⁾ }

Relating the vault cost to actual kg grout deposited, the final salt grout vault cost equation becomes:

vault cost	= \$8.65M * 241 * (actual kg grout) / (7.18 E+5 kg/OD * 2,847 OD (see below))
	= \$8.65M * 241 * (actual kg grout) / (2.04 E+9 kg grout)
	= \$8.65M * (actual kg grout) / (8.48 E+6 kg grout/vault)

D&D:	= \$247M
implies	= 30% of \$605M + 3 yr at \$21.8M/yr

These data imply the following equation:

dryfeed = actual dry feed capacity per day (kg/day)

lifefeed = actual total lifetime grout dry feed (kg)
 {Total kg dry grout feed estimated as
 1.04 E+5 kg/OD * 2,847 OD = 2.96 E+8 kg dry feed}
 (2,847 OD = 13y * 365 * 60% oper. effic.
 actually used in flowsheet model

\$(total) = \$605M(dryfeed/5.21 E+4 kg/day)**0.78
 + \$749M(dryfeed/5.21 E+4 kg/day)**0.75
 + \$220M(lifefeed/2.96E+8 kg)
 + \$8.65M * (actual kg grout)/(8.48 E+6 kg grout/vault)
 + (0.3)(\$605M)(dryfeed/5.21 E+4 kg/day)**0.78
 + (3)(\$21.8M)(dryfeed/5.21 E+4 kg/day)**0.78

Capital equipment exponent (0.78)⁽⁵⁾, operating cost exponent (0.75)⁽⁶⁾.

REFERENCES

1. Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, pp. 8-33 and 8-34, Westinghouse Hanford Company, Richland, Washington.
2. Ibid. pp. H3-34 and H3-35.
3. Ibid. p. H3-30.
4. Ibid. pp. 8-6 through 8-10.
5. Remer, D. S., and L. H. Chai, August 1990, "Design Cost Factors For Scaling-Up Engineering Equipment," *Chemical Engineering Progress*, American Institute of Chemical Engineers, New York, New York, p. 78 (blenders).
6. Black, J. H., "Scaling Operating Costs By Cost-Capacity Factors," 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30 1982, Houston, Texas, H.3.1.

**TRANSPORTATION AND DISPOSAL COST FOR CLASS A
LOW-LEVEL WASTE
(IN LLW LANDFILL)
1-4-93**

The following values are applicable⁽¹⁾.

TRANSPORTATION COSTS

<u>30-miles</u>	<u>300-miles</u>	<u>500-miles</u>
\$0.0172/kg	\$0.0295/kg	\$0.0389/kg

(based on current commercial transportation rates).

DISPOSAL (LANDFILL) CHARGES

<u>Current US Ecology Washington Nuclear Center Charge</u>	<u>Median Value From Study⁽¹⁾</u>
\$1.18/kg	\$2.57/kg

For the time being, the \$2.57 disposal value may be used. One of the transportation charges could be added, but they are negligible. The assumed density of low-level waste is $128 \text{ lb/ft}^3 = 2,050 \text{ kg/m}^3$ ⁽²⁾.

REFERENCES

1. Schlueter, R., J. J. Schafer, 1992, "Low-Level and Transuranic Waste Transportation, Disposal, and Facility Decommissioning Cost Sensitivity Analysis," EGG-WTD-10092, INEL, Idaho Falls, Idaho.
2. Personal communication, R. W. Harmsen to B. D. Zimmerman, Jan. 4, 1993, Westinghouse Hanford Company, Richland, Washington.

MIXED WASTE INCINERATION
4-6-93

For the Savannah River Laboratory (SRL) Consolidated Incinerator Facility (ICF) design, the expected capital cost is approximately \$150M, with an expected throughput of 5.6M lb/year of solids and 860,000 lb/year of liquids⁽¹⁾.

The Oak Ridge mixed waste incinerator has approximately the same capacity as the ICF⁽¹⁾⁽²⁾ but is already in operation. The annual operating cost for the Oak Ridge facility is approximately \$26M/year.

Using standard scaling exponents, and basing the throughput scaling on the total pounds-per-year capacity⁽³⁾⁽⁴⁾:

$$\text{Capital cost(\$)} = \$150\text{M}(\text{actual solid+liquid throughput}/6.46\text{M lb/year})^{**0.8}$$

$$\text{Expense cost(\$)} = \$26\text{M}(\text{actual solid+liquid throughput}/6.46\text{M lb/year})^{**0.75}$$

REFERENCES

1. Personal communication, H. Pope to B. Zimmerman, April 5, 1993, U.S. Department of Energy, Savannah River Operations Office, Aiken, South Carolina.
2. Personal communication, V. Adams (ORNL) to B. Zimmerman, April 6, 1993, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
3. Remer, D. S., and L. H. Chai, August 1990, "Design Cost Factors For Scaling-Up Engineering Equipment," *Chemical Engineering Progress*, American Institute of Chemical Engineers, New York, New York, p. 79 (furnaces).
4. Black, J. H., "Scaling Operating Costs By Cost Capacity Factors," 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30, 1982, Houston, Texas, H.3.1.

GLASS-IN-SULFUR PLANT
3-3-94

The following data are applicable for a glass in sulfur plant:

<u>Capital</u>	<u>Operating</u>	<u>Assumed capacity</u>	<u>Dry feed capacity</u>
\$1.26B ⁽¹⁾	\$2.24B ⁽¹⁾	3.10E+5 kg/OD ⁽²⁾	1.25E+5 kg/OD ⁽²⁾

B = \$Billions; OD = operating day = 2,420 days (see calculation below)

The operating cost includes an allowance for D&D and the capital cost includes any required double-shell tanks to support the facility. The plant operating costs are based on a 13-year operating period with a 60% plant efficiency. The capacity numbers are for waste flowing into the glass-in-sulfur plant and do not include added sulfur cement binding material. Using the assumed 60% plant efficiency, this implies a 24-hour day capacity of 7.47E+4 dry kg/day.

The \$2.24B operating cost breakdown is as follows:

Staff cost: \$62.5M/yr for 15 years = \$937M
 Essential materials: \$39.8M/yr for 13 years = \$517M
 Vaults: \$4.95M per vault (without liners) +
 \$2M per acre for closure barriers = \$331M

{ Two vaults require approximately 1 acre of land⁽³⁾.
 Each vault holds 1.4 E+6 gal or 5.3 E+3 m³ of waste⁽¹⁾.
 The LLW glass density is assumed to be 2.67 E+3 kg/m³.
 The glass cullet aggregate makes up 67.1 wt% of the final
 glass-in-sulfur product⁽²⁾.
 The glass-in-sulfur product flow = 2.94 E+5 kg/OD,
 yielding a total of 56 vaults⁽²⁾. }

Relating the vault cost to actual kilograms of glass deposited, the final glass-in-sulfur vault cost equation becomes:

$$\begin{aligned}
 \text{vault cost} &= \$5.95\text{M} * 56 * (\text{actual kg glass}) / 2.94 \text{ E}+5 \text{ kg/OD} * 0.671 * \\
 &\quad 2,420 \text{ OD (see below)} \\
 &= \$5.95\text{M} * 56 * (\text{actual kg glass}) / (4.77 \text{ E}+8 \text{ kg glass}) \\
 &= \$5.95\text{M} * (\text{actual kg glass}) / (8.518 \text{ E}+6 \text{ kg glass/vault})
 \end{aligned}$$

D&D: = \$455M
 implies = 30% of \$1260M + 3 years at \$25.7M/yr

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

4 of 6

These data imply the following equation:

dryfeed = actual dry feed capacity per day (kg/day)

Lifefeed = actual total lifetime grout dry feed (kg)
 {Total kg dry grout feed estimated as
 1.25 E+5 kg/OD * 2,420 OD = 3.02 E+8 kg dry feed}
 (2,420 OD = 13y * 365 * 60% oper. effic. * 0.85
 actually used in flowsheet model

\$(total) = \$1260M(dryfeed/7.47 E+4 kg/day)**0.78
 + \$937M(dryfeed/7.47 E+4 kg/day)**0.75
 + \$517M(lifefeed/3.02 E+8 kg)
 + \$5.95M * (actual kg glass)/(8.518 E+6 kg glass/vault)
 + (0.3)(\$1260M)(dryfeed/7.47 E+4 kg/day)**0.78
 + (3)(\$25.7M)(dryfeed/7.47 E+4 kg/day)**0.78

Capital equipment exponent (0.78)⁽⁵⁾, operating cost exponent (0.75)⁽⁶⁾.

REFERENCES

1. Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, pp. 8-33 and 8-34, Westinghouse Hanford Company, Richland, Washington.
2. Ibid. pp. H3-44 through H3-51.
3. Ibid. p. H3-30.
4. Ibid. pp. 8-21 through 8-24.
5. Remer, D. S., and L. H. Chai, August 1990, "Design Cost Factors For Scaling-Up Engineering Equipment," *Chemical Engineering Progress*, American Institute of Chemical Engineers, New York, New York, p. 78 (blenders).
6. Black, J. H., "Scaling Operating Costs By Cost-Capacity Factors," 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30 1982, Houston, Texas, H.3.1.

WATER TREATMENT PLANT - FACILITY NO. 8
3-17-93

The ROM Cost Estimate document⁽¹⁾, suggests a water treatment facility cost estimate of \$3.43B (\$1.31B capital and \$2.12B operations, for the life of the plant) for an actual lifetime feed into the plant of 34.3M m³ (34.3 E+9 kg) over a 30-year operating life. Using a general 0.7 scaling exponent, this leads to the formula:

$$\text{Water treatment cost} = \$3.43\text{B}(\text{actual lifetime feed}/34.3 \text{ E+9 kg})^{**0.7}$$

This presumably includes tanks and decontamination and decommissioning (D&D). Decontamination and decommissioning is generally assumed to be 30% of capital cost + 3 years of operating cost, which would = \$0.56B. Decontamination and decommissioning is always included as part of operating cost. The number of tanks assumed in the estimate, if any, is unknown.

REFERENCES

1. "ROM Cost Estimate For Hanford Strategic Analysis Study Strategy IX Option 2," Facility Specification Sheet for Facility No. 8, January 29, 1992, R. C. Hoyt, Westinghouse Hanford Company, Richland, Washington.

HLW DISPOSAL TO GLASS

5-11-93

GLASS PLANT

The term for the glass plant includes capital, expense, tanks, and D&D. The plant probably operates for about 35 years. It is derived in detail in reference 1.

INTERIM STORAGE

The second term is for interim storage of glass at Hanford. Relevant data are:

	<u>Cap. cost⁽²⁾</u>	<u>m³ of glass⁽³⁾</u>	<u>kg of glass</u>	<u>\$/kg</u>
HWVP option	\$0.56B	7,000	1.87e7*	\$29.95
Large melter option	\$1.22B	23,400	6.25e7*	\$19.52

*based on 2.67 E+3 kg/m³ for glass

Based on these values, \$25/kg for interim storage seems reasonable.

TRANSPORTATION

Relevant data are:

	<u>Transportation cost⁽⁴⁾</u>	<u>Canisters⁽⁵⁾</u>	<u>\$/canisters</u>
Option 1	\$290M	16,800	\$17,262
Option 2	\$66M	4,900	\$13,469
Option 3	\$8M	890	\$8,989
Option 4	\$1,712M	96,400	\$17,759
total	<u>\$2,076M</u>	total 1.1899 E+5 avg.	<u>\$17,447</u>

Assuming 3,738 kg per (1.4 m³) canister: \$17,447/3,738 kg = \$4.67/kg.

REPOSITORY CHARGE

A curve fit of the following data was made to estimate repository charge as a function of total kilograms of glass disposed⁽⁶⁾:

<u>Total canisters</u>	<u>Total kg*</u>	<u>Total \$</u>	<u>\$/kg</u>
890	3.33 E+6	\$0.49B	\$112.63
4,900	18.32 E+6	\$2.56B	\$139.91
16,800	62.8 E+6	\$7.07B	\$148.21
96,400	360.34 E+6	\$24.73B	\$68.75

The curve fit produced the following equation:

$$\text{Repository charge} = \$0.342 \text{ E-15} * (\text{kg of glass})^{**3} - 0.3244 \text{ E-6} * (\text{kg of glass})^{**2} + \$142.4 * (\text{kg of glass})$$

The functional form used for the fit was a quadratic. The resulting equation was multiplied by kg of glass to produce the total repository charge.

The data used to produce the equation were for the West Valley canister, assuming two repositories are required. Note that if BR-100 canisters are assumed, the cost would be lowered by \$1B or less for $\leq 63\text{M}$ kg of glass. (63M kg of glass corresponds to the case where only sludge wash is performed for separation.) The cost would be lowered by about \$4B (\$24.7B versus \$20.9B) in the case of 360M kg of glass, where 360M kg of glass corresponds to no pretreatment.

TOTAL

The resulting total cost equation is:

$$\$(\text{total cost}) =$$

$$\begin{aligned} & \$3.74 \text{ E+9} (\text{actual kg per day dry feed} / 0.683 \text{ E+3 kg/day})^{**0.29} \\ & + \$25 * (\text{kg of glass}) \\ & + \$4.67 * (\text{kg of glass}) \\ & + \$0.342 \text{ E-15} * (\text{kg of glass})^{**3} - 0.3244 \text{ E-6} * (\text{kg of glass})^{**2} + \\ & \quad \$142.4 * (\text{kg of glass}) \end{aligned}$$

REFERENCES

1. Zimmerman, B. D., "Volume Scale-Up For HLW Glass Production Plant," personal notes dated Jan. 22, 1993, Westinghouse Hanford Company, Richland, Washington.
2. Boomer, K. D., et al., 1993 *Tank Waste Technical Options Report*, WHC-EP-0616, p. 9-32, Westinghouse Hanford Company, Richland, Washington.
3. Ibid., p. 9-6.
4. "Total System Life Cycle Cost Estimates, Preliminary Draft," Table 4 of estimated repository costs from Weston, Feb. 20, 1993, Washington, D.C.
5. Ibid., Table 1.
6. "Summary of Preliminary Repository Disposal Fee Estimates For Hanford Tank Waste Remediation Study Cases (2/25/93)," from P. LaMont, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

**VOLUME SCALE-UP FOR HLW GLASS PRODUCTION PLANT
1-24-93**

There are at least three concept for HLW glass plants of differing capacities: HWVP, large melter plant, and multi-melter plant. References 1 and 2 provide the following data:

	<u>HWVP</u>	<u>Large Melter</u>	<u>Multi-Melter</u>
	25 wt% waste	25 wt% waste	15 wt% Na2O in glass
	2.6 MT/OD glass 40 years op.	9 MT/OD glass 33 years op.	220 MT/OD glass 30/13 years op.
fac. cap.	\$1.06B	\$2.0B	\$6.4B
fac. exp.	\$2.68B	\$2.53B	\$3.5B

NOTE: For the multi-melter, it appears that the WHC-EP-0405, Rev. A, flowsheet values are based on a 30-year assumed operating period, whereas the Rev. 0 values and figures derived from them (i.e., 220 MT/OD) are based on a 13-year assumed operating period.

The following data is also relevant:

dry feed	1.14 E+3 kg/OD ⁽³⁾	3.2 E+3 kg/OD ⁽⁴⁾	2.77 E+4 kg/OD ⁽⁵⁾
24-hr day at 60% eff.	0.68 E+3 kg/day	1.9 E+3 kg/day	1.66 E+4 kg/day

Graphing these data suggests that it makes the most sense to correlate total cost with volume of dry feed (rather than expense and capital costs individually). The result is:

$$$(cap+exp) = \$3.74 \text{ E}+9(\text{actual kg per day dry feed capacity} / 0.683 \text{ E}+3 \text{ kg/day})^{**0.29}$$

REFERENCES

1. Boomer, K. D., et al., 1991, *Tank Waste Systems Engineering Study*, WHC-EP-0405, Rev. A, p. H-56, Westinghouse Hanford Company, Richland, Washington.
2. Boomer, K. D., et al., 1992, *Tank Waste Systems Engineering Study*, WHC-EP-0405, Rev. 0, p. 9-31, Westinghouse Hanford Company, Richland, Washington.
3. Ibid. p. H-5.
4. Ibid. p. H-36.
5. Ibid. p. H-60.

WIPP DISPOSAL

1/27/93

Tang Chou⁽¹⁾ has uncovered the following numbers for disposal of transuranic material at the Waste Isolation Pilot Plant (WIPP) repository (processed into glass):

preparation for shipment:	\$9,175/m**3
transportation to WIPP:	\$750/m**3
WIPP charge:	\$13,520/m**3

Assuming a glass density of 2,650 kg/m**3:

preparation for shipment:	\$3.46/kg
transportation to WIPP:	\$0.28/kg
WIPP charge:	\$5.10/kg

	\$8.84/kg

REFERENCES

1. Personal communication, R. Karnesky to B. Zimmerman, January 27, 1993, Westinghouse Hanford Company, Richland, Washington.

IN SITU GROUT 3-23-93

This activity consists of mixing in-tank waste with a grout mixture, possibly including selected chemicals, completely filling the tank with grout. An offgas system is required, and engineered intrusion and infiltration barriers are installed.

For treatment of single-shell tanks, the estimated costs are:

<u>capital</u>	<u>operating</u>	<u>waste volume</u>	<u>des & const time</u>	<u>oper. time</u>
\$1.9B ⁽¹⁾	\$2.1B ⁽¹⁾	37 Mgal ⁽²⁾	9 years ⁽³⁾	8 years @ 50% effic. ⁽⁴⁾

Reference 5 suggests that the construction cost for one chemical stabilization unit is \$162M, which implies that increases in required processing capacity would be obtained by building more units. In this situation, capital and operating cost would likely vary directly with required capacity.

$$$(total\ cost) = \$4.0B * (actual\ volume\ of\ waste\ to\ be\ retrieved / 37\ E+6\ gal)$$

It may be noted that this option involves grouting all high-level waste in place. This option has been dropped from recent documents and seems very unlikely to ever be feasible from a regulatory stand point.

REFERENCES

1. Boomer, K. D., et al., 1992, *Tank Waste Systems Engineering Study*, WHC-EP-0405, Rev. 0, p. 12-17, Westinghouse Hanford Company, Richland, Washington.
2. Ibid, 1. p. 4-5.
3. Ibid, 1. p. 12-9.
4. Boomer, K. D., et al., 1991, *Tank Waste Systems Engineering Study*, WHC-EP-0405, Rev. A, p. K-19, Westinghouse Hanford Company, Richland, Washington.
5. Ibid. 4. p. K-27.

IMMOBILIZATION AND DOME FILLING

3-24-93

There are several possible activities that might be included under this heading:

- Filling tanks for which retrieval activities are complete with gravel or grout ("Dome Filling")
- Filling past-practice unit facilities, such as trenches and pits, with gravel or grout ("Past-Practice Unit Stabilization")
- Installing intrusion barriers above emptied tanks ("Intrusion Barriers")
- In situ vitrification (ISV) of emptied tanks rather than grout filling.

The following costs are applicable for the 149 single-shell tanks:

	<u>Operating</u>	<u>Capital</u>
Dome Filling	\$0.27B ⁽¹⁾	\$0.09B ⁽¹⁾
Past-Practice Unit Stabilization	\$0.27B ⁽¹⁾	\$0.05B ⁽¹⁾
Intrusion Barriers	\$0 ⁽¹⁾	\$0.15B ⁽¹⁾
ISV	total of \$0.55B more than simple grout dome filling ⁽²⁾	

To include both single-shell and double-shell tanks, the above numbers were multiplied by 177/149 (the ratio of single-shell + double-shell tanks to single-shell tanks).

Note that the dome filling or ISV costs assume that these activities are taking place in conjunction with retrieval, so that the tank confinement system is already in place. The tank confinement system cost is not included in the numbers given here; it is assumed to be included as part of retrieval cost.

REFERENCES

1. "SST Closure Estimate For Sensitivity Study," personal communication R. Parazin to B. Zimmerman, January 24, 1992, Westinghouse Hanford Company, Richland, Washington.
2. "Question On Heel Vitrification Cost," personal communication by CC:Mail, R. Parazin to B. Zimmerman, Feb. 5, 1992, Westinghouse Hanford Company, Richland, Washington.

CLEAN
9-1-93

The assumption here is that CLEAN will be accomplished by some combination of CPUs (compact processing units) for supernate and salt cake and a central facility for sludge.

CENTRAL FACILITY

This sludge processing facility is assumed to contain unit operations to perform the following processing steps⁽⁵⁾:

- Sludge washing/clarification
- Organic destruction by supercritical water oxidation with precipitation/separation of transuranic (TRU)/actinides
- Cesium ion exchange and waste concentration
- Strontium ion exchange and concentration
- Technetium ion exchange and concentration
- Calcination of LLW fractions and dissolution of calcine and reductive precipitation of chromium from calcine solution
- Recycle of caustic from calcine solution
- Sequential dissolution of solids by caustic, nitric/oxalic acid, and nitric/hydrofluoric acid
- Tributyl phosphate (TBP) extraction from dissolver solution and stripping of plutonium, neptunium, and thorium followed by stripping of uranium
- Purification of uranium for recycle
- CMPO extraction from the TBP raffinate and stripping of americium and lanthanum followed by bismuth stripping
- Crown ether extraction of strontium, barium, and technetium from CMPO raffinate
- Ammonium phosphomolybdate ion exchange of cesium from Crown ether raffinate
- Band ion exchange separation of americium from lanthanides in the CMPO25 strip solution
- Band ion exchange separation of strontium and technetium from barium in the Crown Ether strip solution.

The total sludge to be processed in SSTs and DSTs is $5.1 \text{ E}+4 \text{ m}^3$ ⁽¹⁾.

It is assumed that the central facility will process this sludge in 13 years at an operating availability of 60%⁽²⁾. Densities from sludge, salt cake, and supernate are⁽⁶⁾:

sludge: $1.7 \text{ E}+3 \text{ kg/m}^3$ salt cake: $1.5 \text{ E}+3 \text{ kg/m}^3$

supernate (interstitial liquor): $1.6 \text{ E}+3 \text{ kg/m}^3$

The costs associated with the central sludge processing facility are estimated to be⁽³⁾⁽⁴⁾:

Capital: \$2.68B

Expense: \$3.98B (includes staff,
materials, and D&D)

Because there is a variety of chemical processing equipment in the CLEAN facility, a capacity scaling factor of 0.7 for capital equipment scaling will be used⁽⁷⁾. Also, a fairly standard expense scaling factor of 0.75 will be used⁽⁸⁾.

The average daily sludge processing capacity for the facility is:

$$(5.1 \text{ E}+4 \text{ m}^3)(1.7 \text{ E}+3 \text{ kg/m}^3)/((13 \text{ years})(365 \text{ days/yr})) = 1.83 \text{ E}+4 \text{ kg/day}$$

The above information leads to the following equations for the central facility:

Capital:

$$\text{\$} = \$2.68 \text{ E}+9 (\text{avg. daily capacity at 60\% avail.}/1.83 \text{ E}+4 \text{ kg/day})^{**0.7}$$

Operating:

$$\text{\$} = \$3.98 \text{ E}+9 (\text{avg. daily capacity at 60\% avail.}/1.83 \text{ E}+4 \text{ kg/day})^{**0.75}$$

COMPACT PROCESSING UNITS

Cost equations for CPUs are derived in detail in reference 9. To summarize, the equations are:

$$\text{Capital \$} = \$9.9\text{M} (\text{actual throughput per day}/2.1 \text{ E}+4 \text{ kg/day})^{**0.7} \text{ per CPU}$$

$$\text{Expense \$} = \$4\text{M} (\text{actual throughput per day}/2.1 \text{ E}+4 \text{ kg/day})^{**0.75} \text{ per CPU per year}$$

$$\text{Capital \$} = \$7.4\text{M per tank farm, per CPU operating in parallel}$$

$$\text{Capital \$} = \$2.2\text{M per CPU type}$$

$$\text{Capital \$} = \$0.96\text{M one time charge}$$

There are various ideas about how CPUs would be employed as part of CLEAN. For example, one concept⁽¹⁰⁾ is that three different types of CPUs would be created: cesium removal, technetium removal, and nitrate/nitrite processing. One of each of these three types would be operating at a time (i.e., in parallel). If CPU processing extends over a period of 17 years⁽¹¹⁾ and CPUs last an average of 3 years, then:

- $\text{Integer}(17/3) * 3 = 18$ CPUs total would be required
- $(18 \text{ tank farms}) * (3 \text{ sets of infrastructure per farm}) = 54$ sets of tank farm infrastructure would be required if tanks in all farms are to be processed.

The total CPU cost, for the nominal throughput of 2.5 gal/minute, would then be:

Cap. \$ = \$9.9M * 18 =	\$178M
Exp. \$ = \$4M * 3 CPUs * 17 years =	\$204M
Cap. \$(infrastructure) = \$7.4M * 54 sets =	\$400M
Cap. \$(per CPU type) = \$2.2 * 3 =	\$ 7M
Cap. \$(enclosure design) =	\$ 1M

\$790M

Note, however, that a 2.5 gal/minute CPU operating for 17 years will process approximately 22 Mgal of material. The SST and DST inventories are as follows⁽¹⁾:

SST salt:	8.77 E+4 m**3	=	23.2 Mgal
SST sludge:	4.72 E+4 m**3	=	12.5 Mgal
SST supernate:	2.29 E+3 m**3	=	0.6 Mgal
DST sludge:	3.83 E+3 m**3	=	1.0 Mgal
DST supernate:	7.43 E+4 m**3	=	19.6 Mgal

Consequently, one 2.5 gal/minute CPU operating for 17 years can approximately process either the SST salt and supernate, or the DST supernate (no salt inventory given for DSTs), but not both. If both SST and DST salt and supernate are required to be processed, the capacity and/or the number of CPUs must be increased.

Another different approach to the CPU reusability issue assumes that CPUs can be repaired in a maintenance facility, so that they nominally last for the entire cleanup campaign rather than being discarded when they fail. It has been estimated that such a maintenance facility might have a capital cost of \$100M to \$200M⁽¹²⁾ and an annual expense cost of approximately \$20M⁽¹³⁾.

Because the current CLEAN concept (central facility/CPU) is ill defined, the above data are given so that a cost appropriate to a particular concept may be created as needed.

REFERENCES

1. Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, Rev. 0, Appendix D, "Tank Waste Radionuclide and Chemical Compositions," Table D-3 and Table D-8, Westinghouse Hanford Company, Richland, Washington.
2. Ibid., Appendix G, "Waste Receipt, Storage, and Separations," April 1993, pp. G13-3 and G13-9.
3. Ibid. 2., G13-10.
4. Shen, P. K., 1993, Internal Memo, Systems Engineering, to M. L. Grygiel, Westinghouse Hanford Company, Richland, Washington, "Transmittal of Report 'TWRS System Engineering Analysis Costing Data, Estimated Cost Validation'", March 29, 1993, pp. A-2 and C-3.
5. Ibid. 2., pp. G13-3 and G13-4.
6. O'Toole, S. M., Internal Memo, "Tank Waste Inventory Revision," to J. N. Appel et al., May 24, 1993, Table B.2.2, Westinghouse Hanford Company, Richland, Washington,.
7. Remer, D. S., and L. H. Chai, August 1990, "Design Cost Factors For Scaling-Up Engineering Equipment," *Chemical Engineering Progress*, American Institute of Chemical Engineers, New York, New York, p. 82.
8. Black, J. H., "Scaling Operating Costs By Cost-Capacity Factors", 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30, 1982, Houston, Texas, H.3.6.
9. B.D. Zimmerman, "GENERIC CPU COST", August 30, 1993, personal notes, Westinghouse Hanford Company, Richland, Washington.
10. Ibid. 4., p. 9.
11. Ibid. 4., p. 4.
12. Tauscher, H. T., "Clean\$- .XLS", Feb. 18, 1993, personal spreadsheet notes, Westinghouse Hanford Company, Richland, Washington.
13. Tauscher, H. T., to B. D. Zimmerman, "CPU Cost Estimate Spreadsheet Assumptions," August 11, 1993, personal communication. Telecon states that a staff of 200 is required. Ref. 12 states that \$100K per person is assumed.

GENERIC CPU COST **8-30-93**

The CPU concept really consists of the following pieces:

- Mobile CPU chemical processing unit (ion exchange equipment and enclosure)
- Mobile instrumentation and control unit
- Mobile power module
- Assorted piping, offgas facilities, and diversion boxes (infrastructure).

A different CPU chemical processing unit is assumed required for each chemical processing unit operation.

CAPITAL COSTS

The following data are applicable. These data are actually based on a cesium separation CPU:

CPU chemical processing unit

Ion exchange equipment fabrication	\$2,484,000 ⁽¹⁾⁽⁹⁾	(3.1)
Enclosure fabrication	\$6,072,000 ⁽¹⁾⁽⁹⁾	(3.4)
Initial unit disposal cost is	\$1,000,000 ⁽²⁾	
Expected lifetime is 3 years ⁽¹⁾		
Expected flow rate is 2.5 gal/minute (5 gal/minute @ 50% availability) ⁽²⁾		

	\$9,920,000	

Per CPU type

Ion exchanger design	\$ 497,000 ⁽¹⁾⁽⁹⁾	(2.4)
Ion exchanger test and installation	\$ 0 ⁽¹⁾⁽⁹⁾	(4.1)
Instrumentation & control design	\$ 146,000 ⁽¹⁾⁽⁹⁾	(2.5)
Instrument. & control test/install	\$1,525,000 ⁽¹⁾⁽⁹⁾	(4.2)

	\$2,168,000	

Per-tank-farm per parallel CPU

Instrumentation & control fabrication	\$ 730,000 ⁽¹⁾⁽⁹⁾	[3.2]
Tank farm infrastructure design	\$1,017,000 ⁽¹⁾⁽⁹⁾	(2.6)
Tank farm infrastructure fabrication	\$5,681,000 ⁽¹⁾⁽⁹⁾	[3.3]

	\$7,428,000	

("Parallel CPUs" refers to CPUs that would require duplicate sets of infrastructure and instrumentation and control modules at each tank farm).

One-time Charges

Enclosure design \$ 960,000⁽¹⁾⁽⁹⁾ (2.3)

Note that the numbers in () and [] near the right margin are index numbers from reference 1.

EXPENSE COSTS

Reference 3 estimates the total cost of CPUs for 15 years of operation to be between (low) \$2.25B and (high) \$3.0B. These estimates are for a total of 50 CPUs, operating for 15 years each⁽⁴⁾, which implies a per CPU, per year cost of:

$$\$2.25B / (50 \times 15) = \$3M \quad (\text{low})$$

or

$$\$3B / (50 \times 15) = \$4M \quad (\text{high})$$

Both of these figures include an allowance of approximately 10% for operation of a maintenance facility. The \$4M figure is intended to also include an allowance for miscellaneous expenses, such as chemical makeups.

Another estimate of operating cost was made in reference 5, where direct operating labor only was estimated to be \$8.2M.

Based on review of the estimating effort involved in producing these various estimates, it appears the \$4M per CPU per year figure is most likely to be accurate.

CAPACITY SCALING

Because there is a variety of equipment involved in the CPUs, a capital equipment scaling factor of 0.7 is appropriate⁽⁶⁾. A standard 0.75 scaling factor will be used for operating costs⁽⁷⁾.

Assuming that an individual CPU has a processing capacity of 2.5 gal/minute (5 gal/minute with 50% availability)⁽²⁾, and the following densities⁽⁸⁾:

Salt cake: 1.5 E+3 kg/m³

Supernate (interstitial liquor): 1.6 E+3 kg/m³

then:

$$(2.5 \text{ gal/minute})(1.55 \text{ E+3 kg/m}^3)(60 \text{ minute/h})(24 \text{ h/day}) / (264.2 \text{ gal/minute}^3) = 2.1 \text{ E+4 kg/day}$$

The final equations then become:

Capital \$ = \$9.9M (actual throughput per day/2.1 E+4 kg/day)**0.7 per CPU

Expense \$ = \$4M (actual throughput per day/2.1 E+4 kg/day)**0.75 per CPU per year

Capital \$ = \$7.4M per tank farm, per CPU operating in parallel

Capital \$ = \$2.2M per CPU type (i.e., Cs, Tc, nitrate, etc.)

Capital \$ = \$0.96M one time charge

REFERENCES

1. Richmond, W. G., "Compact Processing Unit, Cost Estimate Review," personal correspondence, Pacific Northwest Laboratory, Richland, Washington.
2. Richmond, W. G., "Compact Processing Unit Assumptions/Basis for Systems Study Input," personal correspondence, Pacific Northwest Laboratory, Richland, Washington.
3. Tauscher, H. T., "CLEAN\$- .XLS," Feb. 18, 1993, personal spreadsheet notes, Westinghouse Hanford Company, Richland, Washington.
4. Tauscher, H. T., to B. D. Zimmerman, "CPU Cost Estimate Spreadsheet Assumptions," August 11, 1993, personal communication, Westinghouse Hanford Company, Richland, Washington.
5. Richmond, W. B., note to cost estimator at Kaiser Engineers Hanford, ("My Dearest Friends at KEH, ..."), Pacific Northwest Laboratory, Richland, Washington.
6. Remer, D. S., and L. H. Chai, August 1990, "Design Cost Factors For Scaling-Up Engineering Equipment," *Chemical Engineering Progress*, American Institute of Chemical Engineers, New York, New York, p. 82.
7. Black, J. H., "Scaling Operating Costs By Cost-Capacity Factors," 1982 Transactions of the American Association of Cost Engineers 26th Annual Meeting, June 27 - June 30, 1982, Houston, Texas, H.3.1.
8. O'Toole, S. M., Internal Memo, "Tank Waste Inventory Revision," to J. N. Appel, et al., May 24, 1993, Table B.2.2, Westinghouse Hanford Company, Richland, Washington.
9. Richmond, W. B., "CPU COSTS - II", CC:Mail message to B. Zimmerman, August 26, 1993, Westinghouse Hanford Company, Richland, Washington.

Figure F1. Cost Summary for CLEAN Option Process Strategy.

Figure F2. Cost Summary for TRUEx-C and Sludge Wash C Process Strategies.

Figure F3. Cost Summary for CLEAN Option Process Strategy.

Figure F4. Cost Summary for TRUEX-C and Sludge Wash C Process Strategies.

Figure F5. Cost Summary of Major Process Categories With Primary Low-Level Waste Glass Product.

Figure F6. Cost Summary of Major Process Categories With Primary Low-Level Waste Grout Product.

Table F1. Cost Summary for Model CLEANG31.

PRIMARY LLW TO GROUT					PRIMARY LLW TO GLASS IN SULFUR				
COST (M\$) SUMMARY (PRIMARY WASTE)					COST (M\$) SUMMARY (PRIMARY WASTE)				
PROCESS(S)	CAPITAL	EXPENSE	TOTAL	PERCENT	CAPITAL	EXPENSE	TOTAL	PERCENT	
RETRDST+XFRDST	***	***	8091.00	27.9	***	***	8091.00	28.5	
SEPSOLIO	917.70	1077.00	1995.00	6.9	917.70	1077.00	1995.00	7.0	
DESTORG	484.90	142.80	627.70	2.2	484.90	142.80	627.70	2.2	
CAUSLEAC	394.80	435.90	830.50	2.9	394.80	435.90	830.50	2.9	
CSIX	671.60	644.20	1316.00	4.5	671.60	644.20	1316.00	4.6	
SPRX	87.61	446.10	533.70	1.8	87.61	446.10	533.70	1.9	
TCIX	84.58	430.90	515.50	1.8	84.58	430.90	515.50	1.8	
DISOLVA	49.35	44.74	94.07	0.3	49.33	44.74	94.07	0.3	
DISOLVF	18.38	15.53	33.92	0.1	18.38	15.53	33.92	0.1	
EXTRUFU	1350.00	515.70	1865.00	6.4	1350.00	515.70	1865.00	6.6	
PURIFYU	86.07	27.57	113.60	0.4	86.07	27.57	113.60	0.4	
EXTRAMLN	551.50	545.30	1097.00	3.8	551.50	545.30	1097.00	3.9	
AMLANIX	16.53	40.71	57.24	0.2	16.53	40.71	57.24	0.2	
SREX	368.40	363.10	731.50	2.5	368.40	363.10	731.50	2.6	
SRBAIX	6.51	15.44	21.95	0.1	6.51	15.44	21.95	0.10	
APMCSIX	57.89	238.20	296.00	1.0	57.89	238.20	296.00	1.0	
RCOVACID	107.20	107.90	215.10	0.7	107.20	107.90	215.10	0.8	
DNITRH	17.20	14.47	31.67	0.1	17.20	14.47	31.67	0.1	
DNITRL	177.20	176.10	353.30	1.2	177.20	176.10	353.30	1.2	
REMCR	912.90	1071.00	1984.00	6.8	912.90	1071.00	1984.00	7.0	
TREATWAT	***	***	602.30	2.1	***	***	602.30	2.1	
GROUTW(LLW):					VITRW(LLW):				
PLANT	319.20	647.50	966.70	3.3	778.40	1198.00	1976.40	7.0	
VAULTS	1995.00	***	1995.00	6.9	386.30	***	386.30	1.4	
CALCINE	926.70	702.40	1629.00	5.6	926.70	702.40	1629.00	5.7	
VITRW(HLW):									
PLANT	2335.00	***	2335.00	8.1	2335.00	***	2335.00	8.2	
INTERIM STOR	***	30.94	30.94	0.1	***	30.94	30.94	0.1	
TRANSPORT	***	5.78	5.78	0.0	***	5.78	5.78	0.0	
REPOSITORY	***	175.80	175.80	0.6	***	175.80	175.80	0.6	
IMMOBILZ:									
DOME FILLING	106.90	320.70	427.70	1.5	106.90	320.70	427.70	1.5	
INTRUSN BARRIER	178.20	0.00	***		178.20	0.00	***		
INSITU VITRIF.	244.40	733.20	***		244.40	733.20	***		
TOTAL	***	***	28970.00	100.0	***	***	28372.97	100.0	

*** = TABLE PLACE HOLDER

COST (M\$) SUMMARY (TERTIARY WASTE)					COST (M\$) SUMMARY (TERTIARY WASTE)				
PROCESS(S)	CAPITAL	EXPENSE	TOTAL	PERCENT	CAPITAL	EXPENSE	TOTAL	PERCENT	
TREATWAT	***	***	162.90	1.3	***	***	162.90	1.3	
GROUTW:									
PLANT	2026.00	4110.00	6137.00	48.5	2093.00	4226.00	6319.00	49.2	
VAULTS	2054.00	***	2054.00	16.2	2054.00	***	2054.00	16.0	
LANDFILL:									
TRANSP: 30. MI	***	20.40	***		***	20.40	***		
TRANSP: 300. MI	***	35.00	***		***	35.00	***		
TRANSP: 500. MI	***	46.15	46.15	0.4	***	46.15	46.15	0.4	
US ECOLOGY	***	1400.00	***		***	1400.00	***		
INEL ANALYSIS	***	3049.00	3049.00	24.1	***	3049.00	3049.00	23.7	
INCIN	1048.00	160.90	1209.00	9.6	1048.00	160.90	1209.00	9.4	
TOTAL	***	***	12660.00	100.0	***	***	12840.05	100.0	

*** = TABLE PLACE HOLDER

TERTIARY/PRIMARY	0.44	0.45
PRIMARY LLW PROCESSING COSTS:		
(PLANT + VAULTS)	2961.70	2362.70
GLASS / GROUT		0.80

Table F2. Cost Summary for Model TRUEXC31.

PRIMARY LLW TO GROUT					PRIMARY LLW TO GLASS IN SULFUR				
COST (M\$) SUMMARY (PRIMARY WASTE)					COST (M\$) SUMMARY (PRIMARY WASTE)				
PROCESS(S)	CAPITAL	EXPENSE	TOTAL	PERCENT		CAPITAL	EXPENSE	TOTAL	PERCENT
RETRST+XFRST+	***	***	8091.00	33.4		***	***	8091.00	34.2
RETRDST+XFRDST	917.70	1077.00	1995.00	8.2		917.70	1077.00	1995.00	8.4
WASHSLUD	22.72	6.69	29.41	0.1		22.72	6.69	29.41	0.1
DESTORG+FILTA DBS	410.80	396.30	808.90	3.3		410.80	396.30	808.90	3.4
CSX	87.05	451.40	538.50	2.2		87.05	451.40	538.50	2.3
TCIX1									
DISSOLVA+TRUEX+									
SREX+UTCSTRIP+									
TCIX2	828.00	802.10	1630.00	6.7		828.00	802.10	1630.00	6.9
PURIFYU	150.50	50.18	200.70	0.8		150.50	50.18	200.70	0.8
TREATWAT	***	***	478.80	2.0		***	***	478.80	2.0
GROUTW(LLW):					VITRW(LLW):				
PLANT	566.30	1141.00	1707.00	7.0		1170.00	1847.00	3017.00	12.7
VAULTS	2349.00	***	2349.00	9.7		451.30	***	451.30	1.9
CALCINE	0.00	0.00	0.00	0.0		0.00	0.00	0.00	0.0
VITRW(HLW):									
PLANT	3548.00	***	3548.00	14.6		3548.00	***	3548.00	15.0
INTERIM STOR	***	366.40	366.40	1.5		***	366.40	366.40	1.5
TRANSPORT	***	68.44	68.44	0.3		***	68.44	68.44	0.3
REPOSITORY	***	2018.00	2018.00	8.3		***	2018.00	2018.00	8.5
IMMOBILZ.									
DOME FILLING	106.90	320.70	427.70	1.8		106.90	320.70	427.70	1.8
INTRUSN BARRIER	178.20	0.00	***			178.20	0.00	***	
INSITU VITRIF.	244.40	733.20	***			244.40	733.20	***	
TOTAL	***	***	24250.00	100.0		***	***	23664.95	100.0

*** = TABLE PLACE HOLDER

COST (M\$) SUMMARY (TERTIARY WASTE)					COST (M\$) SUMMARY (TERTIARY WASTE)				
PROCESS(S)	CAPITAL	EXPENSE	TOTAL	PERCENT		CAPITAL	EXPENSE	TOTAL	PERCENT
TREATWAT	***	***	118.70	1.4		***	***	118.70	1.3
GROUTW.									
PLANT	1395.00	2810.00	4205.00	49.1		1503.00	3001.00	4504.00	50.9
VAULTS	1344.00	***	1344.00	15.7		1344.00	***	1344.00	15.2
LANDFILL:									
TRANSP. 30. MI	***	13.35	***			***	13.35	***	
TRANSP. 300 MI	***	22.90	***			***	22.90	***	
TRANSP. 500 MI	***	30.20	30.20	0.4		***	30.20	30.20	0.3
US ECOLOGY	***	916.10	***			***	916.10	***	
INEL ANALYSIS	***	1995.00	1995.00	23.3		***	1995.00	1995.00	22.5
INCIN	746.60	117.10	863.70	10.1		746.60	117.10	863.70	9.8
TOTAL	***	***	8557.00	100.0		***	***	8855.60	100.0

*** = TABLE PLACE HOLDER

TERTIARY/PRIMARY	0.35	0.37
PRIMARY LLW PROCESSING COSTS:		
(PLANT + VAULTS)	4056.00	3468.30
GLASS / GROUT		0.86

Table F3. Cost Summary for Model SLUG31.

PRIMARY LLW TO GROUT					PRIMARY LLW TO GLASS IN SULFUR				
COST (M\$) SUMMARY (PRIMARY WASTE)					COST (M\$) SUMMARY (PRIMARY WASTE)				
PROCESS(S)	CAPITAL	EXPENSE	TOTAL	PERCENT	CAPITAL	EXPENSE	TOTAL	PERCENT	
RETRST+XFRST+	***	***	8091.00	26.2	***	***	8091.00	26.5	
RETRST+XFRST	***	***	8091.00	26.2	***	***	8091.00	26.5	
WASHSLUD	917.70	1077.00	1995.00	6.5	917.70	1077.00	1995.00	6.5	
DESTORG+FILTDSS	460.10	135.50	595.60	1.9	460.10	135.50	595.60	2.0	
CSX	353.40	322.90	676.30	2.2	353.40	322.90	676.30	2.2	
TCIX1	74.93	368.00	442.90	1.4	74.93	368.00	442.90	1.5	
DISSOLVA+TRUEX+									
SREX+UTCSTRIP+									
TCIX2	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.0	
PURIFYU	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.0	
TREATWAT	***	***	329.50	1.1	***	***	329.50	1.1	
GROUTW(LLW):					VITRW(LLW):				
PLANT	451.50	899.50	1351.00	4.4	912.60	1418.00	2330.60	7.6	
VAULTS	1679.00	***	1679.00	5.4	354.90	***	354.90	1.2	
CALCINE	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.0	
VITRW(HLW):									
PLANT	4894.00	***	4894.00	15.9	4894.00	***	4894.00	16.0	
INTERIM STOR	***	1710.00	1710.00	5.5	***	1710.00	1710.00	5.6	
TRANSPORT	***	319.40	319.40	1.0	***	319.40	319.40	1.0	
REPOSITORY	***	8332.00	8332.00	27.0	***	8332.00	8332.00	27.3	
IMMOBILZ:									
DOMFILLING	106.90	320.70	427.70	1.4	106.90	320.70	427.70	1.4	
INTRUSN BARRIER	178.20	0.00	***		178.20	0.00	***		
INSITU VITRIF.	244.40	733.20	***		244.40	733.20	***		
TOTAL	***	***	30840.00	100.0	***	***	30498.90	100.0	

*** = TABLE PLACE HOLDER

COST (M\$) SUMMARY (TERTIARY WASTE)					COST (M\$) SUMMARY (TERTIARY WASTE)				
PROCESS(S)	CAPITAL	EXPENSE	TOTAL	PERCENT	CAPITAL	EXPENSE	TOTAL	PERCENT	
TREATWAT	***	***	86.98	1.5	***	***	86.98	1.5	
GROUTW:									
PLANT	962.00	1917.00	2879.00	50.7	1047.00	2068.00	3115.00	52.6	
VAULTS	845.40	***	845.40	14.9	845.40	***	845.40	14.3	
LANDFILL:									
TRANSP: 30. MI	***	8.40	***		***	8.40	***		
TRANSP: 300. MI	***	14.40	***		***	14.40	***		
TRANSP: 500. MI	***	18.99	18.99	0.3	***	18.99	18.99	0.3	
USE ECOLOGY	***	576.10	***		***	576.10	***		
INEL ANALYSIS	***	1255.00	1255.00	22.1	***	1255.00	1255.00	21.2	
INCIN	515.20	82.67	597.80	10.5	515.20	82.67	597.80	10.1	
TOTAL	***	***	5683.00	100.0	***	***	5919.17	100.0	

*** = TABLE PLACE HOLDER

TERTIARY/PRIMARY	0.18	0.19
PRIMARY LLW PROCESSING COSTS:		
(PLANT + VAULTS)	3030.00	2685.50
GLASS / GROUT		0.89

Table F4. Cost Summary for Model CLEANG31 Incorporating Compact Processing Units.

PRIMARY LLW TO GROUT					PRIMARY LLW TO GLASS IN SULFUR				
COST (M\$) SUMMARY (PRIMARY WASTE)					COST (M\$) SUMMARY (PRIMARY WASTE)				
PROCESS(S)	CAPITAL	EXPENSE	TOTAL	PERCENT		CAPITAL	EXPENSE	TOTAL	PERCENT
RETRST+XFRST+ RETRDST+XFRDST	***	***	8091.00	36.4		***	***	8091.00	37.4
CENTRAL PROC (SLUDGE)	2680.00	3980.00	6660.00	29.9		2680.00	3980.00	6660.00	30.8
CPU (SALT + SUPERNATE)	745.86	204.00	949.86	4.3		745.86	204.00	949.86	4.4
TREATWAT	***	***	602.30	2.7		***	***	602.30	2.8
GROUTW(LLW):					VITRW(LLW):				
PLANT	319.20	847.50	966.70	4.3		778.40	1198.00	1976.40	9.1
VAULTS	1995.00	***	1995.00	9.0		386.30	***	386.30	1.8
VITRW(HLW):									
PLANT	2335.00	***	2335.00	10.5		2335.00	***	2335.00	10.8
INTERIM STOR	***	30.94	30.94	0.1		***	30.94	30.94	0.1
TRANSPORT	***	5.78	5.78	0.0		***	5.78	5.78	0.0
REPOSITORY	***	175.80	175.80	0.8		***	175.80	175.80	0.8
IMMOBILZ:									
DOMES FILLING	106.90	320.70	427.70	1.9		106.90	320.70	427.70	2.0
INTRUSN BARRIER	178.20	0.00	***			178.20	0.00	***	
INSITU VITRIF.	244.40	733.20	***			244.40	733.20	***	
TOTAL	***	***	22240.08	100.0		***	***	21641.08	100.0

*** = TABLE PLACE HOLDER

COST (M\$) SUMMARY (TERTIARY WASTE)					COST (M\$) SUMMARY (TERTIARY WASTE)				
PROCESS(S)	CAPITAL	EXPENSE	TOTAL	PERCENT		CAPITAL	EXPENSE	TOTAL	PERCENT
TREATWAT	***	***	121.70	1.3		***	***	121.70	1.3
GROUTW:									
PLANT	1547.00	3107.00	4654.00	49.8		1602.00	3205.00	4807.00	50.6
VAULTS	1458.00	***	1458.00	15.6		1458.00	***	1458.00	15.3
LANDFILL:									
TRANSP. 30. MI	***	14.49	***			***	14.49	***	
TRANSP. 300. MI	***	24.85	***			***	24.85	***	
TRANSP. 500. MI	***	32.76	32.76	0.4		***	32.76	32.76	0.3
US ECOLOGY	***	993.90	***			***	993.90	***	
INEL ANALYSIS	***	2165.00	2165.00	23.1		***	2165.00	2165.00	22.8
INCIN	796.90	124.40	921.40	9.9		796.90	124.40	921.40	9.7
TOTAL	***	***	9352.00	100.0		***	***	9505.86	100.0

*** = TABLE PLACE HOLDER

TERTIARY/PRIMARY	0.42	0.44
PRIMARY LLW PROCESSING COSTS: (PLANT + VAULTS)	2961.70	2362.70
GLASS / GROUT		0.80

Table F5. Total Cost (Million \$) Summary for Process Strategies.

WASTE STREAM	MODEL	PRIMARY LLW TO GROUT				PRIMARY LLW TO GLASS IN SULFUR			
		CLEANG31 CLEAN OPTION (0% HEEL)	TRUEXC31 TRUEX-C (0% HEEL)	SLUDWC31 SLUDGE WASH C (0% HEEL)	CLEAN W/ CPU's CLEAN OPTION (0% HEEL)	CLEANG31 CLEAN OPTION (0% HEEL)	TRUEXC31 TRUEX-C (0% HEEL)	SLUDWC31 SLUDGE WASH C (0% HEEL)	CLEAN W/ CPU's CLEAN OPTION (0% HEEL)
PRIMARY		28970	24250	30840	22240	28373	23665	30499	21641
TERTIARY		12660	8557	5683	9352	12840	8856	5919	9506
TOTAL		41630	32807	36523	31592	41213	32521	36418	31147
TERTIARY/PRIMARY		0.44	0.35	0.18	0.42	0.45	0.37	0.19	0.44
PERCENT OF COST:									
PRIMARY		69.6	73.9	84.4	70.4	68.8	72.8	83.7	69.5
TERTIARY		30.4	26.1	15.6	29.6	31.2	27.2	16.3	30.5
CLEANG31/"MODEL" COST:									
PRIMARY			1.19	0.94	1.30		1.20	0.93	1.31
TERTIARY			1.48	2.23	1.35		1.45	2.17	1.35
TOTAL			1.27	1.14	1.32		1.27	1.13	1.32
TRUEX-C/"MODEL" COST:									
PRIMARY		0.84		0.79	1.09	0.83		0.78	1.09
TERTIARY		0.68		1.51	0.91	0.69		1.50	0.93
TOTAL		0.79		0.90	1.04	0.79		0.89	1.04
SLUDGE WASH C/"MODEL" COST:									
PRIMARY		1.06	1.27		1.39	1.07	1.29		1.41
TERTIARY		0.45	0.66		0.61	0.46	0.67		0.62
TOTAL		0.88	1.11		1.16	0.88	1.12		1.17
CLEAN W/ CPU's/"MODEL" COST:									
PRIMARY		0.77	0.92	0.72		0.76	0.91	0.71	
TERTIARY		0.74	1.09	1.65		0.74	1.07	1.61	
TOTAL		0.76	0.96	0.86		0.76	0.96	0.86	
LLW GROUT vs. GLASS PRODUCT COSTS:									
PRIMARY						0.98	0.98	0.99	0.97
TERTIARY						1.01	1.03	1.04	1.02
TOTAL						0.99	0.99	1.00	0.99

Table F6. Summary of Process Distribution Across Major Process Categories.

MAJOR PROCESS CATEGORY	MODEL: CLEAN G31 CLEAN OPTION	TRUEXC31 TRUEX-C	SLUDWC31 SLUDGE WASH C	CLEAN W/ CPUs CLEAN OPTION
RETRIEVE TANK WASTE AND PARTITION LIQUID WASTE:	RETRSSST XFRSSST RETRDST XFRDST	RETRSSST XFRSSST RETRDST XFRDST	RETRSSST XFRSSST RETRDST XFRDST	RETRSSST XFRSSST RETRDST XFRDST
SEPARATE SOLIDS AND LIQUIDS AND DISSOLVE SOLIDS:	SEPSOLQ DESTORG CAUSLEAC DISOLVA DISOLVF	WASHSLUD DESTORG FILTADBS DISSOLVA*	WASHSLUD DESTORG FILTADBS	.
REMOVE NUCLEIDES FROM ALKALINE LIQUIDS:	CSIX SPIX TCIX	CSIX TCIX1	CSIX TCIX1	CENTRAL PROC (SLUDGE)
REMOVE NUCLEIDES FROM ACIDIC LIQUIDS:	EXTRUPU PURIFYU EXTRAMLN AMLANIX SREX SRBAIX APMCSIX	TRUEX PURIFYU UTCSTRIP TCIX2 SREX		CPU (SALT + SUPERNATE)
REMOVE AND PURIFY BULK CHEMICALS:	RCOVACID DNITRH DNITRL REMOX CALCINE			.
HLW TREATMENT AND DISPOSAL:	VITRW(HLW): PLANT INTERIM STOR TRANSPORT REPOSITORY	VITRW(HLW): PLANT INTERIM STOR TRANSPORT REPOSITORY	VITRW(HLW): PLANT INTERIM STOR TRANSPORT REPOSITORY	VITRW(HLW): PLANT INTERIM STOR TRANSPORT REPOSITORY
LLW TREATMENT AND DISPOSAL:				
OPTION 1: GLASS IN SULFUR PRIMARY WASTE:	VITRW(LLW): PLANT VAULTS	VITRW(LLW): PLANT VAULTS	VITRW(LLW): PLANT VAULTS	VITRW(LLW): PLANT VAULTS
OPTION 2: GROUT PRIMARY WASTE:	GROUTW(LLW): PLANT VAULTS	GROUTW(LLW): PLANT VAULTS	GROUTW(LLW): PLANT VAULTS	GROUTW(LLW): PLANT VAULTS
TERTIARY WASTE:	GROUTW: PLANT VAULTS	GROUTW: PLANT VAULTS	GROUTW: PLANT VAULTS	GROUTW: PLANT VAULTS
TANK IMMOBILIZATION:	IMMOBILZ: DOME FILLING INTRUSN BARRIER INSITU VITRIF.	IMMOBILZ: DOME FILLING INTRUSN BARRIER INSITU VITRIF.	IMMOBILZ: DOME FILLING INTRUSN BARRIER INSITU VITRIF.	IMMOBILZ: DOME FILLING INTRUSN BARRIER INSITU VITRIF.
WATER TREATMENT:				
PRIMARY WASTE:	TREATWAT	TREATWAT	TREATWAT	TREATWAT
TERTIARY WASTE:	TREATWAT	TREATWAT	TREATWAT	TREATWAT
TERTIARY WASTE TO LANDFILL:	LANDFILL: TRANSP: 30. MI TRANSP: 300. MI TRANSP: 500. MI US ECOLOGY INEL ANALYSIS	LANDFILL: TRANSP: 30. MI TRANSP: 300. MI TRANSP: 500. MI US ECOLOGY INEL ANALYSIS	LANDFILL: TRANSP: 30. MI TRANSP: 300. MI TRANSP: 500. MI US ECOLOGY INEL ANALYSIS	LANDFILL: TRANSP: 30. MI TRANSP: 300. MI TRANSP: 500. MI US ECOLOGY INEL ANALYSIS
TERTIARY WASTE INCINERATION:	INCIN	INCIN	INCIN	INCIN

* DISSOLVA = 0.15*(TRUEX+SREX+DISSOLVA+TCIX2+UTCSTRIP)

Table F7. Cost (Million \$) Summary of Major Process Categories.

No.	MAJOR PROCESS CATEGORY	PRIMARY LLW TO GROUT				PRIMARY LLW TO GLASS IN SULFUR			
		MODEL: CLEANG31 CLEAN OPTION (0% HEEL)	TRUEXC31 TRUEX-C (0% HEEL)	SLUDWC31 SLUDGE WASH C (0% HEEL)	CLEAN W/ CPUs CLEAN OPTION (0% HEEL)	CLEANG31 CLEAN OPTION (0% HEEL)	TRUEXC31 TRUEX-C (0% HEEL)	SLUDWC31 SLUDGE WASH C (0% HEEL)	CLEAN W/ CPUs CLEAN OPTION (0% HEEL)
1	RETRIEVE TANK WASTE AND PARTITION LIQUID WASTE:	8091	8091	8091	8091	8091	8091	8091	8091
2	SEPARATE SOLIDS AND LIQUIDS AND DISSOLVE SOLIDS:	3581	2269	2591	6660	3581	2269	2591	8660
3	REMOVE NUCIDES FROM ALKALINE LIQUIDS:	2365	1345	1119	950	2365	1345	1119	950
4	REMOVE NUCIDES FROM ACIDIC LIQUIDS:	4182	1586			4182	1586		
5	REMOVE AND PURIFY BULK CHEMICALS:	4213				4213			
6	HLW TREATMENT AND DISPOSAL:	2548	6001	15255	2548	2548	6001	15255	2548
7	LLW TREATMENT AND DISPOSAL:								
	OPTION 1: GLASS IN SULFUR PRIMARY WASTE:					2363	3468	2686	2363
	OPTION 2: GROUT PRIMARY WASTE:	2962	4056	3030	2962				
	TERTIARY WASTE:	8191	5549	3724	6112	8373	5848	3960	6265
8	TANK IMMOBILIZATION:	428	428	428	428	428	428	428	428
9	WATER TREATMENT:								
	PRIMARY WASTE:	602	477	330	602	602	477	330	602
	TERTIARY WASTE:	163	119	87	122	163	119	87	122
10	TERTIARY WASTE TO LANDFILL:	3095	2025	1274	2198	3095	2025	1274	2198
11	TERTIARY WASTE INCINERATION:	1209	864	598	921	1209	864	598	921.40
	COMBINATIONS:								
C1	PROCESSING: 2+3+4+5	14342	5201	3710	7610	14342	5201	3710	7610
C2	PROCESSING + HLW: C1+6	16889	11201	18965	10157	16889	11201	18965	10157
C3	PROCESSING + HLW + LLW: C2 + 7(PRI. ONLY)	19851	15257	21995	13119	19252	14670	21651	12520
C4	TERTIARY: (7+9 TERT. ONLY)+10+11	12658	8557	5683	9353	12840	8856	5919	9506
C5	TOTAL OF ALL CATEGORIES:	41630	32809	36527	31593	41213	32521	36418	31147

F-63

MHC-EP-0791

Table F8. Differential Cost (Million \$) Compared to Model CLEANG31 for Major Process Categories.

No.	MAJOR PROCESS CATEGORY	PRIMARY LLW TO GROUT				PRIMARY LLW TO GLASS IN SULFUR			
		MODEL: CLEANG31 CLEAN OPTION (0% HEEL)	TRUEXC31 TRUEX-C (0% HEEL)	SLUDWC31 SLUDGE WASH C (0% HEEL)	CLEAN W/ CPUs CLEAN OPTION (0% HEEL)	CLEANG31 CLEAN OPTION (0% HEEL)	TRUEXC31 TRUEX-C (0% HEEL)	SLUDWC31 SLUDGE WASH C (0% HEEL)	CLEAN W/ CPUs CLEAN OPTION (0% HEEL)
1	RETRIEVE TANK WASTE AND PARTITION LIQUID WASTE:		0	0	0		0	0	0
2	SEPARATE SOLIDS AND LIQUIDS AND DISSOLVE SOLIDS:		-1312	-991			-1312	-991	
3	REMOVE NUCLIDES FROM ALKALINE LIQUIDS:		-1020	-1246			-1020	-1246	
4	REMOVE NUCLIDES FROM ACIDIC LIQUIDS:		-2596	-4182			-2596	-4182	
5	REMOVE AND PURIFY BULK CHEMICALS:		-4213	-4213			-4213	-4213	
6	HLW TREATMENT AND DISPOSAL:		3453	12708	0		3453	12708	0
7	LLW TREATMENT AND DISPOSAL:								
	OPTION 1: GLASS IN SULFUR PRIMARY WASTE:						1106	323	0
	OPTION 2: GROUT PRIMARY WASTE:		1094	68	0		-2525	-4413	-2108
	TERTIARY WASTE:		-2642	-4467	-2079				
			0	0	0		0	0	0
8	TANK IMMOBILIZATION:								
9	WATER TREATMENT: PRIMARY WASTE:		-126	-273	0		-126	-273	0
	TERTIARY WASTE:		-44	-76	-41		-44	-76	-41
10	TERTIARY WASTE TO LANDFILL:		-1070	-1821	-897		-1070	-1821	-897
11	TERTIARY WASTE INCINERATION:		-345	-611	-288		-345	-611	-288
	COMBINATIONS:								
C1	PROCESSING: 2+3+4+5		-9141	-10632	-6732		-9141	-10632	-6732
C2	PROCESSING + HLW: C1+6		-5688	2076	-6732		-5688	2076	-6732
C3	PROCESSING + HLW + LLW: C2 + 7(PRI. ONLY)		-4594	2144	-6732		-4582	2399	-6732
C4	TERTIARY: (7+9 TERT. ONLY)+10+11		-4101	-6975	-3305		-3984	-6921	-3334
C5	TOTAL OF ALL CATEGORIES:		-8821	-5103	-10037		-8692	-4795	-10066

F-64

MHC-EP-0791

APPENDIX E

TERTIARY NONPROCESS WASTE GENERATION

LIST OF TERMS

AQUELLW	aqueous liquids
CBUSTL	combustible solids and liquids
CPU	compact processing unit
DISS	dissolver
DOE	U.S. Department of Energy
DST	double-shell tank
HLW	high-level waste
INEL	Idaho National Engineering Laboratory
OFFGAS	cell air and offgas
NCBUSTS	noncombustible solids
SE	solvent extraction
SRS	Savannah River Site
SST	single-shell tank
TRU	transuranic
VAQUELLW	varied aqueous liquids
VCBUSTL	varied combustible solids and liquids
VOFFGAS	varied cell air and offgas
VNCBUSTS	varied noncombustible solids
WMIS	Waste Management Information System
WVDP	West Valley Demonstration Project

TERTIARY NONPROCESS WASTE GENERATION

This appendix discusses the development of the tertiary waste generation estimation models and the results from using these models. The tertiary waste models are based on data collected from various U.S. Department of Energy (DOE) sites. These models were implemented in the global process models using FORTRAN calculation blocks.

E1.0 DEVELOPMENT OF THE TERTIARY WASTE GENERATION MODEL

In previous work the wastes that did not result directly from splitting or partitioning of the main process streams were termed secondary waste. To avoid confusion with the smaller process streams these wastes are renamed here as tertiary nonprocess waste or simply tertiary waste.

For this study, the tertiary waste has been divided into combustible solids and liquids (CBUSTL), noncombustible solids (NCBUSTS), aqueous liquids (AQUELLW), and cell air and offgas (OFFGAS). The portions of these wastes that vary when the primary process flow rate is varied, after the plant design has been fixed, are called VCBUSTL, VNCBUSTS, VAQUELLW, and VOFFGAS.

To estimate the tertiary waste feed rates, printouts were requested from L. J. Wachter, manager of the Waste Management Information System (WMIS) database at Hazardous Waste Remedial Actions Program in Oak Ridge, Tennessee, for the major DOE integrated processing sites: Hanford, Idaho National Engineering Laboratory (INEL), Rocky Flats, and West Valley Demonstration Project (WVDP). This gave values of inventories and rates for 563 DOE waste streams. The streams were then classified into the four desired tertiary waste categories (CBUSTL, NCBUSTS, AQUELLW, and OFFGAS) plus the primary aqueous waste streams. Because data for cell air and offgas rates were not available, the volume of filters resulting from offgas treatment was substituted. Aqueous solutions used for offgas scrubbing were assumed to be already included in the primary flowsheets.

For each DOE site the ratio of the volume of each tertiary waste category to the volume of the primary stream was estimated. Whenever possible, the current rates were used, but for plants that are no longer operating it was necessary to use data from accumulated inventories from unknown past practices. For sites that had sufficient information, the ratio of transuranic (TRU) waste to nonTRU waste was estimated for each waste category.

The aggregated waste rates, shown in Table E1, gave ratios that were often inconsistent. Each site seemed to have a different ratio of streams, perhaps because each DOE site was a special case: Rocky Flats had no primary aqueous waste stream; INEL included much stored waste from Rocky Flats in its solid wastes; and the Savannah River Site (SRS) included tritiated wastes from its reactors and tritium processing plants. No processes are currently operating at the Hanford Site and its only nonhigh-level liquid waste was an

enormous volume of very dilute process condensate. There is a great deal of information relevant to tertiary wastes contained in the WMIS reports. However, in the future it is recommended that access be gained to the detailed tertiary process waste rates from individual facilities with currently operating processes before the wastes are reprocessed and aggregated into DOE site integrated totals.

After examining wastes from the major DOE sites (Hanford, INEL, Rocky Flats, SRS, and WVDP) it was concluded that only the Savannah River F and H canyon data in Tables E2 and E3 covered a long enough time period of startups, shutdowns, and idle periods to provide substantive data for establishing credible tertiary waste generation rates as they relate to specific pretreatment processes. Nevertheless, the data from other sites provided more complete breakdowns of the tertiary waste that could be classified into four main categories for which typical treatment processes could be defined. The flow diagram for treatment of these tertiary waste categories is shown in Figure E1 as implemented in the ASPEN PLUS¹ global models.

Although the SRS operations include wastes from several plants, the 98 waste streams gave the best opportunity for estimating tertiary process waste rates for operating solvent extraction (SE) plants. The flowsheet in Figure E2 was devised to represent waste flows from Savannah River SE operations. It is a composite flowsheet, which combines major stream flow data for a typical period of startups, shutdowns, and idle periods in Table E2 from 1987 to 1992 with the more detailed solid waste data from Table E3 for the 1992 calendar year predicted as of August 29, 1991. The major difficulties are that the bulk of the combustible and noncombustible wastes are mixed in two categories, compactible and job control wastes, and that the ratio of tertiary-to-primary wastes from F canyon is six times higher than from H canyon. An F-H canyon composite volume ratio of tertiary-to-primary of 2:1 was used for the study. When the Savannah River waste stream categories, classifications, and compositions were inadequate, estimates of ratios were taken first from the Hanford Site and then from INEL and Rocky Flats.

The four waste types and treatment processes are as follows.

1. Treat noncombustible solids by processes, such as compaction, leaching, and decontamination. (TRTSSOL)
2. Incinerate combustible solids and liquids. (INCIN)
3. Ion exchange and concentrate aqueous wastes. (EVAPIX)
4. Treat cell air and offgas with high-efficiency particulate air filters. (OGASTRT)

The net result of combining all of the site information is shown in Figure E1 for the SRS F and H canyons.

¹ASPEN PLUS is a trademark of Aspen Technology, Inc.

Nearly all of the tertiary wastes were found to be only a function of the size of the process and plant design. Only a small fraction, mainly TRU wastes, varied with the plant throughput after the plant had been operating. The variable tertiary waste fraction was designated VCBUSTL, VNCBUSTS, VAQUELLW, and VOFFGAS. Early plant data suggested that a satisfactory description of treatment of tertiary waste would require a matrix of the constant plant design throughput portion and the variable throughput portion of the four waste types for all of the processes in the plant. However, there was insufficient information available on the layouts of the F and H canyon processes to ascribe the tertiary wastes to individual processes. Thus, the matrix approach was temporarily abandoned, and, instead, the composition and ratio of the total F and H canyon tertiary waste flow to the total high-level waste (HLW) flow rate in our plant design was applied to give tertiary waste flows and compositions.

Additional information has now been obtained on the SRS plant layouts and on the proposed Hanford TRUEX-D space allocations (Figure E3) that has allowed improving the estimation of the tertiary wastes from the individual processes in our plant flowsheets. Therefore, we can return to the matrix approach.

To facilitate the waste allocations to individual process the following assumptions were made:

- The variable throughput coefficients (VCBUSTL, VNCBUSTS, VAQUELLW, and VOFFGAS) were not used (i.e., they were temporarily set to zero and included in the design stream) because the current analyses are only concerned with plant design and not with variable rate of operation of a plant after it has been designed.
- The tertiary waste volume was proportional to space allocation for each process in the SRS F or H canyon.
- The SRS F and H canyons were operated at the same waste flow rate (i.e., the flow rates were averaged).
- It was assumed that an SRS dissolver (DISS) is equivalent to 0.25 SE cycles for the purposes of tertiary waste generation estimation.
- It was assumed that the high activity waste throughput rate is the same as the feed rate to the F or H canyon. The average 1987 to 1990 rate from the data given in Table E2 was 182,000 gal/yr HLW or 91,000 gal/yr for one canyon. Converting units gives 344.5 m³/yr (3.786 m³/gal) or 344,500 kg/yr HLW (assuming a liquid density of 1,000 kg/m³).
- It was assumed that the flow rates through all process equipment in the SRS F and H canyons were equal because the actual relative flow rates through the F or H canyon equipment or any other part of the main SRS processing plants were not available for use.

From SRS canyon layout data the total tertiary waste generation volume was assigned to the various canyon processes based on the number of pieces of major equipment involved in each of the specific processes relative to the total. This assignment method is based on the fact that tertiary waste

generation seems to depend most on the number of staff operating the plant processes. This number was assumed to be proportional to the number of tanks and major sets of equipment involved in the plant processes because such entities tend to require observation, sampling, control, and maintenance, which requires staff attention and particularly staff ingress into radiation zones. These assignments are shown in Table E4 in the form of equipment fractions or volume ratios for each process.

From the equipment ratio data the four-cycle SE process accounts for 44% of the total tertiary waste generation or 11% for each SE cycle ($9 \times 11\% = 100\%$). Therefore, the total tertiary waste generation from F or H canyon is equivalent to approximately nine SE cycles. For nine SE cycles (in series), Table E5 shows the mass ratios of tertiary wastes to primary waste liquid HLW along with the mass ratios per SE equivalent. To apply this waste generation data, the CLEAN Option and TRUEX-C/Sludge Wash C suite of processes were first represented by 21 and 13 main processes, respectively, each of which was categorized by SE equivalents as shown in Table E6. These SE equivalents were chosen, based on estimates of major pieces of equipment needed for each specific process. The tertiary waste generation rate from each of these processes is found using the following equation:

$$\text{TertWaste}_j = \text{ProcFlow} * \text{Equivs} * \text{MassRatio}_j$$

where:

TertWaste_j = Tertiary waste j generation (kg).

ProcFlow = Primary waste flow (kg) through the equipment in a particular process.

Equivs = SE equivalents (1 DISS = 0.25 SE) for a particular process.

MassRatio = Mass ratio of tertiary waste j to the primary waste per SE cycle.

For example, if the design mass flow rate through the WASHSLUD process was 100,000 kg/yr, then NCBUSTS (noncombustibles) tertiary waste is calculated as follows:

$$\text{NCBUSTS(WASHSLUD)} = 100,000 * (0.5 * 0.25) * 0.12 = 1,500 \text{ kg NCBUSTS/yr}$$

The calculations of tertiary waste generation were implemented in FORTRAN subroutines that compiled directly with each global model ASPEN PLUS run. These FORTRAN subroutines automatically retrieve the specific process flow rate and use the above equation to calculate the 12 elements comprising the tertiary waste (i.e., NCBUSTS, CBUSTSL, etc.) for each main process.

The waste generation for each process is then summed to provide the input streams for the tertiary process waste treatment portion of the model. The tertiary waste was assigned to four components as follows:

AQUELLW		CBUSTL, NCBUSTS, OFFGAS	
H ₂ O	(89%)	H ₂ O	(0%)
NaNO ₃	(10%)	NaNO ₃	(0%)
OHAZ1	(1%)	OHAZ1	(10%)
OTH2	(<1%)	OTH2	(90%)

E2.0 SUMMARY OF RESULTS

Figure E4 shows the calculated tertiary waste generation by process for the CLEAN Option (with and without compact processing units [CPUs]) and TRUEX-C/Sludge Wash C processes with 0% heel to show maximum process throughput. For the CLEAN Option using CPUs, the tertiary waste stream flows were estimated by using single-shell tank (SST) and double-shell tank (DST) feedstreams with only 36 and 4% of the SST and DST tank waste feedstream mass flows, respectively. These percentages represent only the sludge portion of the respective feedstreams that would be processed in a central processing facility when CPUs are also used.

As shown in Figure E4, the cesium ion exchange, strontium ion exchange, and technetium ion exchange processes produced the most tertiary waste because of their high throughput and high SE cycle equivalency assignment (see Table E6). Figure E5 shows the tertiary waste stream flows for each of the process strategies. Note how large the tertiary waste flows are compared to the primary waste feedstream flow of approximately 7.6 E+08 kg. As discussed in Appendix H, the total tertiary to primary waste flow ratios were 4.4, 2.9, 1.8, and 3.1 (calculated based on results in Table E10) for the CLEAN Option without CPUs, TRUEX-C, Sludge Wash C, and CLEAN Option with CPUs, respectively.

Tables E7 through E10 show the detailed tertiary waste generation data for each global model from which Figures E4 and E5 were created. The tertiary waste table data are shown for each of the main global model processes with a breakdown into each tertiary waste stream. The process flow rates that determined the quantity of tertiary waste generated are also shown.

It should be clear from the data that the tertiary waste generation is substantial and cannot be ignored when evaluating process technologies. As shown by Figure E5, the CLEAN Option with and without CPUs generates the largest amount of tertiary waste owing to its intensive chemical processing strategy. Indeed, the cost for processing this tertiary waste is very substantial as discussed in Appendix F. The large tertiary waste costs could be decreased significantly if process design is also focused on reducing the amount of tertiary waste produced.

Figure E1. Tertiary Waste Processing Flow Diagram.

Figure E2. Savannah River Site Waste Management Information System
Waste Streams (1987 - 1991 Average).

(all flows expressed as volume ratio to HLW flow rate)

Figure E3. TRUEX D Canyon Space Allocation.

Figure E4. Tertiary Waste Generation by Process.

Figure E5. Tertiary Waste Stream Mass Flows.

Table E1. Aggregated Rates and Inventories for U.S. Department of Energy Sites (Projected for 1992 as of August 29, 1991).

	HANFORD	INEL	ROCKY F	SAV RIV	WVDP
HLW Liquid, m ³ /yr	464	2500	0	8539	0
Inventory, m ³	45190	11000	0	131853	5360
Secondary Aqueous, m ³ /yr	-----	2243	3	4285	2
Inventory, m ³	-----	-----	-----	-----	2
TRU Inv, m ³	-----	538	-----	210	-----
Combustibles, m ³ /yr	464	-----	-----	-----	-----
TRU, m ³ /yr	-----	-----	50	-----	2
Inventory, m ³	100	30287	-----	7122	4
TRU Inv, m ³	0.13	-----	-----	-----	-----
Mixed Comb.& Nonc, m ³ /yr	-----	-----	-----	28764	-----
Inventory, m ³	-----	-----	-----	-----	-----
TRU Inv, m ³	-----	-----	-----	435	-----
Noncombustibles, m ³ /yr	325	2985	753	3450	-----
TRU, m ³ /yr	-----	-----	17	-----	-----
Inventory, m ³	607	30196	8000	12600	8
TRU Inv, m ³	14	24095	-----	-----	-----
Filters, m ³ /yr	-----	4	70	11	-----
Inventory, m ³	-----	2089	64	40	-----
Tru Inventory, m ³	-----	328	49	-----	-----

Table E2. Savannah River Waste Management Information System
Waste Stream Data (Operation During 1987 through 1991).

	<u>Low Level Job Control Waste</u>	<u>Low Level Compactor Waste</u>	<u>TRU Waste</u>
1987			
F Separations	285,300		
H Separations	124,200		
1988			
F Separations	322,700		
H Separations	134,300		
1989			
F Separations	237,400		12,200
H Separations	161,400		1,200
1990			
F Separations	208,900	26,100	5,950
H Separations	159,100	8,060	920
1991			
F Separations	124,500	31,860	5,211
H Separations	107,300	17,900	610
1992 (up to 4/92)			
F Separations	20,100	13,300	29
H Separations	21,400	5,950	1,323

NOTES:

All values are in cubic feet per year.
TRU values for 1989 are estimates.

Table E3. Savannah River Waste Management Information System List of 98 Waste Streams
(Projected for 1992 as of August 29, 1991). (sheet 1 of 3)

A=AQUEOUS C=COMBUSTIBLE F=FILTERS M=MIXED COMBUSTIBLE-NONCOMBUSTIBLE N=NONCOMBUSTIBLE SOLIDS
O=OTHER UNRELATED ACTIVITIES T=FROM TANK FARM OPERATIONS W=FROM WASTE TREATMENT

SITE WMIS WASTE STREAM NAME					M ³ /YR	M3 INV	REMARKS
HLW	RH	A	SAVR	221-F CANYON HIGH LEVEL LIQUID WASTE	1700.0000	54719.0000	INV IS F-AREA HLW TANK 27 ONLY
HLW	RH	A	SAVR	221-H CANYON HIGH LEVEL LIQUID WASTE	4000.0000	64825.0000	INV IS H-AREA HLW TANK FARM ONLY
HLW	RH	A	SAVR	244-H RBOF HIGH ACTIVITY LIQUID WASTE	2838.7500	12319.0000	INV IS H-AREA HLW TANK 21 ONLY
LLW	CH	A	SAVR	SCINTILLATION SOLUTION	1.5000		MIXED FISSION PRODUCT VALUES
LLW	CH	A	SAVR	SRL HIGH ACTIVITY WASTE	200.0000	71.1000	ANALYZED
LLW	CH	A	SAVR	SRL LOW ACTIVITY WASTE	970.0000		ANALYZED
LLW	CH	C	SAVR	SOLVENT CONTAMINATED APPLICATORS (LLW)	0.1000		MIXED FISSION PRODUCT VALUES
TRU	CH	C	SAVR	SOLVENT TRU WASTE		3853.0000	ISOTOPES IDENTIFIED
LLW	CH	C	SAVR	SOLVENT WASTE <100 NCI/G TRU RAD	0.2000	3269.0000	ISOTOPES IDENTIFIED
LLW	CH	C	SAVR	TOXIC CLEANUP MATERIAL	8.5000		CHEMICAL COMPOSITION
LLW	CH	F	SAVR	CADMIUM - COATED HEPA FILTERS	0.7100	38.7000	9908.0000 KG
LLW	RH	F	SAVR	ITP FILTERS	85.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	M	SAVR	COMPACTIBLE WASTE - 772F	3400.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	M	SAVR	COMPACTIBLE WASTE - F AREA SEPARATIONS	312.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	M	SAVR	COMPACTIBLE WASTE - H AREA SEPARATIONS	45.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	M	SAVR	COMPACTIBLE WASTE -SRL	21.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	M	SAVR	FACILITIES AND SERVICES LLW SOLID WASTE	61.0000		MIXED FISSION PRODUCT VALUES
LLW	RH	M	SAVR	INTERMEDIATE LEVEL JOB CONTROL - SRL	9268.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	M	SAVR	JOB CONTROL WASTE - F AREA SEPARATIONS	2280.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	M	SAVR	JOB CONTROL WASTE -H AREA SEPARATIONS	1800.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	M	SAVR	JOB CONTROL/LAB WASTE -772F	540.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	M	SAVR	JOB CONTROL/LAB WASTE - SRL	200.0000		PU COMPOSITION VALUES
TRU	CH	M	SAVR	PU239 JOB CONTROL WASTE -221F/F-B LINE	12.5000		PU COMPOSITION VALUES
TRU	CH	M	SAVR	PU239 LAB WASTE - 772-F/772-1F	198.0000		PU COMPOSITION VALUES
TRU	CH	M	SAVR	PU239 LAB WASTE - SRL	24.5000		ISOTOPES IDENTIFIED
TRU	CH	M	SAVR	THIRDS TRU WASTE	8.1000		ISOTOPES IDENTIFIED
LLW	CH	M	SAVR	THIRDS WASTE <100 NCI/GM TRU RAD	623.0000		PLUTONIUM COMPOSITION
TRU	CH	M	SAVR	TRU D & R WASTE - OLD H-B LINE	31.0000		MIXED FISSION PRODUCT VALUES
LLW	RH	N	SAVR	CONTAMINATED EQUIPMENT - F CANYON	91.0000		MIXED FISSION PRODUCT VALUES
LLW	RH	N	SAVR	CONTAMINATED EQUIPMENT - H CANYON	127.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	N	SAVR	F/H RETENTION BASIN SEDIMENT	6.0000	202.0000	12470 KG/YR
LLW	RH	N	SAVR	LLW LEAD	40.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	N	SAVR	SALVAGE PARTS - FAC & SERVICES	1.0000		CHEMICAL COMPOSITION
LLW	RH	N	SAVR	SILVER COATED PACKING MATERIAL	<0.0200		AM241
TRU	CH	N	SAVR	SMOKE DETECTORS	<0.0200		COBALT-57
LLW	CH	N	SAVR	SOURCES - C057	<0.0200		
LLW	CH	N	SAVR	SOURCES - CS-137	<0.0200		
LLW	CH	N	SAVR	SOURCES - PU239	<0.0200		
TRU	CH	N	SAVR	SOURCES - U235	2.0000	16.0000	ISOTOPES IDENTIFIED
LLW	CH	N	SAVR	WASTE SITES/SPILL SITE SOIL	1360.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	T	SAVR	COMPACTIBLE WASTE -F AREA TANK FARM	1564.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	T	SAVR	COMPACTIBLE WASTE -H AREA TANK FARM	29.0000		MIXED FISSION PRODUCT VALUES
LLW	RH	T	SAVR	CONTAMINATED EQUIPMENT - F TANK FARM	368.0000		MIXED FISSION PRODUCT VALUES
LLW	RH	T	SAVR	CONTAMINATED EQUIPMENT - H TANK FARM			

Table E3. Savannah River Waste Management Information System List of 98 Waste Streams
(Projected for 1992 as of August 29, 1991). (sheet 2 of 3)

A=AQUEOUS C=COMBUSTIBLE F=FILTERS M=MIXED COMBUSTIBLE-NONCOMBUSTIBLE N=NONCOMBUSTIBLE SOLIDS
O=OTHER UNRELATED ACTIVITIES T=FROM TANK FARM OPERATIONS W=FROM WASTE TREATMENT

SITE	WMIS	WASTE STREAM NAME	M ³ /YR	M3 INV	REMARKS
LLW	CH	T SAVR JOB CONTROL WASTE - F AREA TANK FARM	885.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	T SAVR JOB CONTROL WASTE - H AREA TANK FARM	3185.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	T SAVR POISONED CATALYST MATERIAL	0.0111		
LLW	CH	W SAVR COMPACTED WASTE - 253 H	970.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	W SAVR COMPACTIBLE WASTE - ETF	221.0000		
LLW	CH	W SAVR COMPACTIBLE WASTE - SWDF	120.0000		
LLW	CH	W SAVR COMPACTIBLE WASTE - Z AREA	75.0000		
LLW	CH	W SAVR DMPF BENZENE			IN 150000 GAL DMPF ORGANIC WASTE STORAGE TANK
LLW	CH	W SAVR JOB CONTROL WASTE - ETF	189.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	W SAVR JOB CONTROL WASTE - SWDF	397.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	W SAVR JOB CONTROL WASTE - Z AREA	34.0000		MIXED FISSION PRODUCT VALUES
TRU	CH	W SAVR MIXED TTA/XYLENE		0.0100	
LLW	CH	W SAVR SALTSTONE	2500.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	O SAVR COMPACTED WASTE - 313 M	140.0000		
LLW	CH	O SAVR COMPACTIBLE WASTE - 300 AREA	561.0000		
LLW	CH	O SAVR COMPACTIBLE WASTE - REACTORS	969.0000		
LLW	CH	O SAVR COMPACTIBLE WASTE - TRITIUM	408.0000		
TRU	RH	O SAVR CONTAMINATED FILTERS - REACTORS	2.0000		
LLW	CH	O SAVR DEPLETED URANIUM - UO3			40000 DRUMS
LLW	CH	O SAVR FILTER PAPER TAKEUP ROLLS	30.0000		8000 KG/YR CHEMICAL COMPOSITION
LLW	CH	O SAVR FMF SALTCRETE		92400	GAL MIXED FISSION PRODUCT VALUES
LLW	CH	O SAVR GOLD TRAPS	1.8500		MIXED WASTE
LLW	CH	O SAVR JOB CONTROL WASTE - 400 D	30.0000		
LLW	CH	O SAVR JOB CONTROL WASTE - NAVAL FUELS	136.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	O SAVR JOB CONTROL WASTE - REACTORS	2158.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	O SAVR JOB CONTROL WASTE - TRITIUM	1224.0000		MIXED FISSION PRODUCT VALUES
LLW	CH	O SAVR JOB CONTROL/PROCESS WASTE - RMP(300)AREA	356.0000		CONTAINS DEPLETED U
LLW	CH	O SAVR LAB WASTE - 7720	25.0000		H-3 SUSPECT
LLW	CH	O SAVR M-AREA PLATING LINE WASTE SLURRY (TANK7		1784.0000	
LLW	CH	O SAVR M-AREA SLUDGE TREATABILITY SAMPLES-F006	0.2000		
LLW	CH	O SAVR MARK 15 FILTER PAPER -F006		0.8000	
LLW	CH	O SAVR MARK 15 FILTERCAKE -F006		15.4000	
LLW	CH	O SAVR MERCURY CONTAMINATED EQUIPMENT	3.8500		18.7000
LLW	CH	O SAVR MERCURY CONTAMINATED HEAVY WATER			8.9500
LLW	CH	O SAVR PLATING LINE SLURRY	189.0000		2884.0000
LLW	CH	O SAVR PLATING LINE SUMP MATERIAL			0.4200
LLW	CH	O SAVR PROCESS BEDS - TRITIUM	1.0000		
TRU	CH	O SAVR PU238 JOB CONTROL WASTE -221H/H B LINE	8.4000		PU COMPOSITION VALUES
TRU	CH	O SAVR PU238 JOB CONTROL WASTE -235F	4.1000		PU COMPOSITION VALUES
TRU	CH	O SAVR PU238 LAB WASTE - 772F/1F	0.4000		PU COMPOSITION VALUES
TRU	CH	O SAVR PU238 LAB WASTE - SRL	0.2000		PU COMPOSITION VALUES
LLW	CH	O SAVR RADIOACTIVE FREON-113	0.6000		TRITIUM CONCENTRATION
LLW	CH	O SAVR RADIOACTIVE TRICHLOROETHANE	0.0200		TRITIUM CONCENTRATION
LLW	CH	O SAVR REACTOR AREAS - CONTAMINATED SOILS	119.0000		MIXED FISSION PRODUCT VALUES

Table E3. Savannah River Waste Management Information System List of 98 Waste Streams
(Projected for 1992 as of August 29, 1991). (sheet 3 of 3)

A=AQUEOUS C=COMBUSTIBLE F=FILTERS M=MIXED COMBUSTIBLE-NONCOMBUSTIBLE N=NONCOMBUSTIBLE SOLIDS
O=OTHER UNRELATED ACTIVITIES T=FROM TANK FARM OPERATIONS W=FROM WASTE TREATMENT

SITE	WMIS WASTE STREAM NAME	M ³ /YR	MS INV	REMARKS
LLW RH O	SAVR REACTOR HARDWARE/IRRADIATED EQUIPMENT	130.0000		MIXED FISSION PRODUCT VALUES
LLW RH O	SAVR SAFETY/CONTROL RODS	0.0200		SOME INVENTORIES
LLW CH O	SAVR SCRAP NAVAL FUEL DRUMS			10,000 DRUMS/YR FILLED WITH GROUT
LLW CH O	SAVR SPENT CARBON FILTERS - REACTOR AREAS	70.0000		MIXED FISSION PRODUCT VALUES
LLW CH O	SAVR SPENT DEIONIZER RESINS		0.8400	MIXED FISSION PRODUCT VALUES
LLW CH O	SAVR SPENT FILTER CARTRIDGES	35.0000		TRITIUM & CO-60
LLW CH O	SAVR SPENT LI-AL MELTS		0.1400	ANALYZED
LLW CH O	SAVR SPENT METHANOL SOLUTION		0.1820	
LLW CH O	SAVR TRITIATED MERCURY		0.0160	
LLW CH O	SAVR URANIUM AND CHROMIUM IN SOLUTION			

Table E4. Equipment Ratios for Processes Involved in Tertiary Waste Generation.

Process type	Equipment ratio
Overhead Processes	
Facility support	0.16
Rerun and frame waste	0.12
Solvent recovery	0.12
Subtotal	0.40
Waste Processes	
Dissolvers	0.04
First cycle solvent extraction	0.08
Third cycle solvent extraction	0.36
Subtotal	0.48
High-Activity Waste and Head End	0.12
Total F or H canyon	1.00

Table E5. Ratios of Tertiary Wastes to Primary Liquid High-Level Waste
(Revised to Savannah River Site 1987 through 1991 Basis).

STREAM	MASS RATIO	DENSITY kg/m ³	MASS RATIO/ SE CYCLE
TREAT NONCOMBUSTIBLE SOLIDS (TRTSSOL)			
NCBUSTS	1.0942	2.00E+3	0.12
VNCBUSTS	0.0257*	2.00E+3	0.0029
S1CM	1.1199	1.00E+3	0.12
INCINERATE COMBUSTIBLE SOLIDS AND LIQUIDS (INCIN)			
CBUSTSL	0.5471	1.00E+3	0.061
VCBUSTSL	0.0129*	1.00E+3	0.0014
S2CM	0.0000	1.00E+3	0.0
ION EXCHANGE AND EVAPORATE TERTIARY AQUEOUS WASTES (EVAPIX)			
AQUELLW	1.2801	1.00E+3	0.14
VAQUELLW	0.0299*	1.00E+3	0.0033
S3CM	0.1310	1.00E+3	0.015
TREAT CELL AIR AND OFFGAS WITH HEPA FILTERS (OGASTRT)			
OFFGAS	0.0009	1.00E+0	0.0001
VOFFGAS	0.0001*	1.00E+0	0.00001
S4CM	0.0000	1.00E+3	0.0

* Assumed zero but included in design stream

Table E6. Solvent Extraction Equivalent Assignments.

Main CLEAN Option Processes			Main TRUEX-C/SLUDGE WASH C Processes		
Main Process		Equivalents	Main Process		Equivalents
1.) SEPSOLIQ		0.5 DISS	1.) WASHSLUD		0.5 DISS
2.) DESTORG		0.5 DISS	2.) DESTORG		0.5 DISS
3.) CAUSLEAC		1.0 DISS	3.) FILTABS		0.5 SE
4.) CSIX		1.0 SE	4.) CSIX		1.0 SE
5.) SRIX		1.0 SE	5.) TCIX1		1.0 SE
6.) TCIX		1.0 SE	6.) DISSOLVA		1.0 DISS
7.) DISOLVA		1.0 DISS	7.) TRUEX		1.0 SE
8.) DISOLVF		1.0 DISS	8.) SREX		1.0 SE
9.) EXTRUPU		1.0 SE	9.) UTCSTRIP		0.5 SE
10.) PURIFYU		1.0 SE	10.) TCIX2		1.0 SE
11.) EXTRAMLN		1.0 SE	11.) PURIFYU		1.0 SE
12.) AMLANIX		1.0 SE	12.) NEUTDCAN		0.5 DISS
13.) SREX		1.0 SE	13.) NEUTRAL		0.5 DISS
14.) SRBAIX		1.0 SE			
15.) APMCSIX*		0.5 SE			
16.) RCOVACID		1.0 DISS			
17.) DNITRL		1.0 DISS			
18.) CALCINE		1.0 DISS			
19.) REMCR		1.0 DISS			
20.) EVAPORH		0.5 DISS			
21.) DNITRH		1.0 DISS			
TOTALS		9.5 DISS (2.38 SE)			3.0 DISS (0.75 SE)
		9.5 SE			7.0 SE

Equivalent Waste from DISSOLVER (DISS) = 0.25 SOLVENT EXTRACTION (SE)

* The APM is not eluted but is redissolved in an existing dissolver CAUSLEAC.

Table E7. Tertiary Waste Generation Data for Model CLEANG31.

TOTAL MASS FLOWS (KG):													
PROCESS	NCBUSTS	VNCBUSTS	S1CM	CBUSTSL	VCBUSTSL	S2CM	AQUELLW	VAQUELLW	S3CM	OFFGAS	VOFFGAS	S4CM	TOTALS
SEPSOLIQ	1.20E+07	2.70E+05	1.20E+07	5.80E+06	1.40E+05	0.00E+00	1.30E+07	3.10E+05	1.40E+06	9.50E+03	1.10E+03	0.00E+00	4.49E+07
DESTORG	1.20E+07	2.80E+05	1.20E+07	6.10E+06	1.40E+05	0.00E+00	1.40E+07	3.30E+05	1.40E+06	1.00E+04	1.10E+03	0.00E+00	4.63E+07
CAUSLEAC	7.50E+06	1.80E+05	7.70E+06	3.70E+06	8.80E+04	0.00E+00	8.80E+06	2.00E+05	9.00E+05	6.20E+03	6.90E+02	0.00E+00	2.91E+07
CSIX	1.40E+08	3.20E+06	1.40E+08	6.80E+07	1.60E+06	0.00E+00	1.60E+08	3.70E+06	1.60E+07	1.10E+05	1.20E+04	0.00E+00	5.33E+08
SRIX	1.40E+08	3.20E+06	1.40E+08	6.90E+07	1.60E+06	0.00E+00	1.60E+08	3.80E+06	1.60E+07	1.10E+05	1.30E+04	0.00E+00	5.34E+08
TCIX	1.40E+08	3.30E+06	1.40E+08	6.90E+07	1.60E+06	0.00E+00	1.60E+08	3.80E+06	1.70E+07	1.10E+05	1.30E+04	0.00E+00	5.35E+08
DISOLVA	1.90E+06	4.50E+04	2.00E+06	9.60E+05	2.30E+04	0.00E+00	2.20E+06	5.20E+04	2.30E+05	1.60E+03	1.70E+02	0.00E+00	7.41E+06
DISOLVF	4.60E+05	1.10E+04	4.80E+05	2.30E+05	5.50E+03	0.00E+00	5.40E+05	1.30E+04	5.60E+04	3.80E+02	4.20E+01	0.00E+00	1.80E+06
EXTRURU	3.90E+07	9.10E+05	3.90E+07	1.90E+07	4.50E+05	0.00E+00	4.50E+07	1.10E+06	4.60E+06	3.20E+04	3.50E+03	0.00E+00	1.49E+08
PURIFYU	9.20E+06	2.20E+05	9.40E+06	4.60E+06	1.10E+05	0.00E+00	1.10E+07	2.50E+05	1.10E+06	7.50E+03	8.40E+02	0.00E+00	3.59E+07
EXTRAMUN	4.00E+07	9.40E+05	4.10E+07	2.00E+07	4.70E+05	0.00E+00	4.70E+07	1.10E+06	4.80E+06	3.30E+04	3.60E+03	0.00E+00	1.55E+08
AMLANIX	2.50E+07	5.90E+05	2.60E+07	1.30E+07	3.00E+05	0.00E+00	3.00E+07	6.90E+05	3.00E+06	2.10E+04	2.30E+03	0.00E+00	9.86E+07
SREX	4.50E+07	1.00E+06	4.60E+07	2.20E+07	5.30E+05	0.00E+00	5.20E+07	1.20E+06	5.30E+06	3.70E+04	4.10E+03	0.00E+00	1.73E+08
SRBAIX	7.40E+07	1.70E+06	7.60E+07	3.70E+07	8.70E+05	0.00E+00	8.70E+07	2.00E+06	8.90E+06	6.10E+04	6.80E+03	0.00E+00	2.88E+08
APMCSIX	3.10E+07	7.30E+05	3.20E+07	1.60E+07	3.70E+05	0.00E+00	3.60E+07	8.50E+05	3.70E+06	2.60E+04	2.80E+03	0.00E+00	1.21E+08
RCOVACID	2.30E+07	5.40E+05	2.40E+07	1.20E+07	2.70E+05	0.00E+00	2.70E+07	6.30E+05	2.80E+06	1.90E+04	2.10E+03	0.00E+00	9.03E+07
DNITRL	2.20E+07	5.20E+05	2.20E+07	1.10E+07	2.60E+05	0.00E+00	2.60E+07	6.00E+05	2.80E+06	1.80E+04	2.00E+03	0.00E+00	8.50E+07
CALCINE	7.70E+07	1.80E+06	7.80E+07	3.80E+07	9.00E+05	0.00E+00	9.00E+07	2.10E+06	9.20E+06	6.30E+04	7.00E+03	0.00E+00	2.97E+08
REMOR	2.30E+07	5.40E+05	2.30E+07	1.10E+07	2.70E+05	0.00E+00	2.70E+07	6.20E+05	2.70E+06	1.90E+04	2.10E+03	0.00E+00	8.82E+07
EVAPORH	1.10E+07	2.60E+05	1.10E+07	5.60E+06	1.30E+05	0.00E+00	1.30E+07	3.10E+05	1.30E+06	9.20E+03	1.00E+03	0.00E+00	4.26E+07
DNITRH	6.70E+05	1.60E+04	6.90E+05	3.40E+05	7.90E+03	0.00E+00	7.90E+05	1.80E+04	8.10E+04	5.50E+02	6.20E+01	0.00E+00	2.61E+06

PROCESS BLOCK INPUT
STREAM FLOWS (KG)

PROCESS	MASS FLOW
SEPSOLIQ	7.57E+08
DESTORG	7.97E+08
CAUSLEAC	2.47E+08
CSIX	1.12E+09
SRIX	1.13E+09
TCIX	1.14E+09
DISOLVA	8.30E+07
DISOLVF	1.53E+07
EXTRURU	3.17E+08
PURIFYU	7.53E+07
EXTRAMUN	3.28E+08
AMLANIX	2.08E+08
SREX	3.67E+08
SRBAIX	6.09E+08
APMCSIX	5.12E+08
RCOVACID	7.82E+08
DNITRL	7.22E+08
CALCINE	2.52E+09
REMOR	7.52E+08
EVAPORH	7.35E+08
DNITRH	2.22E+07

PROCESS BLOCK TERTIARY
STREAM FLOWS (KG)

PROCESS	MASS FLOW
SEPSOLIQ	4.49E+07
DESTORG	4.63E+07
CAUSLEAC	2.91E+07
CSIX	5.33E+08
SRIX	5.34E+08
TCIX	5.35E+08
DISOLVA	7.41E+06
DISOLVF	1.80E+06
EXTRURU	1.49E+08
PURIFYU	3.59E+07
EXTRAMUN	1.55E+08
AMLANIX	9.86E+07
SREX	1.73E+08
SRBAIX	2.88E+08
APMCSIX	1.21E+08
RCOVACID	9.03E+07
DNITRL	8.50E+07
CALCINE	2.97E+08
REMOR	8.82E+07
EVAPORH	4.26E+07
DNITRH	2.61E+06

TOTAL MASS FLOWS (KG) FOR
TERTIARY WASTE STREAMS

STREAM	MASS FLOW
NCBUSTS	8.86E+08
VNCBUSTS	0.00E+00
S1CM	8.86E+08
CBUSTSL	4.33E+08
VCBUSTSL	0.00E+00
S2CM	0.00E+00
AQUELLW	1.01E+09
VAQUELLW	0.00E+00
S3CM	1.04E+08
OFFGAS	7.12E+05
VOFFGAS	0.00E+00
S4CM	0.00E+00

Table E8. Tertiary Waste Generation Data for Model TRUG31.

TOTAL MASS FLOWS (KG):													
PROCESS	NCBUSTS	VNCBUSTS	S1CM	CBUSTSL	VCBUSTSL	S2CM	AQUELLW	VAQUELLW	S3CM	OFFGAS	VOFFGAS	S4CM	TOTALS
WASHSLUD	1.20E+07	2.70E+05	1.20E+07	5.80E+06	1.40E+05	0.00E+00	1.30E+07	3.10E+05	1.40E+06	9.50E+03	1.10E+03	0.00E+00	4.49E+07
DESTORG	1.20E+07	2.80E+05	1.20E+07	6.10E+06	1.40E+05	0.00E+00	1.40E+07	3.30E+05	1.50E+06	1.00E+04	1.10E+03	0.00E+00	4.64E+07
FILTADBS	4.90E+07	1.10E+06	5.00E+07	2.40E+07	5.80E+05	0.00E+00	5.70E+07	1.30E+06	5.90E+06	4.00E+04	4.50E+03	0.00E+00	1.89E+08
CSIX	1.20E+08	2.90E+06	1.30E+08	6.20E+07	1.50E+06	0.00E+00	1.50E+08	3.40E+06	1.50E+07	1.00E+05	1.10E+04	0.00E+00	4.85E+08
TCIX1	2.30E+08	5.50E+06	2.40E+08	1.20E+08	2.80E+06	0.00E+00	2.70E+08	6.40E+06	2.80E+07	1.90E+05	2.10E+04	0.00E+00	9.03E+08
DISSOLVA	2.60E+06	6.10E+04	2.70E+06	1.30E+06	3.10E+04	0.00E+00	3.00E+06	7.10E+04	3.10E+05	2.10E+03	2.40E+02	0.00E+00	1.01E+07
TRUEX	6.10E+07	1.40E+06	6.20E+07	3.00E+07	7.20E+05	0.00E+00	7.10E+07	1.70E+06	7.30E+06	5.00E+04	5.60E+03	0.00E+00	2.35E+08
SREX	3.00E+07	7.10E+05	3.10E+07	1.50E+07	3.60E+05	0.00E+00	3.60E+07	8.30E+05	3.60E+06	2.50E+04	2.80E+03	0.00E+00	1.18E+08
UTCSTRIP	1.90E+07	4.40E+05	1.90E+07	9.30E+06	2.20E+05	0.00E+00	2.20E+07	5.10E+05	2.20E+06	1.50E+04	1.70E+03	0.00E+00	7.27E+07
TCIX2	6.50E+06	2.00E+05	6.70E+06	4.20E+06	1.00E+05	0.00E+00	9.90E+06	2.30E+05	1.00E+06	7.00E+03	7.70E+02	0.00E+00	3.28E+07
PURIFYU	1.30E+07	3.10E+05	1.30E+07	6.50E+06	1.50E+05	0.00E+00	1.50E+07	3.60E+05	1.60E+06	1.10E+04	1.20E+03	0.00E+00	4.99E+07
NEUTDCAN	1.10E+06	2.60E+04	1.20E+06	5.60E+05	1.30E+04	0.00E+00	1.30E+06	3.10E+04	1.30E+05	9.30E+02	1.00E+02	0.00E+00	4.36E+06
NEUTRAL	1.90E+04	4.40E+02	1.90E+04	9.40E+03	2.20E+02	0.00E+00	2.20E+04	5.10E+02	2.30E+03	1.50E+01	1.70E+00	0.00E+00	7.29E+04

PROCESS BLOCK INPUT
STREAM FLOWS (KG)

PROCESS	MASS FLOW
WASHSLUD	7.57E+08
DESTORG	7.98E+08
FILTADBS	8.05E+08
CSIX	1.02E+09
TCIX1	1.93E+09
DISSOLVA	8.55E+07
TRUEX	5.01E+08
SREX	2.50E+08
UTCSTRIP	3.05E+08
TCIX2	6.96E+07
PURIFYU	1.07E+08
NEUTDCAN	7.40E+07
NEUTRAL	1.24E+06

PROCESS BLOCK TERTIARY
STREAM FLOWS (KG)

PROCESS	MASS FLOW
WASHSLUD	4.49E+07
DESTORG	4.64E+07
FILTADBS	1.89E+08
CSIX	4.85E+08
TCIX1	9.03E+08
DISSOLVA	1.01E+07
TRUEX	2.35E+08
SREX	1.18E+08
UTCSTRIP	7.27E+07
TCIX2	3.28E+07
PURIFYU	4.99E+07
NEUTDCAN	4.36E+06
NEUTRAL	7.29E+04

TOTAL MASS FLOWS (KG) FOR
TERTIARY WASTE STREAMS

STREAM	MASS FLOW
NCBUSTS	5.66E+08
VNCBUSTS	0.00E+00
S1CM	5.80E+08
CBUSTSL	2.83E+08
VCBUSTSL	0.00E+00
S2CM	0.00E+00
AQUELLW	6.63E+08
VAQUELLW	0.00E+00
S3CM	6.78E+07
OFFGAS	4.66E+05
VOFFGAS	0.00E+00
S4CM	0.00E+00

Table E9. Tertiary Waste Generation Data for Model SLUG31.

PROCESS	TOTAL MASS FLOWS (KG):												TOTALS
	NCBUSTS	VNCBUSTS	S1CM	CBUSTSL	VCBUSTSL	S2CM	AQUELLW	VAQUELLW	S3CM	OFFGAS	VOFFGAS	S4CM	
WASHSLUD	1.20E+07	2.70E+05	1.20E+07	5.80E+06	1.40E+05	0.00E+00	1.30E+07	3.10E+05	1.40E+06	9.50E+03	1.10E+03	0.00E+00	4.49E+07
DESTORG	1.20E+07	2.80E+05	1.20E+07	6.10E+06	1.40E+05	0.00E+00	1.40E+07	3.30E+05	1.50E+06	1.00E+04	1.10E+03	0.00E+00	4.64E+07
FILTADBS	4.90E+07	1.10E+06	5.00E+07	2.40E+07	5.80E+05	0.00E+00	5.70E+07	1.30E+06	5.90E+06	4.00E+04	4.50E+03	0.00E+00	1.89E+08
CSIX	9.80E+07	2.30E+06	1.00E+08	4.90E+07	1.20E+06	0.00E+00	1.10E+08	2.70E+06	1.20E+07	8.00E+04	8.90E+03	0.00E+00	3.75E+08
TCIX1	1.80E+08	4.30E+06	1.90E+08	9.10E+07	2.20E+06	0.00E+00	2.10E+08	5.00E+06	2.20E+07	1.50E+05	1.70E+04	0.00E+00	7.05E+08
DISSOLVA	3.00E-07	7.00E-09	3.00E-07	1.50E-07	3.50E-09	0.00E+00	3.50E-07	8.10E-09	3.50E-08	2.40E-10	2.70E-11	0.00E+00	1.15E-06
TRUEX	1.20E-06	2.70E-08	1.20E-06	5.80E-07	1.40E-08	0.00E+00	1.40E-06	3.20E-08	1.40E-07	9.50E-10	1.10E-10	0.00E+00	4.59E-06
SREX	2.50E-07	5.90E-09	2.50E-07	1.20E-07	2.90E-09	0.00E+00	2.90E-07	6.80E-09	3.00E-08	2.00E-10	2.30E-11	0.00E+00	9.56E-07
UTCSTRIP	1.50E-07	3.60E-09	1.60E-07	7.60E-08	1.80E-09	0.00E+00	1.80E-07	4.10E-09	1.80E-08	4.70E-11	5.20E-12	0.00E+00	2.19E-07
TCIX2	5.70E-08	1.30E-09	5.80E-08	2.80E-08	6.70E-10	0.00E+00	6.60E-08	1.60E-09	4.70E-09	3.20E-11	3.60E-12	0.00E+00	1.52E-07
PURIFYU	3.90E-08	9.20E-10	4.00E-08	2.00E-08	4.60E-10	0.00E+00	4.60E-08	1.10E-09	4.00E-09	2.70E+03	3.00E+02	0.00E+00	1.29E+07
NEUTDCAN	3.30E+06	7.80E+04	3.40E+06	1.70E+06	3.90E+04	0.00E+00	3.90E+06	9.10E+04	4.00E+05	1.20E+01	1.30E+00	0.00E+00	5.69E+04
NEUTRAL	1.50E+04	3.40E+02	1.50E+04	7.30E+03	1.70E+02	0.00E+00	1.70E+04	4.00E+02	1.70E+03				

PROCESS BLOCK INPUT
STREAM FLOWS (KG)

PROCESS MASS FLOW

WASHSLUD	7.57E+08
DESTORG	7.96E+08
FILTADBS	8.04E+08
CSIX	8.04E+08
TCIX1	1.50E+09
DISSOLVA	9.75E-06
TRUEX	9.53E-06
SREX	2.05E-06
UTCSTRIP	2.49E-06
TCIX2	4.67E-07
PURIFYU	3.24E-07
NEUTDCAN	2.18E+08
NEUTRAL	9.59E+05

PROCESS BLOCK TERTIARY
STREAM FLOWS (KG)

PROCESS MASS FLOW

WASHSLUD	4.49E+07
DESTORG	4.64E+07
FILTADBS	1.89E+08
CSIX	3.75E+08
TCIX1	7.05E+08
DISSOLVA	1.15E-06
TRUEX	4.59E-06
SREX	9.56E-07
UTCSTRIP	5.94E-07
TCIX2	2.19E-07
PURIFYU	1.52E-07
NEUTDCAN	1.29E+07
NEUTRAL	5.69E+04

TOTAL MASS FLOWS (KG) FOR
TERTIARY WASTE STREAMS

STREAM MASS FLOW

NCBUSTS	3.56E+08
VNCBUSTS	0.00E+00
S1CM	3.65E+08
CBUSTSL	1.78E+08
VCBUSTSL	0.00E+00
S2CM	0.00E+00
AQUELLW	4.17E+08
VAQUELLW	0.00E+00
S3CM	4.26E+07
OFFGAS	2.93E+05
VOFFGAS	0.00E+00
S4CM	0.00E+00

Table E10. Tertiary Waste Generation Data for Model CLEANG31
With Compact Processing Units.

TOTAL MASS FLOWS (KG):													
PROCESS	NCBUSTS	VNCBUSTS	S1CM	CBUSTSL	VCBUSTSL	S2CM	AQUELLW	VAQUELLW	S3CM	OFFGAS	VOFFGAS	S4CM	TOTALS
SEPSOLID	3.20E+08	7.80E+04	3.30E+08	1.60E+06	3.80E+04	0.00E+00	3.80E+08	8.90E+04	3.90E+05	2.70E+03	3.00E+02	0.00E+00	1.25E+07
DESTORG	4.50E+06	1.10E+05	4.60E+06	2.30E+06	5.40E+04	0.00E+00	5.30E+06	1.20E+05	5.40E+05	3.70E+03	4.20E+02	0.00E+00	1.75E+07
CAUSLEAC	4.90E+08	1.10E+05	5.00E+08	2.40E+06	5.80E+04	0.00E+00	5.70E+06	1.30E+05	5.90E+05	4.00E+03	4.50E+02	0.00E+00	1.89E+07
CSIX	6.80E+07	1.80E+06	7.00E+07	3.40E+07	8.00E+05	0.00E+00	8.00E+07	1.90E+06	8.20E+06	5.60E+04	6.20E+03	0.00E+00	2.65E+08
SRIX	7.00E+07	1.80E+06	7.10E+07	3.50E+07	8.20E+05	0.00E+00	8.10E+07	1.90E+06	8.30E+06	5.70E+04	6.40E+03	0.00E+00	2.70E+08
TCIX	7.10E+07	1.70E+06	7.30E+07	3.60E+07	8.40E+05	0.00E+00	8.30E+07	1.90E+06	8.50E+06	5.80E+04	6.50E+03	0.00E+00	2.76E+08
DISOLVA	1.40E+06	3.30E+04	1.40E+06	7.10E+05	1.70E+04	0.00E+00	1.70E+06	3.90E+04	1.70E+05	1.20E+03	3.90E+02	0.00E+00	5.47E+06
DISOLVF	4.40E+05	1.00E+04	4.50E+05	2.20E+05	5.20E+03	0.00E+00	5.10E+05	1.20E+04	5.30E+04	3.60E+02	4.00E+01	0.00E+00	1.70E+06
EXTRUPU	3.70E+07	8.60E+05	3.70E+07	1.80E+07	4.30E+05	0.00E+00	4.30E+07	1.00E+06	4.40E+06	3.00E+04	3.30E+03	0.00E+00	1.49E+08
PURIFYU	8.80E+06	2.10E+05	9.10E+06	4.40E+06	1.00E+05	0.00E+00	1.00E+07	2.40E+05	1.10E+06	7.30E+03	8.10E+02	0.00E+00	3.40E+07
EXTRAMUN	3.90E+07	9.00E+05	3.90E+07	1.90E+07	4.50E+05	0.00E+00	4.50E+07	1.10E+06	4.60E+06	3.20E+04	3.50E+03	0.00E+00	1.49E+08
AMLANIX	2.50E+07	5.80E+05	2.50E+07	1.20E+07	2.90E+05	0.00E+00	2.90E+07	6.80E+05	3.00E+06	2.00E+04	2.30E+03	0.00E+00	9.56E+07
SREX	4.50E+07	1.00E+06	4.50E+07	2.20E+07	5.20E+05	0.00E+00	5.10E+07	1.20E+06	5.30E+06	3.60E+04	4.00E+03	0.00E+00	1.70E+08
SRBAIX	7.40E+07	1.70E+06	7.50E+07	3.70E+07	8.70E+05	0.00E+00	8.60E+07	2.00E+06	8.80E+06	6.10E+04	6.70E+03	0.00E+00	2.85E+08
APMCSIX	3.10E+07	7.30E+05	3.20E+07	1.50E+07	3.60E+05	0.00E+00	3.60E+07	8.50E+05	3.70E+06	2.50E+04	2.80E+03	0.00E+00	1.20E+08
RCOVACID	2.30E+07	5.40E+05	2.30E+07	1.10E+07	2.70E+05	0.00E+00	2.70E+07	6.30E+05	2.70E+06	1.90E+04	2.10E+03	0.00E+00	8.82E+07
DNITRL	2.20E+07	5.10E+05	2.20E+07	1.10E+07	2.60E+05	0.00E+00	2.50E+07	5.90E+05	2.60E+06	1.80E+04	2.00E+03	0.00E+00	8.40E+07
CALCINE	6.00E+07	1.40E+06	6.10E+07	3.00E+07	7.00E+05	0.00E+00	7.00E+07	1.60E+06	7.10E+06	4.90E+04	5.50E+03	0.00E+00	2.32E+08
REMOR	1.80E+07	4.20E+05	1.80E+07	8.90E+06	2.10E+05	0.00E+00	2.10E+07	4.90E+05	2.10E+06	1.50E+04	1.60E+03	0.00E+00	6.91E+07
EVAPORH	1.10E+07	2.60E+05	1.10E+07	5.50E+06	1.30E+05	0.00E+00	1.30E+07	3.00E+05	1.30E+06	9.10E+03	1.00E+03	0.00E+00	4.25E+07
DNITRH	5.30E+05	1.20E+04	5.40E+05	2.70E+05	6.20E+03	0.00E+00	6.20E+05	1.40E+04	6.30E+04	4.40E+02	4.80E+01	0.00E+00	2.06E+06

PROCESS BLOCK INPUT
STREAM FLOWS (KG)

PROCESS	MASS FLOW
SEPSOLID	2.13E+08
DESTORG	2.99E+08
CAUSLEAC	1.61E+08
CSIX	5.61E+08
SRIX	5.73E+08
TCIX	5.84E+08
DISOLVA	4.66E+07
DISOLVF	1.44E+07
EXTRUPU	3.01E+08
PURIFYU	7.28E+07
EXTRAMUN	3.17E+08
AMLANIX	2.04E+08
SREX	3.61E+08
SRBAIX	6.08E+08
APMCSIX	5.09E+08
RCOVACID	7.54E+08
DNITRL	7.16E+08
CALCINE	1.96E+09
REMOR	5.86E+08
EVAPORH	7.30E+08
DNITRH	1.74E+07

PROCESS BLOCK TERTIARY
STREAM FLOWS (KG)

PROCESS	MASS FLOW
SEPSOLID	1.25E+07
DESTORG	1.75E+07
CAUSLEAC	1.89E+07
CSIX	2.65E+08
SRIX	2.70E+08
TCIX	2.76E+08
DISOLVA	5.47E+06
DISOLVF	1.70E+06
EXTRUPU	1.42E+08
PURIFYU	3.40E+07
EXTRAMUN	1.49E+08
AMLANIX	9.56E+07
SREX	1.70E+08
SRBAIX	2.85E+08
APMCSIX	1.20E+08
RCOVACID	8.82E+07
DNITRL	8.40E+07
CALCINE	2.32E+08
REMOR	6.91E+07
EVAPORH	4.25E+07
DNITRH	2.06E+06

TOTAL MASS FLOWS (KG) FOR
TERTIARY WASTE STREAMS

STREAM	MASS FLOW
NCBUSTS	8.15E+08
VNCBUSTS	0.00E+00
S1CM	6.29E+08
CBUSTSL	3.07E+08
VCBUSTSL	0.00E+00
S2CM	0.00E+00
AQUELLW	7.19E+08
VAQUELLW	0.00E+00
S3CM	7.36E+07
OFFGAS	5.05E+05
VOFFGAS	0.00E+00
S4CM	0.00E+00

APPENDIX G

GLASS COMPOSITION OPTIMIZATION

LIST OF TERMS

CLEAN31	CLEAN Option HLW stream
CLELLW	CLEAN Option LLW stream
CVS	Composition Variability Study
HLW	high-level waste
LLW	low-level waste
OTHHI	Other upper limit
SLUD31	Sludge Wash C HLW stream
SLULLW	Sludge Wash C LLW stream
TPA	Tri-Party Agreement
TRUEX	transuranic extraction
TRUEX-C	Transuranic Extraction Option C
TRULLW	TRUEX-C LLW stream
TRUX31	TRUEX-C HLW stream

GLASS COMPOSITION OPTIMIZATION

The nonlinear optimization methods used in determining the glass composition are described in this section. The discussion first considers a general nonlinear optimization problem and proceeds to describe the method of finding a global optimum to the problem. These nonlinear optimization methods are then applied to the optimal glass waste loading problem with development of a glass composition optimization model. This model was developed by Mark Hoza of Pacific Northwest Laboratory. He also provided the glass optimization calculations along with the model description text that follows. The final section describes the glass optimization results for the different process model runs.

G1.0 THE GENERAL CONSTRAINED OPTIMIZATION PROBLEM

This section describes a general optimization problem. In optimization problems, one wants to find the point x that produces the maximum (or minimum) value of some function and that meets a set of criteria called constraints. The problem would be stated as:

$$\begin{aligned}
 &\text{maximize} && f(x_1, x_2, \dots, x_n) \text{ (objective function)} \\
 &\text{subject to} && h_1(x_1, x_2, \dots, x_n) = 0 \text{ (equality constraints)} \\
 & && h_2(x_1, x_2, \dots, x_n) = 0 \\
 & && \vdots \\
 & && h_p(x_1, x_2, \dots, x_n) = 0 \\
 & && g_1(x_1, x_2, \dots, x_n) \leq 0 \text{ (inequality constraints)} \\
 & && g_2(x_1, x_2, \dots, x_n) \leq 0 \\
 & && \vdots \\
 & && g_q(x_1, x_2, \dots, x_n) \leq 0
 \end{aligned}$$

The objective function is a single (scalar) function of the unknown variables $(x_1, x_2, \dots, x_n)$, which one wants to maximize or minimize. Each of the equality and inequality constraints is also a function of the unknowns. In general, the objective function and any or all constraints may be nonlinear.

The above problem can be stated more compactly in vector notation, in which a vector is represented in bold type.

$$\begin{aligned}
 &\max && f(\mathbf{x}) \\
 &\text{subject to} && h(\mathbf{x}) = 0 \\
 & && g(\mathbf{x}) \leq 0
 \end{aligned}$$

62.0 UNDERSTANDING THE CONSTRAINED OPTIMIZATION PROBLEM

It is useful to visualize a few simple optimization problems. Consider first a simple unconstrained optimization problem, as represented by the surface in Figure G1. One can easily identify the minimum of that function. For an unconstrained problem, the gradient of the function at the optimum must equal zero. This indicates there is no direction one can go from the optimum to produce a better (lower) value.

The situation is analogous for constrained optimization. Figure G1 shows the same simple function but with two linear constraints, one an equality and the other an inequality. The minimum must lie on the function surface, within the equality constraint plane, and to the left of the inequality (vertical) plane. The feasible region is the arc resulting from the intersection of the equality plane and the function surface which lies to the left of the inequality constraint. The optimum is identified on the figure. For a constrained optimum, the Karush-Kuhn-Tucker conditions must be satisfied. These essentially state that the constraints must be satisfied and that the gradient of the Lagrangian (a function made up of the objective function and the constraints) be equal to zero. Much more detail can be found in any optimization book, such as *Optimization of Chemical Processes* (Edgar and Himmelblau 1988).

63.0 FINDING THE GLOBAL OPTIMUM

In any moderately complex system, there will likely be more than one point that satisfies the optimality conditions. These points are called local optima. Only one of them, however, is the true (global) optimum. The following discussion will try to provide an intuitive understanding of why this is so.

Consider a simple function of one variable as shown in Figure G1.

This function has two local minima, A and B. A is the global minimum. If the starting point for the calculation is C or D, the optimization will return B as the optimum. (At either of those points, the gradient points toward B.) If the starting point is either E or F, the correct global optimum is found.

This does not mean that the optimization algorithm does not work. An optimization algorithm can be proven to find the global optimum only for a convex function (which will, by definition, only have one optimum). Because many functions of interest are nonconvex, the best one can do directly is to find a local optimum. By providing a number of different starting points over a fairly wide range; however, one can select the best local optimum and be reasonably sure it is the global optimum.

64.0 THE OPTIMAL WASTE LOADING PROBLEM

This section discusses the simple waste loading problem around which most of the waste optimization calculations are based. In this problem, glass formers are added to a single waste composition, and the mass fraction of waste in the glass is maximized such that all the constraints are satisfied. The glass former composition is varied as part of the optimization. The general formulation of the problem is given below, while the objective function and the constraints are described in the following subsections. Specialized variations of this general problem are described later in this report.

For the single mixture or single tank case, the optimization problem can be generally stated as follows.

Single Mixture Waste Loading Optimization Problem:

min	<i>number of canisters</i>
or	
max	<i>waste loading per canister</i>
s.t.	<i>mass balance constraints</i> <i>single component constraints</i> <i>multiple component constraints</i> <i>critical solubility constraints</i> <i>glass property constraints</i>

The possible objective functions and each category of constraints will be discussed in turn in the next few sections.

64.1 OBJECTIVE FUNCTION

For the process model evaluations, it is desired to minimize the number of canisters of glass produced. The number of canisters can be expressed as total mass of waste oxides divided by the total mass of waste in the glass per canister. In the notation used throughout the optimal waste loading (OWL) models, our objective is to

$$\text{minimize} \quad \frac{\text{OxideMass}}{\text{TMWG}}$$

Because the numerator is constant for a given problem, one can equivalently maximize the amount of waste in each canister or the mass fraction of waste in each canister.

TMWG maximize

or

$$\frac{\text{TMWG}}{\text{MaxLogMass}}$$

For the single mixture calculations one can use the latter form for the objective function.

64.2 MASS BALANCE CONSTRAINTS

The mass balance constraints are equalities. A list was developed to include the mass balance constraints for the waste + glass formers = glass (i.e., no recycle) case. The extensions for the recycle case are straightforward.

Mass of glass in a canister = Total Mass of Waste in the Glass + Total Mass of Glass Formers in the Glass

$$\text{MaxLogMass} = \text{TMWG} + \text{TMFG}.$$

Define the mass fraction of each component in the glass (FG) in terms of its mass fractions in the waste (FW) and the glass formers (FF), and the masses of waste and glass formers in the glass

$$FG_i = \frac{FW_i \cdot \text{TMWG} + FF_i \cdot \text{TMFG}}{\text{MaxLogMass}}.$$

And finally, require that the mass fractions of all ten CVS components sum to one in the glass former stream and in the glass product.

$$\sum_{i=1}^{10} FF_i = 1.0$$

$$\sum_{i=1}^{10} FG_i = 1.0$$

64.3 SINGLE COMPONENT CONSTRAINTS

These constraints limit the range of the mass fraction values each component can have in the glass. They reflect the composition region over which the Composition Variability Study (CVS) was performed. The upper and lower limits used in the calculations are the bounds from phase 2a of CVS-II (Hrma and Piepel 1992). For each of the ten CVS components, these constraints would be expressed as:

$$FG_{i,LL} \leq FG_i \leq FG_{i,UL}$$

The limits for each component are given in Table G1.

64.4 MULTIPLE COMPONENT CONSTRAINTS

These constraints (also known as crystallinity constraints) limit the range of values some combination of components can have. The constraints and the names by which they will be referred are given below:

$$\frac{FG_{SiO_2}}{FG_{Al_2O_3}} \geq 3.0 \quad \text{Crystal1}$$

$$FG_{MgO} = FG_{CaO} \leq 0.08 \quad \text{Crystal2}$$

$$FG_{Fe_2O_3} + FG_{Al_2O_3} + FG_{ZrO_2} + FG_{Other} \leq 0.225 \quad \text{Crystal3}$$

$$FG_{Al_2O_3} + FG_{ZrO_2} \leq 0.18 \quad \text{Crystal4}$$

$$FG_{MgO} + FG_{CaO} + FG_{ZrO_2} \leq 0.18 \quad \text{Crystal5}$$

64.5 CRITICAL SOLUBILITY CONSTRAINTS

These constraints limit the maximum value for the mass fraction of one or a combination of components (e.g., noble metals: $Rh_2O_3 + PdO + Ru_2O_3$). These limits cover species not included among the nine species covered in the CVS studies. (They are, of course, included within the tenth component "Other.") These limits are of the form

$$FG_k \leq FG_{k,UL}$$

Their limits are given in Table G2.

64.6 GLASS PROPERTY CONSTRAINTS

These constraints will embody the findings of the composition variability study of Hrma and Piepel (1992). The calculation of each property (viscosity, electrical conductivity, durability [actual rate of release of boron] by either the Product Consistency Test or Materials Characterization Center test) is of the form

$$\text{MinPropVal} \leq \sum_{i=1}^{10} b_i FG_i + \sum_{i=1}^{10} \sum_{j>i} b_{ij} FG_i FG_j \leq \text{MaxPropVal}$$

where b_i and b_{ij} are the coefficients of the first and second order terms respectively and 10 is the number of components considered in the study. For each of the nonlinear property models, the coefficients of Model No. 3 from Hrma and Piepel (1992) were used. The limits on each of the constraints are given in Table G3.

65.0 GLASS OPTIMIZATION RESULTS

The current glass optimization models are based on analyses and experimental glass formulation data relative to expected high-level waste (HLW) stream compositions (Hrma and Piepel 1992 and Hoza 1993). Recent Tri-Party Agreement (TPA) (Ecology 1994) changes have also designated glass as the final waste product form for the low-level waste (LLW) stream. However, no extensive analyses or experimental glass formulation data relative to expected LLW stream compositions have been done. Therefore, the HLW glass composition specifications and associated optimization models will be used for the LLW glass streams also. It is expected that the LLW glass will have different glass composition and property limits that will be defined in future work.

The HLW glass will be formed in canisters that will be containerized for storage in an underground repository. The LLW glass is expected to be stored as gravel-sized glass chunks (cullet) within a sulfur cement matrix in underground vaults. Thus, the HLW glass disposal product units are shown as canisters, while the LLW glass disposal product units are shown as vaults. A calculation of the number of LLW glass canisters is included for comparison purposes only.

To obtain feasible solutions when optimizing the glass composition the Fe_2O_3 lower limit of 2 wt% (all limits are weight percents) was removed in all HLW and LLW glass calculations. This was because the waste oxide streams resulting from processing all single- and double-shell tank wastes together (i.e., as a blended waste stream) contained Fe_2O_3 in quantities of small overall mass fraction, requiring unattainable high waste loadings to achieve the lower constraint limit. The Fe_2O_3 lower limit was originally based on maintaining sufficient Fe_2O_3 in the glass to act as a redox buffer to protect against uranium+5 reduction to uranium+4. This lower limit should be reexamined to determine if it is necessary.

The initial limiting constraints for the HLW and LLW glass compositions were as follows: the P_2O_5 upper limit of 1 wt% for the TRUX31 (TRUEX-C HLW stream), SLUD31 (Sludge Wash C HLW stream), CLELLW (CLEAN Option LLW stream), and TRULLW (TRUEX-C Option LLW stream) models; the Other upper limit (OTHHI) of 10 wt% for the CLEAN31 (CLEAN Option HLW stream) model; and the Na_2O upper limit of 20 wt% for the SLULLW (Sludge Wash C LLW stream) model. Another glass optimization run was made in which the initial limiting or binding constraint for each model was relaxed. The next limiting constraints became the crystallinity No. 3 upper limit of 22.5 wt% for the CLEAN31 model, the OTHHI of 10 wt% for the TRUX31 and SLUD31 models, the Na_2O upper limit of 20 wt% for the CLELLW and TRULLW models, and several limits for the SLULLW model.

Relaxing the OTHHI (this limit represents everything other than the nine components considered in the CVS study) was definitely considered to be extrapolating outside the range of applicability of the glass property models and constraints (Hrma and Piepel 1992 and Hoza 1993). However, relaxing the P_2O_5 upper limit was not considered to represent a large extrapolation outside the range of model applicability. Although the same reasoning could be applied to the Na_2O upper limit only the P_2O_5 upper limit was relaxed for the process strategy comparisons. Thus, for the LLW glass compositions (CLELLW, TRULLW, and SLULLW models) the limiting constraint was the Na_2O upper limit of 20 wt% and for the HLW glass compositions (CLEAN31, TRUX31, and SLUD31 models) the limiting constraint was the OTHHI of 10 wt%.

Table G4 shows the glass optimization results with the initial binding constraint relaxed (e.g., Other, P_2O_5 , or Na_2O upper constraint limits) while Table G5 shows the glass optimization results with the initial binding constraint. The global models used the glass compositions that result with only the P_2O_5 upper constraint limit relaxed. Table G6 shows comparison data between the HLW glass canister and LLW glass-in-sulfur vault results with and without the initial binding constraints. Figures G2 and G3 show the HLW and LLW glass production results, respectively, with and without the P_2O_5 upper constraint limit. Figures G4 and G5 show the weight fractions of components in the HLW and LLW waste oxide streams, respectively. Figures G6 and G7 show

the weight fractions of components in the HLW and LLW glass without the P_2O_5 upper constraint limit, respectively. Figures G8 and G9 show the weight fractions of components in the HLW and LLW glass with the P_2O_5 upper constraint limit, respectively.

The impact of the glass composition constraints on waste loading in the glass is shown in Table G6. Waste loadings of approximately 19 wt%, 36 wt%, and 26 wt% were achieved in the CLEAN Option, TRUEX-C, and Sludge Wash C HLW glass products, respectively, without the P_2O_5 upper limit of 1 wt% in place. Table G4 and Figure G6 show that the resulting P_2O_5 weight fraction in glass was 1.7 and 3.6% for the TRUEX-C and Sludge Wash C HLW glass products, respectively. However, with the P_2O_5 upper limit, the HLW waste loadings were significantly lower, approximately 21 and 7 wt% for the TRUEX-C and Sludge Wash C models, respectively. No impact on the CLEAN Option HLW glass resulted from relaxing the P_2O_5 limit because it was not the limiting constraint. Increasing the OTHHI of 10 wt% will also have a significant impact on the HLW glass production as shown by the comparison of the CLEAN Option HLW glass stream (CLEAN31 model) results in Table G6. When the OTHHI was relaxed, the CLEAN Option HLW glass stream showed a 39% reduction of canisters (from 750 to 457), with a substantial increase in waste loading from 19 to 32 wt%.

The LLW glass had waste loadings from 22 to 24 wt% with the P_2O_5 upper limit in place. When the P_2O_5 upper limit was relaxed and the Na_2O upper limit became binding, only the CLEAN Option LLW glass waste loading increased significantly from 22 to 27 wt%. Increasing the Na_2O upper limit will also have a significant impact on the LLW glass production as shown by the comparison of the Sludge Wash C LLW glass stream (SLULLW model) results with and without the Na_2O upper limit of 20 wt% relaxed, where an 8% reduction of vaults (60 down to 55) was seen. The resulting Na_2O weight fraction in glass was 21.5% as shown in Table G4. The Tank Waste Technical Options Report (Boomer et al. 1993) suggests that a higher Na_2O limit of 25 wt% is possible because of the ability to recycle out-of-specification glass cullet. It also claims that higher Na_2O limits in borosilicate glass compositions are reported in other literature. Increasing this limit will have a significant impact on the LLW glass production as shown by the comparison of the SLULLW model results.

Table G6 gives a summary of the HLW glass canister and LLW glass-in-sulfur vault counts achieved by the different process strategies relative to the inclusion of the P_2O_5 upper limit. Note that the CLEAN Option HLW glass canister count was dramatically lower than the other process strategies, with only approximately 5 and 1% of the TRUEX-C and Sludge Wash C process strategy glass product magnitudes with the P_2O_5 upper limit, respectively, and only approximately 8 and 2% without the P_2O_5 upper limit, respectively. Relaxing the P_2O_5 upper limit reduced the TRUEX-C and Sludge Wash C HLW canister counts by 41 and 72%, respectively, and the LLW vault counts by 18 and 0.4% for the CLEAN Option and TRUEX-C process strategies, respectively.

The CLEAN Option LLW glass-in-sulfur vault total was highest for the P_2O_5 limiting case but ranged between the TRUEX-C and Sludge Wash C results without the P_2O_5 upper limit, showing vault counts of 86 and 109% of the TRUEX-C and Sludge Wash C results, respectively. Note the large amount of glass mass inventory (kilograms) associated with the LLW glass. This is due to the large

amount of Na_2O in the LLW oxide streams as shown in Figure G5. Indeed Na_2O constitutes 74, 85, and 89 wt% of the LLW oxide stream for the CLEAN Option, TRUEX-C, and Sludge Wash C process strategies, respectively. Removing this sodium would dramatically reduce the LLW glass mass inventory.

As discussed in the previous report on the evaluation of the TRUEX-C and Sludge Wash C process strategies (Knutson et al. 1993), over 90% of the HLW glass oxides in those two models come from the undissolved solids stream that is sent to glass before transuranic extraction (TRUEX) processing and eventual neutralization. Therefore, significant glass oxide reduction for those two models must come in the acid dissolution process step.

Based on previous work (Knutson et al. 1993), a 5% heel left in the tanks during retrieval would result in an approximately 5% reduction in the HLW glass canister counts (Knutson et al. 1993).

The glass former compositions resulting from the glass optimization models should not be considered unique. When a particular glass property limit becomes constraining (e.g., P_2O_5 and OTHHI) the feasible glass former compositions can vary considerably.

With these aggressive pretreatment strategies it is clear that more glass property data and glass melting data in HLW and LLW waste composition ranges could possibly allow relaxing current composition constraints. If such limits were relaxed, higher waste oxide loadings in the glass could be achieved (and hence, reduced glass canister and vault counts, costs, etc.), and other pretreatment process choices will be seen. Indeed, the critical component constraints have not been explored as a function of the mass fraction of major glass components, such as SiO_2 or Na_2O , and, therefore, should be taken as current estimates and not as scientifically established values that cannot be challenged if they represent severe constraints on the rest of a tank waste remediation system. Therefore, there should be additional focus on HLW and LLW immobilization activities with emphasis on currently constraining limits, such as P_2O_5 , Other, and Na_2O .

G6.0 REFERENCES

- Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Ecology 1994, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.
- Edgar, T. F., and D. M. Himmelblau, 1988, *Optimization of Chemical Processes*, McGraw-Hill, New York, New York.
- Hoza, M., 1993, *Optimal Waste Loading Models for Vitrification of Hanford High-Level Waste*, PHTD-693.03.01M, Pacific Northwest Laboratory, Richland, Washington.

Hrma, P. R., and G. F. Piepel, 1992, *Property/Composition Relationships for Hanford Waste Vitrification Plant Glasses -- Preliminary Results Through CVS-II Phase 2*, PHTD-92-03.01/K897, Pacific Northwest Laboratory, Richland, Washington.

Knutson, B. J., et al., 1993, "Advanced Chemical Separation Study: TRUEX Strategy Compared To Sludge Wash Ion Exchange," Letter report, July 1993.

Figure G1. Simple Function With Two Local Minima.

Figure G2. High-Level Waste Glass Production Results Versus P_2O_5 High-Limit Constraint.

Figure G3. Low-Level Waste Glass Production Results Versus P_2O_5 High-Limit Constraint.

Figure G4. Weight Fractions of Components in High-Level Waste Oxide Stream.

Figure G5. Weight Fractions of Components in Low-Level Waste Oxide Stream.

Figure G6. Weight Fractions of Components in High-Level Waste Glass Without P_2O_5 High-Limit Constraint.

Figure G7. Weight Fractions of Components in Low-Level Waste Glass Without P_2O_5 High-Limit Constraint.

Figure G8. Weight Fractions of Components in High-Level Waste Glass With P_2O_5 High-Limit Constraint.

Figure G9. Weight Fractions of Components in Low-Level Waste Glass With P_2O_5 High-Limit Constraint.

Table G1. Upper and Lower Limits on Ten Composition Variability Study Components.

Component, i	Lower limit - $FG_{i,LL}$	Upper limit - $FG_{i,UL}$
SiO_2	0.42	0.57
B_2O_3	0.05	0.20
Na_2O	0.05	0.20
Li_2O	0.01	0.07
CaO	0	0.10
MgO	0	0.08
Fe_2O_3	0.02	0.15
Al_2O_3	0	0.15
ZrO_2	0	0.13
Other	0.01	0.10

Table G2. Upper Limits on Critical Solubility Components.

Solubility component, k	Upper limit - $FG_{k,UL}$
Cr_2O_3	0.005
F	0.017
P_2O_5	0.01
SO_3	0.005
Noble metals ($Rh_2O_3 + PdO + Ru_2O_3$)	0.025

Table G3. Minimum and Maximum Glass Property Values.

Property, units	MinPropVal	MaxPropVal
Viscosity, PaS	2	10
Electrical conductivity, S/m	18	50
Durability (release rate of boron by PCT), g/m ²	N/A	10
Durability (release rate of boron by MCC), g/m ²	N/A	28

MCC = Materials Characterization Center.

PCT = Product Consistency Test.

Table G4. Glass Optimization Results With Initial Binding Constraint Relaxed.

MODEL:	CLEAN31 CLEAN31 HLW GLASS (0% HEEL)	TRUX31 TRUEX-C HLW GLASS (0% HEEL)	SLUD31 SLUDWC HLW GLASS (0% HEEL)	CLELLW CLEAN31 LLW GLASS (0% HEEL)	TRULLW TRUEX-C LLW GLASS (0% HEEL)	SLULLW SLUDWC LLW GLASS (0% HEEL)
WASTE OXIDES(kg)	2.39E+05	5.29E+06	1.74E+07	1.51E+08	1.52E+08	1.14E+08
GLASS FORMER ADDITION(kg)	5.15E+05	9.36E+06	5.10E+07	4.03E+08	4.94E+08	3.57E+08
WASTE LOADING FRACTION	0.317	0.361	0.255	0.272	0.236	0.243
GLASS(kg)	7.55E+05	1.47E+07	6.84E+07	5.53E+08	6.46E+08	4.71E+08
GLASS CANISTERS*	457	8880	41450	335251	391704	285698
* 1650 kg/canister						
GLASS-IN-SULFUR VAULTS**				65	76	55
** 8.518E+6 kg/vault						
PRODUCT DIFFERENCES:						
CLEAN. VS. TRUEXC		-8423			-11	
CLEAN. VS. SLUDWC			-40993			10
BINDING CONSTRAINT:	CRYS3	OTH-HI	OTH-HI	Na2O	Na2O	SEVERAL
RELAXED CONSTRAINTS:	Fe2O3,OTH-HI	Fe2O3,P2O5	Fe2O3,P2O5	Fe2O3,P2O5	Fe2O3,P2O5	Fe2O3,Na2O
Weight Fractions In Waste Oxide Stream						
COMPONENT						
FW-SiO2	1.57E-01	1.82E-01	6.00E-02	7.00E-03	7.56E-04	2.55E-04
FW-B2O3	1.83E-05	1.74E-04	4.54E-04	5.47E-05	4.81E-05	2.81E-06
FW-NA2O	1.34E-01	2.24E-01	1.05E-01	7.35E-01	8.49E-01	8.87E-01
FW-Li2O	1.07E-07	1.75E-06	2.65E-06	5.87E-07	5.20E-07	3.68E-07
FW-CAO	4.73E-04	4.00E-03	1.20E-02	1.00E-03	1.00E-03	2.13E-06
FW-MGO	1.86E-05	1.39E-04	4.62E-04	5.95E-05	5.39E-05	7.75E-06
FW-FE2O3	1.50E-02	4.30E-02	6.70E-02	8.00E-03	6.00E-03	1.43E-05
FW-AL2O3	1.66E-01	2.57E-01	3.21E-01	1.35E-01	5.10E-02	3.10E-02
FW-ZRO2	1.10E-02	1.20E-02	4.30E-02	5.00E-03	5.00E-03	1.60E-04
FW-OTHER	5.17E-01	2.77E-01	3.92E-01	1.10E-01	8.70E-02	8.20E-02
FW-CR2O3	3.00E-03	5.00E-03	1.50E-02	2.00E-03	2.00E-03	6.69E-06
FW-P2O5	5.68E-04	4.70E-02	1.42E-01	4.50E-02	4.30E-02	3.70E-02
FW-SO3	7.51E-06	5.49E-04	2.00E-03	1.10E-02	1.10E-02	1.40E-02
FW-NOBMET	2.73E-06	4.98E-05	6.77E-05	8.16E-06	6.34E-06	4.24E-07
Weight Fractions In Glass Former Stream						
COMPONENT						
FF-SiO2	5.64E-01	5.76E-01	5.43E-01	7.57E-01	7.25E-01	7.53E-01
FF-B2O3	1.61E-01	1.46E-01	1.38E-01	1.40E-01	1.38E-01	1.28E-01
FF-NA2O	1.76E-01	1.65E-01	2.01E-01			
FF-Li2O	3.30E-02	3.80E-02	3.20E-02	3.40E-02	3.30E-02	1.30E-02
FF-CAO	5.40E-02	4.00E-02	6.90E-02	6.60E-02	7.30E-02	1.40E-02
FF-MGO	1.30E-02	3.60E-02	1.70E-02	4.00E-03	3.10E-02	9.20E-02
Weight Fractions In Glass						
COMPONENT						
FG-SiO2	4.35E-01	4.33E-01	4.20E-01	5.53E-01	5.55E-01	5.70E-01
FG-B2O3	1.10E-01	9.30E-02	1.03E-01	1.02E-01	1.05E-01	9.70E-02
FG-NA2O	1.63E-01	1.87E-01	1.77E-01	2.00E-01	2.00E-01	2.15E-01
FG-Li2O	2.20E-02	2.40E-02	2.40E-02	2.40E-02	2.50E-02	1.00E-02
FG-CAO	3.70E-02	2.70E-02	5.40E-02	4.80E-02	5.60E-02	1.10E-02
FG-MGO	9.00E-03	2.30E-02	1.20E-02	3.00E-03	2.40E-02	6.90E-02
FG-FE2O3	5.00E-03	1.60E-02	1.70E-02	2.00E-03	1.00E-03	3.48E-06
FG-AL2O3	5.30E-02	9.30E-02	8.20E-02	3.70E-02	1.20E-02	7.00E-03
FG-ZRO2	4.00E-03	4.00E-03	1.10E-02	1.00E-03	1.00E-03	3.88E-05
FG-OTHER	1.64E-01	1.00E-01	1.00E-01	3.00E-02	2.10E-02	2.00E-02
FG-CR2O3	9.39E-04	2.00E-03	4.00E-03	4.83E-04	3.72E-04	1.62E-06
FG-P2O5	1.80E-04	1.70E-02	3.60E-02	1.20E-02	1.00E-02	9.00E-03
FG-SO3	2.38E-06	1.98E-04	4.87E-04	3.00E-03	3.00E-03	4.00E-03
FG-NOBMET		1.80E-05	1.73E-05	2.22E-06	1.49E-06	
Glass Properties						
PROPERTY						
VISCOSITY(PaS)	2.00	2.81	2.00	3.28	2.24	4.33
ELECT-CONDUCT(S/m)	43.22	49.29	44.44	49.75	48.75	50.00
DURAB.-B-PCT(gm/m2/day)	2.23	1.10	0.91	1.57	3.16	10.00
DURAB.-B-MCC(gm/m2/day)	18.08	15.68	19.09	18.75	27.31	23.47

Table G5. Glass Optimization Results With Initial Binding Constraint.

MODEL:	CLEAN31 CLEAN31 HLW GLASS (0% HEEL)	TRUX31 TRUEX-C HLW GLASS (0% HEEL)	SLUD31 SLUDWC HLW GLASS (0% HEEL)	CLELW CLEAN31 LLW GLASS (0% HEEL)	TRULLW TRUEX-C LLW GLASS (0% HEEL)	SLULLW SLUDWC LLW GLASS (0% HEEL)
WASTE OXIDES(kg)	2.39E+05	5.29E+06	1.74E+07	1.51E+08	1.52E+08	1.14E+08
GLASS FORMER ADDITION(kg)	9.99E+05	1.94E+07	2.30E+08	5.24E+08	4.97E+08	3.94E+08
WASTE LOADING FRACTION	0.193	0.214	0.070	0.223	0.235	0.225
GLASS(kg)	1.24E+06	2.47E+07	2.47E+08	6.74E+08	6.49E+08	5.08E+08
GLASS CANISTERS*	750	14997	149991	408379	393401	307823
* 1850 kg/canister						
GLASS-IN-SULFUR VAULTS**				79	76	60
** 8.518E+6 kg/vault						
CANISTER DIFFERENCES:						
CLEAN. VS. TRUEXC		-14247			3	
CLEAN. VS. SLUDWC			-149241			19
BINDING CONSTRAINT:	OTH-H	P2O5	P2O5	P2O5	P2O5	Na2O
RELAXED CONSTRAINTS:	Fe2O3	Fe2O3	Fe2O3	Fe2O3	Fe2O3	Fe2O3
Weight Fractions in Waste Oxide Stream						
COMPONENT						
FW-SiO2	1.57E-01	1.82E-01	6.00E-02	7.00E-03	7.56E-04	2.55E-04
FW-B2O3	1.83E-05	1.74E-04	4.54E-04	5.47E-05	4.81E-05	2.81E-06
FW-NA2O	1.34E-01	2.24E-01	1.05E-01	7.35E-01	8.49E-01	8.87E-01
FW-Li2O	1.07E-07	1.75E-06	2.65E-06	5.87E-07	5.20E-07	3.68E-07
FW-CAO	4.73E-04	4.00E-03	1.20E-02	1.00E-03	1.00E-03	2.13E-06
FW-MGO	1.86E-05	1.39E-04	4.82E-04	5.95E-05	5.39E-05	7.75E-06
FW-FE2O3	1.50E-02	4.30E-02	6.70E-02	8.00E-03	6.00E-03	1.43E-05
FW-AL2O3	1.66E-01	2.57E-01	3.21E-01	1.35E-01	5.10E-02	3.10E-02
FW-ZRO2	1.10E-02	1.20E-02	4.30E-02	5.00E-03	5.00E-03	1.60E-04
FW-OTHER	5.17E-01	2.77E-01	3.92E-01	1.10E-01	8.70E-02	8.20E-02
FW-CR2O3	3.00E-03	5.00E-03	1.50E-02	2.00E-03	2.00E-03	6.69E-06
FW-P2O5	5.68E-04	4.70E-02	1.42E-01	4.50E-02	4.30E-02	3.70E-02
FW-SO3	7.51E-06	5.49E-04	2.00E-03	1.10E-02	1.10E-02	1.40E-02
FW-NOBMET	2.73E-06	4.98E-05	6.77E-05	8.18E-06	6.34E-06	4.24E-07
Weight Fractions in Glass Former Stream						
COMPONENT						
FF-SiO2	6.69E-01	6.10E-01	6.09E-01	7.06E-01	7.26E-01	7.29E-01
FF-B2O3	1.28E-01	1.34E-01	1.15E-01	1.39E-01	1.33E-01	1.32E-01
FF-NA2O		1.53E-01	1.64E-01		7.76E-04	3.00E-02
FF-Li2O	7.40E-02	3.60E-02	3.00E-02	5.40E-02	3.60E-02	3.60E-02
FF-CAO	8.90E-02	5.90E-02	7.60E-02	9.50E-02	9.20E-02	9.10E-02
FF-MGO	1.00E-02	8.00E-03	7.00E-03	6.00E-03	1.30E-02	1.20E-02
Weight Fractions In Glass						
COMPONENT						
FG-SiO2	5.70E-01	5.19E-01	5.70E-01	5.50E-01	5.56E-01	5.85E-01
FG-B2O3	1.03E-01	1.05E-01	1.07E-01	1.08E-01	1.02E-01	1.02E-01
FG-NA2O	5.00E-02	1.68E-01	1.59E-01	1.64E-01	2.00E-01	2.00E-01
FG-Li2O	6.00E-02	2.90E-02	2.80E-02	4.20E-02	2.80E-02	2.80E-02
FG-CAO	7.20E-02	4.70E-02	7.10E-02	7.40E-02	7.00E-02	7.00E-02
FG-MGO	8.00E-03	7.00E-03	7.00E-03	5.00E-03	1.00E-02	1.00E-02
FG-FE2O3	3.00E-03	9.00E-03	5.00E-03	2.00E-03	1.00E-03	3.23E-06
FG-AL2O3	3.20E-02	5.50E-02	2.30E-02	3.00E-02	1.20E-02	7.00E-03
FG-ZRO2	2.00E-03	3.00E-03	3.00E-03	1.00E-03	1.00E-03	3.80E-05
FG-OTHER	1.00E-01	5.90E-02	2.80E-02	2.40E-02	2.00E-02	1.80E-02
FG-CR2O3	5.72E-04	1.00E-03	1.00E-03	3.97E-04	3.70E-04	1.51E-06
FG-P2O5	1.10E-04	1.00E-02	1.00E-02	1.00E-02	1.00E-02	6.00E-03
FG-SO3	1.45E-06	1.17E-04	1.35E-04	3.00E-03	3.00E-03	3.00E-03
FG-NOBMET		1.06E-05	4.77E-06	1.82E-06	1.49E-06	
Glass Properties						
PROPERTY						
VISCOSITY(PaS)	4.95	3.54	3.88	2.00	2.00	2.03
ELECT-CONDUCT(S/m)	25.53	39.71	32.66	42.13	50.00	49.85
DURAB.-B-PCT(gm/m2/day)	0.47	1.02	1.01	1.20	2.30	2.49
DURAB.-B-MCC(gm/m2/day)	14.28	16.29	20.55	23.07	27.46	27.69

Table G6. Comparison of Glass Canister/Vault Results
With and Without Specific Constraints.

MODEL:	CLEAN31 CLEAN31 HLW GLASS (0% HEEL)	TRUX31 TRUEX-C HLW GLASS (0% HEEL)	SLUD31 SLUDWC HLW GLASS (0% HEEL)	CLELLW CLEAN31 LLW GLASS (0% HEEL)	TRULLW TRUEX-C LLW GLASS (0% HEEL)	SLULLW SLUDWC LLW GLASS (0% HEEL)
With The P2O5 High Constraint						
KG GLASS CANISTERS	1.24E+06 750	2.47E+07 14997	2.47E+08 149991	6.74E+08	6.49E+08	5.08E+08
VAULTS				79	76	60
% LOAD	19.3	21.4	7.0	22.3	23.5	22.5
Without The P2O5 High Constraint						
KG GLASS CANISTERS	1.24E+06 750	1.47E+07 8880	6.84E+07 41450	5.53E+08	6.46E+08	5.08E+08
VAULTS				65	76	60
% LOAD	19.3	36.1	25.5	27.2	23.6	22.5
Without The NA2O High Constraint						
KG GLASS VAULTS						4.71E+08
% LOAD						55 24.3
Without The OTH High Constraint						
KG GLASS CANISTERS	7.55E+05 457					
% LOAD	31.7					
Comparison Of Results With And Without P2O5 Constraint						
(WITH P2O5/ WITHOUT P2O5)	1.00	1.69	3.62	1.22	1.00	1.00
(WITHOUT P2O5/ WITH P2O5)	1.00	0.59	0.28	0.82	1.00	1.00
% REDUCTION	0.0	40.8	72.4	17.9	0.4	0.0
CLEAN/*MODEL*:						
WITH P2O5		0.05	0.01		1.04	1.33
WITHOUT P2O5		0.08	0.02		0.86	1.09
(KG LLW GLASS/KG HLW GLASS)						
WITH P2O5				544.39	26.23	2.05
WITHOUT P2O5				446.91	44.11	7.43

This page intentionally left blank.

APPENDIX H

ASPEN PLUS¹ GLOBAL MODEL MASS BALANCE RESULTS

¹ASPEN PLUS is a trademark of Aspen Technology, Inc.

LIST OF TERMS

CPU	compact processing unit
HLW	high-level waste
LLW	low-level waste
TRUEX-C	Transuranic Extraction Option C

ASPEN PLUS GLOBAL MODEL MASS BALANCE RESULTS

Table H1 shows the stream mass balance and waste product summaries for each of the global model runs. Table H2 shows a comparison of the CLEAN Option, Transuranic Extraction Option C (TRUEX-C), and Sludge Wash C process strategies in terms of mass flows of the final waste product forms. Table H2 includes a breakdown of the waste products attributable to the primary waste feed stream processing and the tertiary waste processing. Also, sending the primary low-level waste (LLW) to a glass-in-sulfur product versus salt grout was considered for each process strategy (Appendix G).

As discussed in Appendix E, a large amount of tertiary waste is generated for each of the process strategies. With tertiary waste treatment, approximately 38% of the tertiary waste (S10GRT, S30CONC) is destined for grout, approximately 26% of the tertiary waste (S30COND) is destined for water treatment, and 36% (S10BUR, S20ASH) is destined for landfill burial. Note from Table H2 that the CLEAN Option process strategy produces a factor of 1.5 and 2.4 more tertiary waste than the TRUEX-C and Sludge Wash C process strategies, respectively, because of its more process-intensive strategy.

Using compact processing units (CPUs) to process the supernate and salt cake reduced the CLEAN Option tertiary waste generation by approximately 29%. This reduction was estimated by processing only the sludge portion of the tank waste (i.e., approximately 36 and 4% of the single- and double-shell tank waste, respectively) through a central processing facility.

Figure H1 shows the LLW vault requirements for both primary and tertiary waste. Note that the primary LLW-to-glass option required only 30% of the vaults that the LLW salt grout option required. Also, note that the CLEAN Option tertiary LLW required nearly the same number of salt grout vaults as the primary LLW. Using CPUs, the CLEAN Option tertiary LLW waste required only 73% of the salt grout vaults as the primary LLW. The TRUEX-C and Sludge Wash C process strategies had tertiary grout vault requirements that were approximately 57 and 50% of those associated with primary LLW, respectively.

It was interesting to note that while the amount of primary LLW reporting to the salt grout facility was lower for the CLEAN Option than for the Sludge Wash C process strategy, the grouting process required more chemical adds for adjustment of sodium concentration, resulting in a larger grout product volume for the CLEAN Option.

As shown in Table H2, in terms of kilograms of waste product produced per primary waste kilogram processed, the primary LLW-to-glass option production ratios were 0.73, 0.85, and 0.67 for the CLEAN Option, TRUEX-C, and Sludge Wash C process strategies, respectively. Thus, the CLEAN Option process strategy produces 14% less primary LLW glass than the TRUEX-C process strategy and 9% more than the Sludge Wash C process strategy. The primary LLW-to-salt grout option production ratios were 2.58, 3.04, and 2.17 for the CLEAN Option, TRUEX-C, and Sludge Wash C process strategies, respectively. Thus, the CLEAN Option process strategy produces 15% less primary LLW salt grout than the TRUEX-C process strategy and 19% more than the Sludge Wash C process strategy.

For the high-level waste (HLW) stream, note the significant reduction of HLW glass canisters for the CLEAN Option. The CLEAN Option process strategy produced only 8 and 2% of the HLW glass as the TRUEX-C and Sludge Wash C process strategies, respectively. In terms of kilograms of waste product produced per primary waste kilograms processed, the HLW glass production ratios were 0.002, 0.019, and 0.090 for the CLEAN Option, TRUEX-C, and Sludge Wash C process strategies, respectively.

Note that the LLW and HLW glass production results are based on the glass composition optimization results discussed in Appendix G. Relaxation of key glass component constraints in the optimization process can have a significant impact on the glass production results shown in Tables H1 and H2.

Note that all process strategies assumed that a 0% heel (i.e., the unretrieved waste) was left in the waste tanks. Generally, if a 5% heel was assumed, the process strategy would decrease the HLW glass product by 4 to 5% as compared to the 0% heel case, while decreasing the LLW product by 2% to 3% (Knutson et al. 1993). There would be an associated major increase of the amount of waste resident in the dome-fill-tank product stream (3200HLWS) when a 5% tank waste heel is assumed for the process strategies.

The conversion factor for glass canisters is based on the 60-cm- (2-ft-) diameter by 317-cm- (10-ft-) long canister (glass volume of 0.625 m³) (Boomer et al. 1993). The conversion factor for grout vaults is based on a vault capacity of 1.4 E+6 gal (5.3 E+3 m³), with a grout density of 1.6 g/cc (i.e., 8.48 E+6 kg of salt grout/vault). The conversion factor for LLW glass-in-sulfur vaults of 8.518 E+6 kg glass/vault is based on the same vault capacity.

Table H3 contains the detailed ASPEN PLUS global model mass balance output results showing the model stream mass (kilograms) and curie (Ci) flows, separated as input, output, and all streams.

REFERENCES

- Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Knutson, B. J., et al., 1993, "Advanced Chemical Separation Study: TRUEX Strategy Compared To Sludge Wash Ion Exchange," Letter report, Westinghouse Hanford Company, Richland, Washington.

Figure H1. Low-Level Waste Vault Requirements for Primary and Tertiary Waste.

Table H1. Stream Mass Balance and Waste Product Summaries.

SUMMARY OF PRODUCT STREAM MASS FLOWS (kg)				
MODEL:	CLEANG31 CLEAN OPTION	TRUG31 TRUEX-C	SLUG31 SLUDGE WASH C	CLEANG41 * CLEAN OPTION w/ CPUs (0% HEEL)
Output Streams	(0% HEEL)	(0% HEEL)	(0% HEEL)	
2200H2O	3.05E+09	2.21E+09	1.31E+09	
3110HLWS	1.24E+06	1.47E+07	6.84E+07	
3200HLWS	1.51E-05	1.51E-05	1.51E-05	
3400LLWS	9.78E+08	1.15E+09	8.23E+08	
3400LMWS	9.78E+08	1.15E+09	8.23E+08	
3530LMWS	1.26E+08	4.62E+07	2.74E+07	
B24U/B212U	1.72E+06	6.52E+06	3.11E-09	
3110GAS		9.41E+08	9.90E+08	
3400GAS	1.99E+09	2.60E+09	1.89E+09	
B112GAS		3.73E+06	3.77E+06	
B13GAS		4.40E+05	1.66E-08	
B21GAS		3.03E+08	2.48E-06	
B22GAS		1.43E+08	4.95E-07	
B23GAS		7.18E+05	2.17E-09	
B24GAS		5.21E+08	2.48E-07	
B311GAS		2.06E+03	1.45E-02	
B312GAS		1.52E+06	2.19E+03	
C14GAS		7.53E-07	9.59E-09	
B43HRCY	1.55E+08			
ALLGAS	1.08E+09			
S10GRT	7.75E+08	5.07E+08	3.19E+08	5.50E+08
S10BUR	7.75E+08	5.07E+08	3.19E+08	5.50E+08
S20ASH	4.11E+08	2.69E+08	1.69E+08	2.92E+08
S30COND	8.56E+08	5.60E+08	3.52E+08	6.08E+08
S30CONC	4.83E+08	3.16E+08	1.99E+08	3.43E+08
S40GAS	2.24E+03	1.47E+03	9.21E+02	1.59E+03
Totals (kg)	1.17E+10	1.13E+10	7.29E+09	

* CLEANG41 MODEL SHOWS THE EFFECT ON TERTIARY WASTE GENERATION
WHEN PROCESSING ONLY TANK SLUDGE IN A CENTRAL PROCESSING FACILITY

Table H2. Waste Product Summaries and Comparisons.

SUMMARY OF PRODUCT MASS FLOW (kg) BY WASTE FORM					
	MODEL:	CLEANG31 CLEAN OPTION	TRUG31 TRUEX-C	SLUG31 SLUDGE WASH C	CLEANG41 * CLEAN OPTION w/ CPUs (0% HEEL)
WASTE FORM		(0% HEEL)	(0% HEEL)	(0% HEEL)	
INITIAL PRIMARY WASTE FEED (kg)		7.57E+08	7.57E+08	7.57E+08	7.57E+08
HLW GLASS (kg)		1.24E+06	1.47E+07	6.84E+07	
LLW GLASS (kg) (Option 1)		5.53E+08	6.46E+08	5.08E+08	
LLW SALT-GROUT (kg) (Option 2)		1.96E+09	2.30E+09	1.65E+09	
WATER TREATMENT IX RESIN (kg)		1.26E+08	4.62E+07	2.74E+07	
DOME-FILL-TNKS (kg)		1.51E-05	1.51E-05	1.51E-05	
URANIUM PROD (kg)		1.72E+06	6.52E+06	3.11E-09	
H2O (kg)		3.05E+09	2.21E+09	1.31E+09	
GAS+ (kg)		3.07E+09	4.52E+09	2.88E+09	
TERTIARY WASTE TO WATER TREATMENT (kg)		8.56E+08	5.60E+08	3.52E+08	6.08E+08
TERT WASTE TO GROUT(NO CEMENT ADD) (kg)		1.26E+09	8.24E+08	5.18E+08	8.94E+08
TERTIARY WASTE TO LANDFILL (kg)		1.19E+09	7.76E+08	4.88E+08	8.42E+08
TERTIARY WASTE SALT GROUT* (kg)		2.01E+09	1.32E+09	8.29E+08	1.43E+09
(*INCLUDES 1.6 FACTOR FOR CEMENT ADD)					
TOTAL GENERATED TERTIARY WASTE (kg)		3.30E+09	2.16E+09	1.36E+09	2.34E+09
TERTW TO WATER TREATMENT / TOT TERTW		0.26	0.26	0.26	0.26
TERTW TO LANDFILL(BUR) / TOT TERTW		0.36	0.36	0.36	0.36
TERTW TO GROUT / TOT TERTW		0.38	0.38	0.38	0.38
TOT TERT WASTE / INIT PRIM WASTE		4.36	2.85	1.79	3.10
HLW GLASS / INIT PRIM FEED		0.002	0.019	0.090	
LLW GLASS (Option 1) / INIT PRIM FEED		0.73	0.85	0.67	
LLW SALT GROUT (Option 2) / INIT PRIM FEED		2.58	3.04	2.17	
TERW GROUT / INIT PRIM FEED		2.66	1.74	1.09	1.89
ALL GROUT / INIT PRIM FEED		5.24	4.78	3.27	4.47
CLEAN/"MODEL" (TOT TERT WASTE)			1.53	2.43	1.41
CLEAN/"MODEL" (HLW GLASS)			0.08	0.02	
CLEAN/"MODEL" (LLW GLASS)			0.86	1.09	
CLEAN/"MODEL" (SALT-GROUT)			0.85	1.19	
CLEAN/"MODEL" (TERT-GROUT)			1.53	2.43	1.41
CLEAN/"MODEL" (ALL-GROUT)			1.10	1.60	1.17
HLW GLASS CANISTERS **		750	8880	41450	
LLW GLASS VAULTS *** (Option 1)		65	76	60	
LLW GROUT VAULTS **** (Option 2)		231	272	194	
LLW GLASS VAULTS / LLW GROUT VAULTS		0.28	0.28	0.31	
TERT WASTE VAULTS ****		237	155	98	169
GROUT VAULT RATIO: TERT/PRIM		1.03	0.57	0.50	0.73

* CLEAN41 MODEL SHOWS THE EFFECT ON TERTIARY WASTE GENERATION
WHEN PROCESSING ONLY TANK SLUDGE IN A CENTRAL PROCESSING FACILITY

** GLASS CANISTERS (1650 KG/CANISTER)

*** GLASS VAULTS (8.518E6 KG/VAULT)

**** GROUT VAULTS (8.48E6 KG/VAULT)

FILE: C:\ASPRUNSCLEAN31.INP (CLEAN OPTION, SST&DST BLEND, 0% HEEL

[illegible]

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 4 of 56)

File: C:\ASPRUNSCLEAN\G31.INP (CLEAN OPTION, SST&DST BLEND, 0% HEEL)

All Streams	TH	NP	LANH	NACH	BA	HNO3	AL2O3	SiO2	NOX	Total (kg)
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.64E-01	0.00E+00	0.00E+00	2.93E+00	3.05E+09
2200LMWS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.64E+03	0.00E+00	0.00E+00	2.93E+04	1.14E+08
22CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.40E+06
2311CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2311EOPT	1.30E-10	4.54E-13	4.02E-12	9.14E-08	5.00E-09	0.00E+00	2.20E-08	0.00E+00	1.90E-08	5.72E-06
2311HLWL	1.30E+04	4.54E+01	4.02E+02	9.14E+06	5.00E+05	0.00E+00	2.20E+06	0.00E+00	1.90E+06	5.72E+08
2312CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2312EOPT	8.26E-12	6.40E-13	1.11E-12	1.03E-07	1.76E-11	6.57E-19	2.20E-08	6.00E-10	1.74E-08	1.85E-06
2312HLWL	8.26E+02	6.40E+01	1.11E+02	1.03E+07	1.76E+03	6.57E-05	2.20E+06	6.00E+04	1.73E+06	1.85E+08
2313CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2313HEEL	1.30E-10	4.54E-13	4.02E-12	9.14E-08	5.00E-09	2.00E-26	2.20E-08	2.30E-26	1.90E-08	5.72E-06
2313HLWL	1.30E+04	4.54E+01	4.02E+02	9.14E+06	5.00E+05	2.00E-14	2.20E+06	2.30E-14	1.90E+06	5.72E+08
2314CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2314HEEL	8.26E-12	6.40E-13	1.11E-12	1.03E-07	1.76E-11	6.57E-19	2.20E-08	6.00E-10	1.74E-08	1.85E-06
2314HLWL	8.26E+02	6.40E+01	1.11E+02	1.03E+07	1.76E+03	6.57E-05	2.20E+06	6.00E+04	1.73E+06	1.85E+08
2322COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.64E+03	0.00E+00	0.00E+00	2.93E+04	3.17E+09
2322HLWL	1.37E+04	1.08E+02	5.12E+02	2.13E+03	2.86E+04	9.43E+03	5.05E+03	2.57E+01	1.11E+02	1.72E+06
2322LWL	7.35E+01	6.03E-01	3.40E-01	2.82E+07	2.37E+05	0.00E+00	5.16E+06	3.00E+04	2.08E+06	3.07E+08
2322LMWL	7.35E+01	6.03E-01	3.40E-01	2.82E+07	2.37E+05	7.67E-06	5.16E+06	3.00E+04	2.08E+06	3.07E+08
2322LWS	1.47E+02	1.21E+00	6.80E-01	5.54E+07	4.73E+05	3.95E-05	1.03E+07	6.00E+04	3.29E+07	3.95E+09
3110COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3110GAS	0.00E+00	0.00E+00	0.00E+00	4.38E+08	0.00E+00	4.38E+07	0.00E+00	0.00E+00	4.39E+08	9.22E+08
3110HLWS	1.56E+04	1.23E+02	5.94E+02	0.00E+00	3.20E+04	0.00E+00	3.98E+04	5.81E+05	0.00E+00	1.24E+06
3200HLWS	2.77E-10	2.20E-12	1.03E-11	3.89E-07	1.00E-08	1.00E-14	8.80E-08	1.20E-09	7.27E-08	1.51E-05
32CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.20E-13
3400GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.95E-05	0.00E+00	0.00E+00	2.89E+07	1.99E+09
3400LWS	7.35E+01	6.03E-01	3.40E-01	2.82E+07	2.37E+05	0.00E+00	5.16E+06	3.00E+04	2.02E+06	9.78E+08
3400LMWS	7.35E+01	6.03E-01	3.40E-01	2.82E+07	2.37E+05	0.00E+00	5.16E+06	3.00E+04	2.02E+06	9.78E+08
34CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	3.33E+09
3530LMWS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	7.64E+03	1.00E-14	1.00E-14	2.93E+04	1.26E+08
353CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.24E+07
ALLGAS	1.55E-05	1.55E-05	1.55E-05	4.38E+08	1.55E-05	4.38E+07	1.55E-05	1.55E-05	5.95E+08	1.08E+09
AQUELLW	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.01E+09
B1110HLL	1.38E+04	1.09E+02	5.13E+02	1.94E+07	5.02E+05	6.53E-05	4.40E+06	6.00E+04	3.63E+06	8.70E+08
B1111CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.13E+08
B1111HLL	1.63E+02	4.52E+00	4.85E+00	1.68E+07	3.08E+02	6.47E-05	2.65E+06	1.34E+04	3.41E+06	7.97E+08
B1111HLS	1.37E+04	1.05E+02	5.08E+02	2.69E+06	5.01E+05	6.04E-07	1.75E+06	4.66E+04	2.30E+05	7.33E+07
B1120HLS	1.63E+02	4.52E+00	4.85E+00	1.76E+07	3.08E+02	6.51E-05	2.65E+06	1.34E+04	6.19E+06	8.13E+08
B122CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.63E+07
B1123GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.55E+06	3.55E+06
B112HLL	1.63E+00	4.52E-02	4.85E-02	1.60E+07	3.07E+00	6.50E-05	1.85E+06	1.34E+04	2.64E+06	7.99E+08
B112HLS	1.61E+02	4.47E+00	4.80E+00	1.60E+06	3.04E+02	2.60E-08	7.96E+05	5.35E+00	1.06E+03	1.06E+07
B120HLL	1.46E+04	1.15E+02	5.19E+02	1.84E+07	6.25E+05	1.16E+03	5.23E+06	6.21E+04	1.27E+06	3.40E+08
B12CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	9.39E+07
B12HLL	4.42E+01	3.72E-01	6.48E-01	1.41E+07	1.17E+05	1.15E+03	4.90E+06	1.49E+04	1.04E+06	2.80E+08
B12HLS	1.45E+04	1.15E+02	5.18E+02	4.37E+06	5.07E+05	9.01E+00	3.33E+05	4.71E+04	2.28E+05	6.07E+07
B1310HLS	1.45E+04	1.15E+02	5.18E+02	4.26E+05	6.25E+05	1.03E+06	3.33E+05	4.71E+04	2.53E+05	2.89E+08
B131CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.29E+06	1.00E-14	1.00E-14	9.12E+04	2.26E+08
B131GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.01E+05	2.82E+05
B131HLL	1.30E+04	1.03E+02	4.65E+02	0.00E+00	5.73E+05	1.03E+06	1.68E+05	4.24E+04	3.03E+04	2.73E+08
B131HLS	1.47E+03	1.17E+01	5.26E+01	4.26E+05	5.17E+04	1.80E+03	1.66E+05	4.78E+03	2.20E+04	1.53E+07
B1320HLS	1.47E+03	1.17E+01	5.26E+01	4.26E+04	5.17E+04	1.18E+05	1.66E+05	4.78E+03	2.47E+04	4.67E+07
B132CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.41E+05	1.00E-14	1.00E-14	9.07E+03	3.14E+07
B132GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-01	0.00E+00	0.00E+00	1.94E+04	2.79E+04
B132HLL	7.41E+02	5.86E+00	4.69E+01	0.00E+00	4.61E+04	1.17E+05	6.46E+04	4.26E+03	3.05E+03	3.66E+07
B132HLS	3.67E+01	2.90E-01	2.83E-01	2.13E+03	2.77E+02	6.10E+01	5.05E+03	2.57E+01	1.11E+02	5.01E+05
B132SPCY	6.97E+02	5.51E+00	5.39E+00	4.05E+04	5.27E+03	1.16E+03	9.59E+04	4.89E+02	2.12E+03	9.53E+06
B2110HLL	1.38E+04	1.09E+02	5.12E+02	4.80E+06	6.19E+05	1.18E+06	2.32E+05	4.66E+04	6.46E+04	4.80E+08
B211CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.52E+04	1.00E-14	1.00E-14	3.13E+04	1.63E+08
B211HLL	1.38E+02	1.09E+00	5.12E+02	4.80E+06	6.19E+05	1.13E+06	2.32E+05	4.66E+04	3.33E+04	3.28E+08
B211LML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.13E+04	3.53E+06
B211THPU	1.36E+04	1.08E+02	5.12E+02	0.00E+00	0.00E+00	4.99E+04	0.00E+00	0.00E+00	0.00E+00	7.32E+07
B211U	1.36E+00	1.08E-02	0.00E+00	0.00E+00	0.00E+00	1.50E+02	0.00E+00	0.00E+00	0.00E+00	7.53E+07

H-11

MHC-EP-0791

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 6 of 56)

File: C:\ASPRUNSCLEANG31.INP (CLEAN OPTION, SST&DST BLEND, 0% HEEL)

Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	Total (kg)
B2120U	1.36E+00	1.08E-02	1.58E-06	1.58E-06	1.58E-06	1.61E+04	1.58E-06	1.58E-06	1.16E+05	1.58E+08
B2120ACY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E+05	6.89E+05
B212CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.67E+04	1.00E-14	1.00E-14	1.35E+04	8.24E+07
B212CONO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.00E+02	0.00E+00	0.00E+00	0.00E+00	1.46E+08
B212LML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E+04	2.21E+06
B212ORCY	1.36E+00	1.08E-02	0.00E+00	0.00E+00	0.00E+00	1.53E+04	0.00E+00	0.00E+00	0.00E+00	6.96E+06
B212U	0.00E+00	0.00E+00	1.58E-06	1.58E-06	1.58E-06	0.00E+00	1.58E-06	1.58E-06	0.00E+00	1.72E+06
B2210HLL	1.38E+02	1.09E+00	5.12E+02	6.59E-06	6.19E+05	1.16E+06	2.32E+05	4.66E+04	7.42E+05	6.59E+08
B221AMLN	1.38E+02	5.45E-01	5.12E+02	0.00E+00	0.00E+00	1.09E+05	0.00E+00	0.00E+00	0.00E+00	2.08E+08
B221CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.81E+04	1.00E-14	1.00E-14	7.09E+05	3.31E+08
B221HLL	1.38E-02	5.45E-01	5.12E-02	0.00E+00	6.19E+05	1.05E+06	2.32E+05	4.66E+04	3.33E+04	3.67E+08
B221LML	1.38E-02	5.45E-05	5.12E-02	6.59E-06	0.00E+00	3.27E+02	0.00E+00	0.00E+00	7.09E+05	8.32E+07
B221HLL	1.38E+02	5.45E-01	5.12E+02	2.47E-06	2.47E-06	1.15E+05	2.47E-06	2.47E-06	2.47E-06	2.47E+08
B221LML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.39E+03	0.00E+00	0.00E+00	0.00E+00	3.72E+07
B221AMLN	0.00E+00	0.00E+00	5.12E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.60E+05
B221BLML	1.38E+02	5.45E-01	5.12E-02	2.47E-06	2.47E-06	1.14E+05	2.47E-06	2.47E-06	2.47E-06	2.10E+08
B222CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.49E+03	1.00E-14	1.00E-14	1.00E-14	3.95E+07
B2310HLL	1.38E-02	5.45E-01	5.12E-02	1.16E-05	6.19E+05	1.27E+06	2.32E+05	4.66E+04	6.89E+05	1.16E+09
B231CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.20E+05	1.00E-14	1.00E-14	6.56E+05	7.96E+08
B231HLL	1.38E-02	5.45E-01	5.12E-02	0.00E+00	6.19E+05	1.20E+06	2.32E+05	4.66E+04	3.33E+04	5.12E+08
B231LML	0.00E+00	0.00E+00	0.00E+00	1.16E-05	0.00E+00	1.10E+04	0.00E+00	0.00E+00	6.56E+05	4.29E+07
B231SRTC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.19E+05	6.17E+04	0.00E+00	0.00E+00	0.00E+00	6.09E+08
B2320HLL	1.20E-05	1.20E-05	1.20E-05	1.20E-05	6.19E+05	7.29E+04	1.20E-05	1.20E-05	1.20E-05	1.20E+09
B232CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.12E+04	1.00E-14	1.00E-14	1.00E-14	5.89E+08
B232LML	1.20E-05	1.20E-05	1.20E-05	1.20E-05	5.91E+05	1.10E+03	1.20E-05	1.20E-05	1.20E-05	5.39E+08
B232SRTC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.83E+04	7.18E+04	0.00E+00	0.00E+00	0.00E+00	6.60E+08
B240HLL	1.38E-02	5.45E-01	5.12E-02	5.12E-06	6.19E+05	1.20E+06	2.70E+05	4.66E+04	3.34E+04	5.12E+08
B24CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	3.71E+04	1.00E-14	1.00E-14	3.97E+01	4.56E+05
B24HLL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.71E+04	0.00E+00	1.17E+01	1.66E+05
B24LML	1.38E-02	5.45E-01	5.12E-02	5.12E-06	6.19E+05	1.20E+06	2.32E+05	4.66E+04	3.33E+04	5.12E+08
B310HLL	4.59E+01	4.17E-01	6.96E-01	3.04E+07	1.17E+05	8.87E+03	6.75E+06	2.83E+04	3.71E+06	1.14E+09
B31CM	1.00E-14	1.00E-14	1.00E-14	9.27E+04	1.00E-14	9.04E+03	1.00E-14	1.00E-14	1.00E-14	1.65E+07
B31CONO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.93E+04	2.93E+04
B31CS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.87E+03	0.00E+00	0.00E+00	0.00E+00	9.39E+06
B31HLL	4.59E+01	4.17E-01	6.96E-01	3.04E+07	1.17E+05	0.00E+00	6.75E+06	2.83E+04	3.68E+06	1.13E+09
B320LML	4.59E+01	4.17E-01	6.96E-01	3.04E+07	1.17E+05	4.86E+03	6.75E+06	2.83E+04	3.68E+06	1.15E+09
B32CM	1.00E-14	1.00E-14	1.00E-14	9.34E+04	1.00E-14	8.43E+03	1.00E-14	1.00E-14	1.00E-14	1.59E+07
B32CONO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.53E+06
B32LML	4.59E+01	4.17E-01	6.96E-01	3.04E+07	0.00E+00	0.00E+00	6.75E+06	2.83E+04	3.68E+06	1.14E+09
B32SR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E+05	4.86E+03	0.00E+00	0.00E+00	0.00E+00	2.31E+06
B330LML	4.59E+01	4.17E-01	6.96E-01	3.72E+07	1.65E-05	2.74E+04	6.75E+06	2.83E+04	3.68E+06	1.65E+09
B33CM	1.00E-14	1.00E-14	1.00E-14	6.82E+06	1.00E-14	2.74E+04	1.00E-14	1.00E-14	1.00E-14	5.14E+08
B33LML	4.59E+01	4.17E-01	6.96E-01	3.72E+07	1.65E-05	1.89E+04	6.75E+06	2.83E+04	3.68E+06	1.65E+09
B33TC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.41E+03	0.00E+00	0.00E+00	0.00E+00	2.13E+06
B3CM	1.00E-14	1.00E-14	1.00E-14	2.33E+05	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.29E+07
B3GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B3HCY	0.00E+00	0.00E+00	0.00E+00	2.33E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.24E+07
B410LLW	1.84E+02	1.51E+00	8.50E-01	7.07E+07	5.91E+05	2.53E-05	1.29E+07	7.49E+04	1.07E+08	2.53E+09
B41CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.13E+07	1.13E+07
B41CONO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.68E+09
B41GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.53E-05	0.00E+00	0.00E+00	1.02E+08	1.02E+08
B41NACR	1.84E+02	1.51E+00	8.50E-01	7.07E+07	5.91E+05	0.00E+00	1.29E+07	7.49E+04	5.05E+06	7.52E+08
B420LML	1.84E+02	1.51E+00	8.50E-01	7.05E+07	5.91E+05	7.67E-06	1.29E+07	7.49E+04	5.20E+06	7.67E+08
B42CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.46E+07
B42CR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.16E+06	6.14E+08
B42LML	1.47E+02	1.21E+00	6.80E-01	5.64E+07	4.73E+05	7.67E-06	1.03E+07	6.00E+04	4.16E+06	1.83E+05
B42NAOH	3.66E+01	3.01E-01	1.70E-01	1.41E+07	1.18E+05	0.00E+00	2.57E+06	1.49E+04	1.04E+06	1.53E+08
B430HNO3	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.37E+06	1.55E-05	1.55E-05	5.04E+07	1.55E+09
B43CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.31E+07	6.05E+07
B43GAS	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05	0.00E+00	1.55E-05	1.55E-05	5.04E+07	5.04E+07
B43HNO3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.84E+03	0.00E+00	0.00E+00	0.00E+00	1.34E+09
B43HCY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E+06	0.00E+00	0.00E+00	0.00E+00	1.55E+08
B440HLS	1.36E+04	1.08E+02	5.12E+02	2.24E-07	2.83E+04	9.37E+03	2.24E-07	2.24E-07	6.78E+05	2.24E+07
B44CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.00E+05

H-13

MHC-EP-0791

(sheet 8 of 56)

H-15

FIG. C.1: ASPRUNSTRUG31.INP (TRUEX-C, 0% HEEL, STADST BLEND)

[illegible]

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

5 of 6

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 14 of 56)

File: C:\ASPRUN\STRUG31.INP (TRUEX-C, 0% HEEL, SST&DST BLEND)

Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	Total (kg)
B211COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.52E+08
B211LML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.34E+04	0.00E+00	0.00E+00	8.18E+05	4.61E+07
B211UTC	6.12E+01	4.66E-01	2.33E+00	0.00E+00	0.00E+00	1.39E+02	0.00E+00	0.00E+00	0.00E+00	3.05E+08
B212HLL	6.12E+01	4.66E-01	2.33E+00	3.71E-06	3.71E-06	1.39E+02	3.71E-06	3.71E-06	9.99E+05	3.71E+08
B212CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	9.99E+05	6.66E+07
B212PCYO	0.00E+00	0.00E+00	0.00E+00	3.71E-06	3.71E-06	0.00E+00	3.71E-06	3.71E-06	1.95E+04	3.02E+08
B212UTC	6.12E+01	4.66E-01	2.33E+00	0.00E+00	0.00E+00	1.39E+02	0.00E+00	0.00E+00	9.79E+05	6.96E+07
B212UTC1	6.12E+01	4.66E-01	2.33E+00	0.00E+00	0.00E+00	1.39E+02	0.00E+00	0.00E+00	9.79E+05	6.96E+07
B212UTC2	6.12E+13	5.00E-15	2.30E-14	0.00E+00	0.00E+00	1.39E-12	0.00E+00	0.00E+00	9.79E-09	6.96E-07
B21GAS	0.00E+00	0.00E+00	0.00E+00	1.16E-05	0.00E+00	3.17E+03	0.00E+00	0.00E+00	0.00E+00	3.03E+08
B21HLL	6.15E+01	4.68E-01	2.35E+00	0.00E+00	4.62E+05	4.62E+05	2.25E+06	4.02E+04	3.22E+04	2.50E+08
B21TRU	1.22E+04	9.27E+01	4.64E+02	0.00E+00	0.00E+00	4.62E+04	0.00E+00	0.00E+00	0.00E+00	9.07E+06
B220HLL	6.15E+01	4.68E-01	2.35E+00	1.53E+06	4.62E+05	2.63E+04	2.25E+06	4.02E+04	4.64E+04	5.92E+08
B22CM	1.00E-14	1.00E-14	1.00E-14	9.30E+06	1.00E-14	2.88E+04	1.00E-14	1.00E-14	1.42E+04	3.42E+08
B22COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.83E+08
B22GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.78E+03	0.00E+00	0.00E+00	0.00E+00	1.43E+08
B22HLL	0.00E+00	0.00E+00	0.00E+00	2.90E+05	0.00E+00	0.00E+00	2.25E+06	0.00E+00	3.21E+04	2.15E+08
B22LML	6.15E+01	4.68E-01	2.35E+00	1.24E+06	4.62E+05	2.38E+02	5.81E+03	4.02E+04	1.42E+04	4.52E+07
B22SR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.43E+04	0.00E+00	0.00E+00	0.00E+00	5.86E+06
B230TCU	6.12E+01	4.66E-01	2.33E+00	1.55E-06	1.55E-06	1.86E+04	1.55E-06	1.55E-06	7.61E+05	1.55E+08
B23CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.14E+04	1.00E-14	1.00E-14	4.30E+04	8.52E+07
B23COND	0.00E+00	0.00E+00	0.00E+00	1.55E-06	1.55E-06	0.00E+00	1.55E-06	1.55E-06	0.00E+00	4.09E+07
B23GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.18E+05	7.18E+05
B23TC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.30E+04	5.96E+06
B23U	6.12E+01	4.66E-01	2.33E+00	0.00E+00	0.00E+00	1.86E+04	0.00E+00	0.00E+00	0.00E+00	1.07E+08
B240U	6.12E+01	4.66E-01	2.33E+00	6.31E+04	6.79E-06	2.98E+04	6.79E-06	6.79E-06	2.76E+04	6.79E+08
B24CM	1.00E-14	1.00E-14	1.00E-14	4.97E+05	1.00E-14	3.70E+04	1.00E-14	1.00E-14	2.76E+04	5.72E+08
B24GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.79E-06	0.00E+00	6.79E-06	6.79E-06	0.00E+00	5.21E+08
B24LML	6.12E+01	4.66E-01	2.33E+00	6.31E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.76E+04	1.52E+08
B24TRCY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B24U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.98E+04	0.00E+00	0.00E+00	0.00E+00	6.52E+06
B3110LML	1.63E+00	4.52E-02	4.85E-02	1.91E-07	3.08E+02	6.51E+04	4.10E+06	1.34E+04	2.67E+06	2.36E+09
B311CM	1.00E-14	1.00E-14	1.00E-14	5.30E+06	1.00E-14	1.62E+05	1.00E-14	1.00E-14	1.00E-14	1.34E+09
B311COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.42E+03	0.00E+00	0.00E+00	0.00E+00	4.33E+08
B311GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.06E+03
B311LML	1.63E+00	4.52E-02	4.85E-02	1.91E-07	3.08E+02	5.56E+04	4.10E+06	1.34E+04	2.67E+06	1.92E+09
B311LML1	1.63E+00	4.52E-02	4.85E-02	1.91E-07	3.08E+02	5.56E+04	4.10E+06	1.34E+04	2.71E+06	1.93E+09
B311LML2	1.60E-14	4.52E-16	4.85E-16	1.91E-07	3.08E+12	5.56E-10	4.10E-08	1.34E-10	2.71E-08	1.93E-05
B3120LML	1.63E+00	4.52E-02	4.85E-02	2.08E+07	3.08E+02	5.46E+03	4.10E+06	1.34E+04	2.16E+06	2.35E+09
B312CM	1.00E-14	1.00E-14	1.00E-14	1.71E+06	1.00E-14	1.93E+04	1.00E-14	1.00E-14	1.00E-14	4.16E+08
B312COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.48E+02	0.00E+00	0.00E+00	0.00E+00	1.34E+09
B312GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.52E+06	1.52E+06
B312LML	1.63E+00	4.52E-02	4.85E-02	2.08E+07	3.08E+02	0.00E+00	4.10E+06	1.34E+04	6.36E+05	1.00E+09
B31CS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.05E+01	0.00E+00	0.00E+00	0.00E+00	5.36E+05
B31HLL1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.75E+03	0.00E+00	0.00E+00	0.00E+00	1.24E+06
B31HLL2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.75E-11	0.00E+00	0.00E+00	0.00E+00	1.24E-08
B31TC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.71E+03	0.00E+00	0.00E+00	0.00E+00	7.02E+05
B320HLL	1.74E-08	1.74E-08	1.74E-08	2.69E+04	1.74E-08	1.74E-08	1.74E-08	1.74E-08	5.68E+00	1.74E+06
B32CM	1.00E-14	1.00E-14	1.00E-14	1.07E+05	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.16E+00	5.04E+05
B32HLL	1.74E-08	1.74E-08	1.74E-08	2.69E+04	1.74E-08	1.74E-08	1.74E-08	1.74E-08	5.68E+00	1.74E+06
B32HLL	1.37E+04	1.08E+02	5.08E+02	5.51E+05	3.88E+04	2.60E-07	2.93E+05	6.39E+03	2.04E+04	2.60E+07
C11CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.24E+06	1.00E-14	9.36E+06
C12CM	1.00E-14	1.00E-14	1.00E-14	4.38E+08	1.00E-14	4.38E+07	1.00E-14	1.00E-14	4.38E+08	9.21E+08
C12HLS	1.56E+04	1.23E+02	5.89E+02	4.38E+08	4.33E+04	4.38E+07	1.36E+06	9.66E+05	4.40E+08	9.47E+08
C13HLS	1.56E+04	1.23E+02	5.89E+02	0.00E+00	4.33E+04	0.00E+00	1.36E+06	9.66E+05	0.00E+00	5.30E+06
C140HLS	7.53E-21	7.53E-21	7.53E-21	3.58E-07	7.53E-21	3.58E-08	7.53E-21	7.53E-21	3.58E-07	7.53E-07
C14CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
C14GAS	0.00E+00	0.00E+00	0.00E+00	3.58E-07	0.00E+00	3.58E-08	0.00E+00	0.00E+00	3.58E-07	7.53E-07
C14HLS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CBUSTSL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.83E+08
CDENSW	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
COST102	1.63E+00	4.52E-02	4.85E-02	1.55E+07	3.08E+02	6.77E+02	4.10E+06	1.34E+04	2.67E+06	1.06E+09
COST304	6.12E+01	4.66E-01	2.33E+00	0.00E+00	0.00E+00	1.86E+04	0.00E+00	0.00E+00	0.00E+00	7.45E+07
COST500	1.64E+00	4.56E-02	4.90E-02	1.76E+07	3.11E+02	0.00E+00	4.14E+06	1.35E+04	2.74E+06	1.49E+09

H-21

WMC-EP-0791

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 15 of 56)

File: C:\ASPRUN\STRUG31.INP (TRUEX-C, 0% HEEL, SST&DST BLEND)

Streams	H2O	PU	U	LANL	CS	SR	TC	I	FP2	AP1	NANO3	CHAZZ	SOI	OTH3	CR2O3	AM
DSTTNKW	1.31E+08	1.58E+02	4.35E+04	1.16E+04	1.23E+03	2.47E+02	2.34E+03	6.25E+02	5.51E+05	5.27E-01	3.59E+07	2.29E+06	1.00E-14	7.72E+05	6.83E+04	2.87E+01
NOBUSTS	0.00E+00	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	0.00E+00	5.66E+07	1.00E-14	5.10E+08	1.00E-14	1.00E-14
OFFGAS	0.00E+00	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	0.00E+00	4.66E+04	1.00E-14	4.19E+05	1.00E-14	1.00E-14
S10BUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.00E-18	0.00E+00	4.29E+07	0.00E+00	4.64E+08	0.00E+00	0.00E+00
S10GRT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.00E-18	0.00E+00	4.29E+07	0.00E+00	4.64E+08	0.00E+00	0.00E+00
S10LEACH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.00E-14	0.00E+00	4.29E+07	0.00E+00	1.03E+08	0.00E+00	0.00E+00
S1CM	0.00E+00	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	3.00E-14	0.00E+00	5.80E+07	1.00E-14	5.22E+08	1.00E-14	1.00E-14
S20ASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-18	0.00E+00	1.42E+07	0.00E+00	2.55E+08	0.00E+00	0.00E+00
S20GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-14	0.00E+00	1.42E+07	0.00E+00	2.55E+04	0.00E+00	0.00E+00
S2CM	0.00E+00	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	9.00E-14	6.63E+07	5.64E+03	0.00E+00	1.64E+04	0.00E+00	0.00E+00
S30CONC	2.95E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.00E-18	6.63E+03	5.64E+03	0.00E+00	6.10E+07	1.00E-14	1.00E-14
S30COND	5.60E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-14	0.00E+00	6.78E+06	1.00E-14	4.44E+05	0.00E+00	0.00E+00
S3CM	0.00E+00	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	3.00E-14	0.00E+00	1.42E+07	0.00E+00	4.45E+01	0.00E+00	0.00E+00
S40FILT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-18	0.00E+00	1.42E+07	0.00E+00	4.45E+02	0.00E+00	0.00E+00
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-17	0.00E+00	1.42E+04	0.00E+00	4.45E+00	1.00E-14	1.00E-14
S40LIQ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-14	0.00E+00	0.00E+00	1.00E-14	1.44E+07	1.15E+05	1.40E+01
S4CM	0.06E+00	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.55E+03	6.19E+02	4.36E+05	7.63E-01	1.54E+08	2.19E+06	1.00E-14	1.48E+07	4.32E+02	1.94E-01
SSTTNKW	3.86E+08	3.80E+02	1.59E+06	2.63E+05	6.46E+02	4.69E+04	4.23E+00	1.24E+03	2.34E+04	1.29E+00	2.41E+08	3.52E+06	1.00E-14	1.77E+05	1.00E-14	1.76E-01
STR102	7.80E+08	1.17E-01	9.47E+02	2.67E+01	1.88E+03	4.23E+00	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.71E+06	5.40E-01	1.00E-14	1.50E+07	4.37E+02	1.96E-01
STR304	6.82E+07	2.35E+00	1.38E+06	1.22E+03	1.00E-14	4.27E+00	4.35E+03	1.26E+03	2.37E+04	1.30E+00	2.55E+08	3.56E+06	0.00E+00	1.52E+07	1.83E+05	4.27E+01
STR500	1.19E+09	1.18E-01	9.56E+02	2.70E+01	1.57E+01	4.71E+04	3.89E+11	1.24E-11	9.87E-09	1.29E+00	1.89E+08	4.48E+06	0.00E+00	1.52E-07	1.83E-09	4.27E-13
T100HLL1	5.17E+08	5.38E+02	1.63E+06	2.75E+05	1.88E+03	4.71E-10	3.89E-11	1.24E-11	9.87E-09	1.30E-14	1.89E-06	4.48E-08	0.00E+00	1.52E-07	1.83E-09	4.27E-13
T100HLL2	5.17E-06	5.38E-12	1.63E-08	2.75E-09	1.88E-11	4.71E-10	3.89E-11	1.24E-11	9.87E-09	1.30E-14	1.89E-06	4.48E-08	0.00E+00	1.52E-07	1.83E-09	4.27E-13
T100HLL3	5.17E-06	5.38E-12	1.63E-08	2.75E-09	1.88E-11	4.71E-10	3.89E-11	1.24E-11	9.87E-09	1.30E-14	1.89E-06	4.48E-08	0.00E+00	1.52E-07	1.83E-09	4.27E-13
T310HLS	8.04E+07	5.33E+02	2.40E+05	2.72E+05	2.11E+01	4.67E+04	9.44E+01	8.60E-01	8.14E+04	9.62E-04	2.09E+06	5.94E+05	9.35E-07	3.16E+06	1.88E+04	4.23E+01
T31CM	1.58E+07	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	9.05E-04	1.23E+06	5.93E+05	9.35E-07	3.26E+06	1.88E+04	4.23E+01
T31HLS	1.77E+07	5.32E+02	2.40E+05	2.72E+05	2.05E+01	4.67E+04	8.59E+01	6.70E-02	4.07E+01	5.67E-05	6.05E+06	7.06E+02	0.00E+00	2.26E+05	9.40E+00	2.12E-02
T31ML	6.27E+07	2.66E-01	1.20E-02	1.36E+02	6.72E-01	2.33E+01	8.44E+00	8.60E-01	7.80E+04	9.61E-18	5.20E+06	5.93E+05	0.00E+00	3.48E+06	1.88E-10	4.23E+01
T34HLS1	6.33E+07	5.33E+12	2.40E+09	2.72E+09	2.11E-13	4.67E-10	9.43E-13	9.00E-15	7.80E-10	9.05E+05	2.73E+08	3.89E+06	1.32E-05	1.67E+07	1.64E+05	3.92E-01
T34HLS2	6.33E-07	5.33E-12	2.40E-09	2.72E+09	2.11E-13	4.67E-10	9.43E-13	9.00E-15	7.80E-10	9.05E+05	2.73E+08	3.89E+06	1.32E-05	1.67E+07	1.64E+05	3.92E-01
T420LLW	9.94E+08	5.10E+00	9.77E+03	2.61E+03	2.42E+01	4.50E+02	3.77E-01	1.24E+03	9.05E+05	1.29E+00	2.73E+08	3.89E+06	1.32E-05	1.67E+07	1.64E+05	3.92E-01
T42CM	2.19E-03	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14
T500ML	6.66E+05	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14
VAQUELLW	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14
VCBUSTSL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14
VNCBUSTS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14
VOFFGAS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14

H-22

MHC-EP-0791

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 16 of 56)

File: C:\ASPRUN\STRUG31.INP (TRUEX-C, 0% HEEL SST&DST BLEND)

Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	Total (kg)
DSTTNKW	8.26E+02	6.40E+01	1.11E+02	1.03E+07	1.76E+03	6.57E-05	2.20E+06	6.00E+04	1.73E+06	1.85E+08
NOBUSTS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.66E+08
OFFGAS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.66E+05
S10BUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.07E+08
S10GRT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.07E+08
S10LEACH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.46E+08
S1CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.80E+08
S20ASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.69E+08
S20GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.42E+07
S2CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.10E-13
S30CONC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.16E+08
S30COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.60E+08
S3CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.78E+07
S40FILT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.46E+07
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.47E+03
S40LIQ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.47E+04
S4CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-13
SSTTNKW	1.30E+04	4.54E+01	4.02E+02	9.14E+06	5.00E+05	1.00E-14	2.20E+06	1.00E-14	1.90E+06	1.02E+08
STR102	1.63E+00	4.52E-02	4.85E-02	1.55E+07	3.08E+02	6.77E+02	4.10E+06	1.34E+04	2.67E+06	1.06E+09
STR304	6.12E+01	4.66E-01	2.33E+00	1.00E-14	1.00E-14	1.86E+04	1.00E-14	1.00E-14	1.00E-14	7.45E+07
STR500	1.64E+00	4.56E-02	4.90E-02	1.76E+07	3.11E+02	1.00E-14	4.14E+06	1.35E+04	2.74E+06	1.49E+09
T100HLL1	1.38E+04	1.09E+02	5.13E+02	1.94E+07	5.02E+05	6.57E-05	4.40E+06	6.00E+04	3.54E+06	7.57E+08
T100HLL2	1.38E-10	1.09E-12	5.13E-12	1.94E-07	5.02E-09	6.57E-19	4.40E-08	6.00E-10	3.64E-08	7.57E-06
T100HLL3	1.38E-10	1.09E-12	5.13E-12	1.94E-07	5.02E-09	6.57E-19	4.40E-08	6.00E-10	3.64E-08	7.57E-06
T310HLS	1.37E+04	1.08E+02	5.08E+02	6.76E+05	3.88E+04	9.35E-07	2.93E+05	6.39E+03	2.05E+04	9.35E+07
T31CM	1.00E-14	1.00E-14	1.00E-14	1.54E+06	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.55E+02	1.94E+07
T31HLS	1.37E+04	1.08E+02	5.08E+02	5.25E+05	3.88E+04	9.35E-07	2.93E+05	6.39E+03	2.04E+04	2.43E+07
T31LML	6.85E+00	5.42E-02	2.54E-01	1.52E+05	1.94E+01	0.00E+00	1.47E+02	3.20E+00	1.23E+02	6.92E+07
T34HLS1	1.37E+04	1.08E+02	5.08E+02	3.55E+05	3.88E+04	7.22E+04	2.93E+05	6.39E+03	2.03E+04	7.40E+07
T34HLS2	1.37E-10	1.08E-12	5.08E-12	3.55E-09	3.88E-10	7.21E-10	2.93E-09	6.39E-11	2.03E-10	7.40E-07
T420LLW	1.31E+02	1.03E+00	4.98E+00	2.21E+07	4.63E+05	1.32E-05	4.11E+06	5.36E+04	1.50E+06	1.32E+09
T42CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.19E-03
T500LML	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05	2.25E-05	1.52E+06
VACUUELLW	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VCBUSTSL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VNCBUSTS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VOFFGAS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13

H-23

WMC-EP-0791

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 20 of 56)

File: C:\ASPRUNSLUG31.NP (SLUDGE WASH C, SST & DST BLEND, 0% HEEL)

All Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	Total (kg)
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.31E+09
2200LWWS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.73E+07
220CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.92E+05
2311CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E+13
2311HEOPT	1.30E+04	4.54E+01	4.02E+02	9.14E+08	5.00E+09	0.00E+00	2.20E+08	0.00E+00	1.90E+08	5.72E+08
2312CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E+13
2312HEOPT	8.26E+12	6.40E+13	1.11E+12	1.03E+07	1.76E+11	6.57E+19	2.20E+06	6.00E+10	1.74E+08	1.85E+06
2312HLWL	8.26E+02	6.40E+01	1.11E+02	1.03E+07	1.76E+03	6.57E+05	2.20E+06	6.00E+04	1.73E+06	1.85E+08
2313CM	1.30E+10	4.54E+13	4.02E+12	9.14E+08	5.00E+09	2.00E+26	2.20E+08	1.00E+14	1.90E+08	5.72E+06
2313HEEL	1.30E+04	4.54E+01	4.02E+02	9.14E+06	5.00E+05	2.00E+14	2.20E+06	2.00E+14	1.90E+06	5.72E+08
2314CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E+13
2314HEEL	8.26E+12	6.40E+13	1.11E+12	1.03E+07	1.76E+11	6.57E+19	2.20E+08	6.00E+10	1.74E+08	1.85E+06
2314HLWL	8.26E+02	6.40E+01	1.11E+02	1.03E+07	1.76E+03	6.57E+05	2.20E+06	6.00E+04	1.73E+06	1.85E+08
2322CONDO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E+09
2322HLWL	1.39E+04	1.10E+02	5.14E+02	4.26E+06	5.03E+05	3.49E+07	2.54E+06	4.67E+04	2.19E+05	8.72E+07
2322LWL	4.28E+00	5.01E+02	1.53E+01	9.28E+06	2.80E+02	9.98E+06	9.35E+05	6.72E+03	1.33E+06	4.99E+08
2322LWWS	8.54E+00	9.99E+02	3.05E+01	1.85E+07	5.59E+02	3.53E+05	1.87E+06	1.34E+04	3.14E+07	3.53E+09
3110CAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.90E+08
3110HWS	1.57E+04	1.24E+02	5.84E+02	4.36E+08	0.00E+00	4.37E+07	5.60E+06	2.87E+07	8.81E+02	6.84E+07
3200HLS	2.77E+04	2.20E+12	1.03E+11	3.89E+07	1.00E+08	1.00E+14	8.90E+08	1.20E+09	7.27E+08	1.51E+05
3200HLS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.20E+13
3400GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.89E+09
3400LWWS	4.27E+00	5.00E+02	1.53E+01	9.28E+06	2.79E+02	9.98E+06	9.35E+05	6.71E+03	1.32E+06	8.23E+08
3400LWWS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	8.23E+08
34CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.53E+09
3530LWWS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.74E+07
ADCELLW	1.39E+04	1.10E+02	5.14E+02	1.95E+07	5.03E+05	6.61E+05	4.41E+06	6.02E+04	3.65E+06	9.86E+08
B1110HSL	1.63E+02	4.54E+00	4.87E+00	1.68E+07	3.09E+02	6.55E+05	2.66E+06	1.34E+04	3.42E+06	7.98E+08
B1111HLL	1.63E+02	4.54E+00	4.87E+00	1.68E+07	3.09E+02	6.55E+05	2.66E+06	1.34E+04	3.42E+06	7.98E+08
B1111HLL2	1.63E+12	4.50E+14	4.90E+14	1.69E+07	3.09E+12	6.55E+19	2.66E+08	1.34E+10	3.42E+08	7.98E+06
B1111HLL3	1.63E+12	4.50E+14	4.90E+14	1.69E+07	3.09E+12	6.55E+19	2.66E+08	1.34E+10	3.42E+08	7.98E+06
B111HLS	1.37E+04	1.05E+02	5.10E+02	2.69E+06	5.03E+05	5.58E+07	1.75E+06	4.67E+04	2.28E+05	1.88E+08
B111HLS1	1.37E+04	1.05E+02	5.10E+02	2.69E+06	5.03E+05	5.58E+07	1.75E+06	4.67E+04	2.28E+05	1.88E+08
B111HLS2	1.37E+10	1.05E+12	5.10E+12	2.69E+08	5.03E+09	5.58E+21	1.75E+08	4.67E+10	2.28E+09	1.88E+06
B1120HLS	1.64E+02	4.56E+00	4.90E+00	1.69E+07	3.11E+02	6.60E+05	2.66E+06	1.35E+04	6.42E+06	6.36E+08
B112CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	3.81E+07
B112CONDO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B112GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.77E+06
B112HLS	1.63E+02	4.51E+00	4.85E+00	1.61E+06	1.23E+01	2.62E+08	8.03E+05	5.36E+00	1.05E+03	2.78E+07
B112HLS1	1.63E+02	4.51E+00	4.85E+00	1.61E+06	1.23E+01	2.62E+08	8.03E+05	5.36E+00	1.05E+03	2.78E+07
B112HLS2	1.63E+12	4.50E+14	4.80E+14	1.53E+07	3.11E+02	6.60E+05	1.87E+06	1.35E+04	2.66E+06	8.04E+08
B112HSL	1.64E+00	4.56E+02	4.90E+02	1.53E+07	3.11E+02	6.61E+05	1.87E+06	1.35E+04	2.66E+06	8.04E+08
B1130HLL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.71E+06
B113CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.72E+06
B113HLL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E+06
B113HLLS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E+06
B113HLS1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E+06
B113HLS2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E+06
B130HLL	5.20E+10	4.12E+12	1.93E+11	1.34E+08	1.89E+08	1.70E+08	9.58E+08	1.75E+09	1.64E+08	9.75E+06
B13CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E+13
B13CAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.66E+08
B13HLL	4.03E+10	3.53E+12	1.77E+11	0.00E+00	1.74E+08	1.69E+08	8.47E+08	1.51E+09	1.21E+09	7.51E+06
B13HLS	5.69E+11	5.89E+13	1.64E+12	1.34E+08	1.46E+09	6.45E+11	1.10E+08	2.41E+10	7.66E+10	2.23E+05
B14CONDO	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.92E+05
B14HLS	1.34E+05	1.34E+05	1.34E+05	1.34E+05	1.34E+05	1.34E+05	1.34E+05	1.34E+05	1.34E+05	1.34E+05
B210HLL	1.01E+10	7.67E+13	3.84E+12	9.53E+20	3.76E+09	4.02E+09	1.84E+08	3.29E+10	6.96E+09	9.53E+06
B211CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E+13

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 22 of 56)

File: C:\ASPRUN\SUG31.INP (SLUDGE WASH C, SST & DST BLEND, 0% HEEL)

Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	Total (kg)
B211COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.06E-06
B211LML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-10	0.00E+00	0.00E+00	6.69E-09	3.77E-07
B211UTC	5.01E-13	4.00E-15	1.90E-14	0.00E+00	0.00E+00	1.14E-12	0.00E+00	0.00E+00	0.00E+00	2.49E-06
B212OHL	4.11E-13	3.00E-15	1.60E-14	2.49E-20	2.49E-20	9.33E-13	2.49E-20	2.49E-20	6.71E-09	2.49E-06
B212CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B212RCYO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.31E-10	2.03E-06
B212UTC	4.11E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.33E-13	0.00E+00	0.00E+00	6.58E-09	4.67E-07
B212UTC1	4.11E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.33E-13	0.00E+00	0.00E+00	6.58E-09	4.67E-07
B212UTC2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B21GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.59E-11	0.00E+00	0.00E+00	0.00E+00	2.48E-06
B21HLL	5.04E-13	4.00E-15	1.90E-14	0.00E+00	3.78E-09	3.50E-09	1.84E-08	3.29E-10	2.64E-10	2.05E-06
B21TRU	9.97E-11	7.59E-13	3.80E-12	0.00E+00	0.00E+00	3.78E-10	0.00E+00	0.00E+00	0.00E+00	7.42E-08
B220HLL	2.13E-13	2.00E-15	8.00E-15	5.29E-09	1.60E-09	9.10E-11	7.80E-09	1.39E-10	1.60E-10	2.05E-06
B22CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B22COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.34E-07
B22GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.15E-12	0.00E+00	0.00E+00	0.00E+00	4.95E-07
B22HLL	0.00E+00	0.00E+00	0.00E+00	1.00E-09	0.00E+00	0.00E+00	7.78E-09	0.00E+00	1.11E-10	7.43E-07
B22LML	0.00E+00	0.00E+00	0.00E+00	4.29E-09	1.60E-09	8.23E-13	2.01E-11	1.39E-10	4.93E-11	1.57E-07
B22SR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.40E-11	0.00E+00	0.00E+00	0.00E+00	2.03E-08
B230TCU	1.85E-13	1.00E-15	7.00E-15	4.67E-21	4.67E-21	5.62E-11	4.67E-21	4.67E-21	2.30E-09	4.67E-07
B23CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B23COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.24E-07
B23GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.17E-09	2.17E-09
B23TC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.30E-10	1.80E-08
B23U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.62E-11	0.00E+00	0.00E+00	0.00E+00	3.24E-07
B240U	2.90E-14	2.22E-16	1.00E-15	3.00E-11	3.24E-21	1.42E-11	3.24E-21	3.24E-21	1.32E-11	3.24E-07
B24CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B24GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.48E-07
B24LML	0.00E+00	0.00E+00	0.00E+00	3.00E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.32E-11	7.22E-08
B24RCYC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B24U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.42E-11	0.00E+00	0.00E+00	0.00E+00	3.11E-09
B310LML	1.63E+00	4.54E-02	4.87E-02	1.75E-07	3.09E-02	1.45E-04	1.86E-06	1.34E-04	2.65E-06	1.84E-09
B311CM	1.00E-14	1.00E-14	1.00E-14	4.10E-06	1.00E-14	1.25E-05	1.00E-14	1.00E-14	1.00E-14	1.03E-09
B311COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.33E-03	0.00E+00	0.00E+00	0.00E+00	3.36E-08
B311GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.45E-02	0.00E+00	0.00E+00	0.00E+00	1.45E-02
B311LML	1.63E+00	4.54E-02	4.87E-02	1.75E-07	3.09E-02	7.16E-03	1.86E-06	1.34E-04	2.65E-06	1.50E-09
B311LML1	1.63E+00	4.54E-02	4.87E-02	1.75E-07	3.09E-02	7.16E-03	1.86E-06	1.34E-04	2.65E-06	1.50E-09
B311LML2	1.60E-14	4.54E-16	4.87E-16	7.5E-07	3.09E-12	7.16E-11	1.86E-08	1.34E-10	2.65E-08	1.50E-05
B3120LML	1.63E+00	4.53E-02	4.87E-02	1.85E-07	3.09E-02	4.25E-03	1.86E-06	1.34E-04	2.64E-06	1.82E-09
B312CM	1.00E-14	1.00E-14	1.00E-14	1.32E-06	1.00E-14	1.49E-04	1.00E-14	1.00E-14	1.00E-14	3.20E-08
B312COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.25E-02	0.00E+00	0.00E+00	0.00E+00	1.00E-09
B312GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.19E-03
B312LML	1.63E+00	4.53E-02	4.87E-02	1.85E-07	3.09E-02	0.00E+00	1.86E-06	1.34E-04	2.64E-06	8.21E-08
B31CS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.15E-01	0.00E+00	0.00E+00	0.00E+00	4.19E-05
B31HLL1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.65E-03	0.00E+00	0.00E+00	0.00E+00	9.59E-05
B31HLL2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.65E-11	0.00E+00	0.00E+00	0.00E+00	9.59E-09
B31TC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.62E-03	0.00E+00	0.00E+00	0.00E+00	5.41E-05
B320HLL	1.35E-08	1.35E-08	1.35E-08	2.08E-04	1.35E-08	1.35E-08	1.35E-08	1.35E-08	3.00E+00	1.35E-06
B32CM	1.00E-14	1.00E-14	1.00E-14	8.22E-04	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.19E+00	3.87E-05
B32HLL	1.35E-08	1.35E-08	1.35E-08	2.08E-04	1.35E-08	1.35E-08	1.35E-08	1.35E-08	3.00E+00	1.35E-06
B3HLW	1.39E+04	1.10E+02	5.14E+02	4.26E+06	5.03E+05	3.49E-07	2.54E+06	4.67E+04	2.19E+05	8.72E-07
C11CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.77E+07	1.00E-14	5.10E-07
C12CM	1.00E-14	1.00E-14	1.00E-14	4.38E-08	1.00E-14	4.38E-07	1.00E-14	1.00E-14	4.38E+08	9.21E-08
C12HLS	1.57E+04	1.24E+02	5.94E+02	4.36E+08	5.60E+05	4.37E+07	5.60E+06	1.05E+06	4.41E+08	1.01E-09
C13HLS	1.57E+04	1.24E+02	5.94E+02	0.00E+00	5.60E+05	0.00E+00	5.60E+06	1.05E+06	8.81E+02	1.75E-07
C140HLS	9.59E-23	9.59E-23	9.59E-23	4.57E-09	9.59E-23	4.57E-10	9.59E-23	9.59E-23	4.57E-09	9.59E-09
C14CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
C14GAS	0.00E+00	0.00E+00	0.00E+00	4.57E-09	0.00E+00	4.57E-10	0.00E+00	0.00E+00	4.57E-09	9.59E-09
C14HLS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CBUSTSL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.78E-08
CDENSW	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
COST102	1.63E+00	4.52E-02	4.85E-02	1.52E-07	3.08E-02	5.26E-02	1.86E-06	1.34E-04	2.63E-06	8.28E-08
COST304	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
COST500	1.64E+00	4.56E-02	4.90E-02	1.69E+00	3.11E+02	0.00E+00	1.87E-06	1.35E-04	2.66E-06	1.15E-09

H-29

MHC-EP-0791

H-35

H-35

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 30 of 56)

File: C:\ASPRUNSCLEC31.INP (CLEAN OPTION, 0% HEEL, SST & DST BLEND, CURIE RUN)

Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	TOTAL (CI)
B212DU	9.87E-05	7.63E-03	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.92E+02
B212ARCY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B212CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B212COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E+00
B212LML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.46E+00
B212ORCY	9.87E-05	7.63E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.07E+02
B212U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.81E+02
B2210HLL	9.97E-03	7.71E-01	1.04E+06	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.77E+07
B221AMLN	9.97E-03	3.86E-01	1.04E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E+06
B221CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B221HLL	9.97E-07	3.86E-01	1.04E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.65E+07
B221LML	9.97E-07	3.86E-05	1.04E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.80E+03
B2220HLL	9.97E-03	3.86E-01	1.04E+06	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.18E+06
B222ALML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.30E+01
B222AMLN	0.00E+00	0.00E+00	1.04E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E+06
B222BLML	9.97E-03	3.86E-01	1.04E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.91E+02
B222CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B2310HLL	9.97E-07	3.86E-01	1.04E+02	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.65E+07
B231CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B231HLL	9.97E-07	3.86E-01	1.04E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.17E+06
B231LML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.40E+01
B231SRTC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.14E+07
B2320HLL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.14E+07
B232CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B232LML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B232SRTC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.14E+07
B240HLL	9.97E-07	3.86E-01	1.04E+02	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.17E+06
B24CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B24CS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.10E+06
B24LML	9.97E-07	3.86E-01	1.04E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.93E+04
B310HLL	3.32E-03	2.95E-01	1.41E+03	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.20E+07
B31CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B31COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B31CS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.16E+07
B31HLL	3.32E-03	2.95E-01	1.41E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.42E+05
B320LML	3.32E-03	2.95E-01	1.41E+03	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.42E+05
B32CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B32COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.43E+16
B32LML	3.32E-03	2.95E-01	1.41E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.77E+05
B32SR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.52E+04
B330LML	3.32E-03	2.95E-01	1.41E+03	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	3.77E+05
B33CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B33LML	3.32E-03	2.95E-01	1.41E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.42E+05
B33TC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.46E+04
B3CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B3GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B3HRCY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.16E+06
B410LW	1.33E-02	1.07E+00	1.72E+03	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.14E+05
B41CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B41COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.01E-13
B41GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.75E+03
B41NACR	1.33E-02	1.07E+00	1.72E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E+05
B420LML	1.33E-02	1.07E+00	1.72E+03	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.08E+05
B42CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B42CR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B42LML	1.06E-02	8.54E-01	1.38E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.27E+05
B42NAOH	2.65E-03	2.13E-01	3.44E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.14E+04
B430HNO3	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B43CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B43GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B43HNO3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B43HRCY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B440HLS	9.87E-01	7.63E+01	1.04E+06	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.14E+08
B44CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13

H-37

MHC-EP-0791

[illegible][illegible]

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 34 of 56)

File C:\ASPRUN\STRUC31.INP (TRUEX-C, 0% HEEL, SST & DST BLEND, CURIE RUN)

Input Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	TOTAL (C)
22CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2311CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2312CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2313CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2314CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
32CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
34CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
353CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B111CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B112CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B113CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B13CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B143CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B211CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B212CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B22CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B23CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B24CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B311CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B312CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B32CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
C11CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
C12CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
C14CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S1CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S2CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S3CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S4CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
T31CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
T42CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
DSTTNKW	1.00E-14	4.54E+01	2.25E+05	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.23E+07
SSTTNKW	1.00E+00	3.20E+01	8.14E+05	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.73E+07
CBUSTSL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VOBUSTSL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
NCOBUSTS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VNCOBUSTS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
OFFGAS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VOFFGAS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
AQUELLW	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VAQUELLW	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
TOTAL (C)	1.00E+00	7.74E+01	1.04E+06	4.00E-13	4.00E-13	4.00E-13	4.00E-13	4.00E-13	4.00E-13	1.10E+08

Output Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	TOTAL (C)
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.31E-03
3110HLWS	9.91E-01	7.67E+01	1.03E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.08E+08
3200HLWS	3.00E-14	1.56E-12	2.08E-08	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.19E-06
3400LLWS	4.75E-03	3.66E-01	5.05E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.85E+05
3400LWWS	4.75E-03	3.66E-01	5.05E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.85E+05
3530LWWS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.31E+01
B24U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E+02
3110GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.19E+02
3400GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.60E-14
B112GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B13GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.92E+02
B21GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.89E+04
B22GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E+03
B23GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B24GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.78E+01
B311GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.28E-20
B312GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C14GAS	0.00E+00	7.77E-13	1.03E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.08E-06
S10GRT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-17
S10BUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-17
S2UASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-14
S30COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E-13
S30CONC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.60E-14
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.30E-17
TOTAL (C)	1.00E+00	7.74E+01	1.04E+06	2.00E-14	2.00E-14	2.00E-14	2.00E-14	2.00E-14	2.00E-14	1.10E+08

H-41

MHC-EP-0791

FILE C:\ASP\RUNSTRUCT1.INP (TRUEX-C, 0% HEE, SST & DST BLEND, CURIE RUN)

[illegible]

FORM C-VASPRUNSTRUC31 INP (TRUEX-C, 0% HEEL SST & DST BLIND, CURIE POINT)

[illegible]

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 40 of 56)

File: C:\ASPRUN\STRUC31.INP (TRUEX-C, 0% HEEL, SST & DST BLEND, CURIE RUN)

Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	TOTAL (CI)
DSTTNKW	1.00E-14	4.54E+01	2.25E+05	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.23E+07
NOBUSTS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
OFFGAS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S10RUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-17
S10GRT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-17
S10LEACH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-13
S1CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S20ASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-14
S20GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-14
S2CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S30CONC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.60E-14
S30COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E-13
S3CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S40FILT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.00E-14
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.30E-17
S40LIQ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.60E-17
S4CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
SSTTNKW	1.00E+00	3.20E+01	8.14E+05	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.73E+07
STR102	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
STR304	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
STR500	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
T100HLL1	1.00E+00	7.74E+01	1.04E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E+08
T100HLL2	1.00E-14	7.74E-13	1.04E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-06
T100HLL3	1.00E-14	7.74E-13	1.04E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-06
T310HLS	9.91E-01	7.67E+01	1.03E+06	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.27E+07
T31CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
T31HLS	9.91E-01	7.67E+01	1.03E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.27E+07
T31LML	4.95E-04	3.84E-02	5.15E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.09E+04
T34HLS1	9.91E-01	7.67E+01	1.03E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.27E+07
T34HLS2	1.00E-14	7.67E-13	1.03E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.37E+06
T420LLW	9.50E-03	7.32E-01	1.01E+04	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
T42CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-17
T500LML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.50E-13
VAQUELLW	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VCBUSTSL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VNCBUSTS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VOFFGAS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 44 of 56)

File: C:\ASPRUN\SLUC31.INP (SLUDGE WASH C. 0% HEEL SST & DST BLEND, CURIE RUN)

All Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	TOTAL (Ci)
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E-04
2200LMWS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E+00
22CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2311CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2311EOPT	1.00E-14	3.20E-13	8.14E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.73E-07
2311HLWL	1.00E+00	3.20E+01	8.14E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.73E+07
2312CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2312EOPT	0.00E+00	4.54E-13	2.25E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.23E-07
2312HLWL	0.00E+00	4.54E+01	2.25E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.23E+07
2313CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2313HEEL	1.00E-14	3.20E-13	8.14E-09	2.00E-26	2.00E-26	2.00E-26	2.00E-26	2.00E-26	2.00E-26	6.73E-07
2313HLWL	1.00E+00	3.20E+01	8.14E+05	2.00E-14	2.00E-14	2.00E-14	2.00E-14	2.00E-14	2.00E-14	6.73E+07
2314CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
2314HEEL	2.00E-25	4.54E-13	2.25E-09	2.00E-26	2.00E-26	2.00E-26	2.00E-26	2.00E-26	2.00E-26	4.23E-07
2314HLWL	2.00E-14	4.54E+01	2.25E+05	2.00E-14	2.00E-14	2.00E-14	2.00E-14	2.00E-14	2.00E-14	4.23E+07
2322COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E+00
2322HLWL	9.99E-01	7.73E+01	1.04E+06	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.09E+08
2322LLWL	3.09E-04	3.54E-02	3.09E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.19E+05
2322LMWL	3.09E-04	3.54E-02	3.09E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.19E+05
2322LWS	6.18E-04	7.07E-02	6.18E+02	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	8.37E+05
3110GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E+02
3110HLWS	9.99E-01	7.73E+01	1.04E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E+08
3200HLWS	3.00E-14	1.56E-12	2.08E-08	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.19E-06
32CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
3400GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.10E-14
3400LWS	3.09E-04	3.54E-02	3.09E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.19E+05
3400LMWS	3.09E-04	3.54E-02	3.09E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.19E+05
34CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
3530LMWS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.85E+00
353CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
AQUELW	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B1110HSL	1.00E+00	7.74E+01	1.04E+06	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.10E+08
B111CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B111HLL	1.18E-02	3.20E+00	9.85E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.21E+07
B111HLL1	1.18E-02	3.20E+00	9.85E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.21E+07
B111HLL2	1.18E-16	3.20E-14	9.85E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.21E-07
B111HLL3	1.18E-16	3.20E-14	9.85E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.21E-07
B111HLS	9.88E-01	7.42E+01	1.03E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.74E+07
B111HLS1	9.88E-01	7.42E+01	1.03E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.74E+07
B111HLS2	1.00E-14	7.42E-13	1.03E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.74E-07
B1120HLS	1.18E-02	3.20E+00	9.85E+03	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.21E+07
B112CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B112COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B112GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.39E+01
B112HLS	1.17E-02	3.17E+00	9.75E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.43E+05
B112HLS1	1.17E-02	3.17E+00	9.75E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.43E+05
B112HLS2	1.17E-16	3.20E-14	9.75E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.43E-09
B112HSL	1.18E-04	3.20E-02	9.85E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.14E+07
B112HSL1	1.18E-04	3.20E-02	9.85E+01	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.14E+07
B1130HLL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B113CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B113HLL	1.18E-04	3.20E-02	9.85E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.14E+07
B113HLS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.11E+02
B113HLS1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.11E+02
B113HLS2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.12E-12
B130HLL	3.00E-14	1.56E-12	2.08E-08	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.78E-06
B13CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B13GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.79E-11
B13HLL	0.00E+00	1.34E-12	1.90E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.59E-06
B13HLS	0.00E+00	2.23E-13	1.77E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E-07
B143CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B143COND	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.85E+00
B210HLL	1.00E-14	1.35E-12	1.90E-08	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.59E-06
B211CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13

H-51

MHC-EP-0791

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 46 of 56)

File C:\ASPRUN\S\LUC31.INP (SLUDGE WASH C. 0% HEEL, SST & DST BLEND, CURIE RUN)

Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	TOTAL (Ci)
B211COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B211LML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B211UTC	0.00E+00	7.00E-15	9.46E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.50E-09
B212OHL	1.00E-14	1.70E-14	9.46E-11	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	3.50E-09
B212CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B212PCYO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.97E-09
B212UTC	0.00E+00	0.00E+00	9.46E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.30E-10
B212UTC1	0.00E+00	0.00E+00	9.46E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.30E-10
B212UTC2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B21GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.99E-09
B21HLL	0.00E+00	7.00E-15	9.51E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.56E-06
B21TRU	0.00E+00	1.33E-12	1.88E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.35E-08
B22OHL	1.00E-14	1.70E-14	9.51E-11	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.56E-06
B22CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B22COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B22GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.53E-11
B22HLL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.64E-07
B22LML	0.00E+00	0.00E+00	9.51E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.25E-08
B22SR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E-06
B230TCU	1.00E-14	1.00E-14	9.46E-11	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.30E-10
B23CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B23COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B23GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B23TC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.98E-10
B23U	0.00E+00	0.00E+00	9.46E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.32E-10
B24U	1.00E-14	1.00E-14	9.46E-11	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.32E-10
B24CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B24GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.77E-12
B24LML	0.00E+00	0.00E+00	9.46E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-10
B24TCRCY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B24U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.22E-12
B311OLML	1.18E-04	3.20E-02	9.85E-01	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.14E+07
B311CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B311COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E-14
B311GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B311LML	1.18E-04	3.20E-02	9.85E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.09E+05
B311LML1	1.18E-04	3.20E-02	9.85E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.09E+05
B311LML2	1.18E-18	3.20E-16	9.85E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.09E-09
B312OLML	1.18E-04	3.20E-02	9.85E-01	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	7.09E+05
B312CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B312COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E+00
B312GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.60E+00
B312LML	1.18E-04	3.20E-02	9.85E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.79E+05
B31CS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.07E+07
B31HLL1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E+07
B31HLL2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E+07
B31TC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E+04
B32OHL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.08E+07
B32CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
B32HLL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.08E+07
B3HLW	9.99E-01	7.73E+01	1.04E+06	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.09E+08
C11CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
C12CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
C12HLS	9.99E-01	7.73E+01	1.04E+06	2.00E-14	2.00E-14	2.00E-14	2.00E-14	2.00E-14	2.00E-14	1.09E+08
C13HLS	9.99E-01	7.73E+01	1.04E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E+08
C14HLS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.08E+07
C14CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
C14GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.08E+07
C14HLS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CBUSTSL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
COENSW	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
COST102	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.70E-14
COST304	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
COST500	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.30E-14

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 48 of 56)

Streams	TH	NP	LANH	NACH	BA	HNO3	AL2O3	SiO2	NOX	TOTAL (G)
DSTTNKW	1.00E-14	4.54E+01	2.25E+05	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.23E+07
NCBUSTS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
OFFGAS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S108UR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-17
S108RT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-17
S10LEACH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E-13
S10CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S20ASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-14
S20GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-14
S20CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S30CONC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.60E-14
S30COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E-13
S30CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
S40FILT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.00E-14
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.30E-17
S40LIQ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.60E-17
S40CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
SSTTNKW	1.00E+00	3.20E+01	8.14E+05	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.73E+07
STR102	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
STR304	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
STR500	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
T100HLL1	1.00E+00	7.74E+01	1.04E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E+08
T100HLL2	1.00E-14	7.74E-13	1.04E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-06
T100HLL3	1.00E-14	7.74E-13	1.04E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-06
T310HLS	1.00E+00	7.74E+01	1.04E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.81E+07
T310CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
T31HLS	9.99E-01	7.73E+01	1.04E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.79E+07
T31LML	5.00E-04	3.87E-02	5.20E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.58E+05
T34HLS1	0.00E+00	1.55E-12	2.06E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.30E-06
T34HLS2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
T420LLW	6.18E-04	7.07E-02	6.18E+02	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	8.37E+05
T42CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
T500LML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.21E-17
VAQUELLW	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VCBUSTSL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VNCBUSTS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VOFFGAS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13

H-55

WMC-EP-0791

FIG. 3. CASPRUNSCLEAN.G1.INP (CLEAN OPTION WITH CPUs, SST&DST BLEND, HEEL = 96% DST + 64% SST)

[illegible]

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 52 of 56)

Fw: C:\ASPRUN\SCLEANG41.MP (CLEAN OPTION WITH CPUs: SSTADST BLEND: HEEL = 96%, DST = 64% SST)

Stream	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	TOTAL (kg)
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.57E-01	0.00E+00	0.00E+00	1.48E+00	2.68E+09
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.57E-03	0.00E+00	0.00E+00	1.48E+00	1.05E+08
2200H2O	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.23E+06
2200H2O	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E+13
2311CM	4.68E-11	1.63E-13	1.45E-12	3.29E-08	1.80E-09	0.00E+00	7.92E-05	0.00E+00	6.84E+05	2.06E+06
2311H2O	4.68E+03	1.63E+02	1.45E+02	3.29E+06	1.80E+05	0.00E+00	7.92E+05	0.00E+00	6.84E+05	2.06E+08
2312CM	3.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E+13
2312H2O	3.00E+13	2.60E+14	4.40E+14	4.12E+09	7.04E+13	2.63E+20	8.00E+10	2.40E+11	6.94E+10	7.40E+08
2312H2O	3.00E+01	2.56E+00	4.44E+00	4.12E+05	7.04E+01	2.63E+06	8.00E+04	2.40E+03	6.94E+04	7.40E+06
2313H2O	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E+13
2313H2O	8.32E+03	2.57E+02	5.85E+06	3.20E+05	1.30E+14	7.92E+05	7.00E+15	1.22E+06	3.66E+08	2.06E+08
2313H2O	4.68E+03	1.63E+01	1.45E+02	3.29E+06	1.80E+05	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E+13
2314H2O	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E+13
2314H2O	7.92E+02	6.14E+01	1.07E+02	8.98E+06	1.69E+03	6.31E+05	2.11E+06	5.78E+04	1.67E+06	1.78E+08
2314H2O	3.00E+01	2.56E+00	4.44E+00	4.12E+05	7.04E+01	2.63E+06	8.00E+04	2.40E+03	6.94E+04	7.40E+06
2322H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.57E-03	0.00E+00	0.00E+00	1.48E+00	2.78E+09
2322H2O	1.00E+04	8.54E+01	4.04E+02	2.13E+03	2.28E+04	7.45E+03	4.95E+03	2.53E+01	1.09E+02	1.42E+06
2322H2O	5.76E+01	2.67E+01	2.21E+07	1.85E+05	6.00E+00	0.00E+00	4.04E+06	2.5E+04	1.63E+06	2.41E+08
2322H2O	1.42E+02	4.73E+01	6.57E+01	5.45E+07	4.57E+05	3.81E+05	9.96E+06	5.80E+04	3.16E+05	3.81E+09
3110CAND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3110H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3110H2O	1.58E+04	1.23E+02	5.84E+02	4.30E+08	3.19E+04	0.00E+00	3.99E+04	5.81E+05	0.00E+00	1.24E+06
3200H2O	9.11E+03	9.05E+01	3.64E+02	1.57E+07	3.22E+05	6.31E+05	3.52E+06	5.78E+04	2.88E+06	5.44E+08
3200H2O	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.21E+06
3400GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3400H2O	7.10E+01	5.83E+01	3.29E+01	2.73E+07	2.29E+05	0.00E+00	4.98E+06	2.90E+04	1.95E+06	9.45E+08
3400H2O	7.10E+01	5.83E+01	3.29E+01	2.73E+07	2.29E+05	0.00E+00	4.98E+06	2.90E+04	1.95E+06	9.45E+08
3400H2O	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.88E+07
3530CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.88E+08
3530CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.22E+07
ADUELLW	1.53E-05	1.53E-05	1.53E-05	4.38E+08	1.53E-05	4.38E+07	1.53E-05	1.53E-05	5.70E+08	1.05E+09
ADUELLW	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	7.19E+08
B1110HLL	5.19E+03	4.10E+01	1.92E+02	7.29E+06	1.88E+05	2.45E+05	1.65E+06	2.25E+04	1.36E+06	3.26E+08
B1110HLL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.13E+08
B111HLL	6.10E+01	1.69E+00	1.82E+00	6.20E+06	1.15E+02	2.43E+05	9.94E+05	5.02E+03	1.28E+06	2.99E+08
B111HLL	5.13E+03	3.93E+01	1.91E+02	7.29E+06	1.88E+05	2.45E+05	1.65E+06	2.25E+04	1.36E+06	3.26E+08
B112HLL	6.31E+01	1.75E+00	1.88E+00	6.83E+06	1.19E+02	2.52E+05	1.03E+06	5.19E+03	2.40E+06	3.15E+08
B112HLL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.63E+07
B112GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B112HLL	6.30E+01	1.75E+00	1.88E+00	6.21E+06	1.19E+02	2.52E+05	7.19E+05	5.19E+03	1.02E+06	3.10E+08
B112HLL	6.24E+01	1.73E+00	1.86E+00	6.19E+05	1.18E+02	2.51E+05	3.08E+05	2.07E+05	4.10E+02	4.09E+06
B120HLL	1.00E+04	8.62E+01	3.88E+02	1.39E+07	4.68E+05	8.68E+02	3.92E+06	4.65E+04	9.51E+05	2.55E+08
B12CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	9.39E+07
B12HLL	2.79E+01	4.85E+01	1.05E+07	8.00E+04	8.61E+02	1.12E+04	1.00E+00	1.12E+04	7.80E+05	2.10E+08
B12HLL	3.21E+01	2.79E+01	3.88E+02	3.27E+06	3.80E+05	6.74E+00	2.50E+05	3.51E+04	1.70E+05	4.54E+07
B130HLL	1.37E+04	4.89E+02	4.02E+05	1.00E+14	5.90E+05	9.69E+05	3.15E+05	4.45E+04	2.39E+05	2.73E+08
B131CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E+00	1.00E+00	1.89E+05	2.66E+05
B131HLL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B131HLL	1.23E+04	9.73E+01	4.39E+02	0.00E+00	5.41E+05	9.68E+05	1.58E+05	4.00E+04	2.86E+04	2.58E+08
B132HLL	1.39E+03	1.00E+01	4.96E+01	4.02E+05	5.07E+04	1.70E+03	1.50E+05	4.51E+03	2.08E+04	1.44E+07
B132HLL	1.45E+03	1.14E+01	5.16E+01	4.18E+04	5.07E+04	1.16E+03	1.62E+05	4.60E+03	2.3E+04	4.58E+07
B132CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E+00	1.00E+00	9.07E+03	3.14E+07
B132GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B132HLL	7.27E+02	5.75E+01	4.61E+01	0.00E+00	4.53E+04	1.15E+05	6.34E+04	4.18E+03	2.99E+03	3.59E+07
B132HLL	3.60E+01	2.85E+01	2.78E+01	2.09E+03	2.72E+02	5.99E+05	4.95E+03	2.50E+03	1.09E+02	4.92E+05
B132HLL	6.84E+02	5.41E+00	5.29E+00	3.97E+04	5.78E+05	1.14E+03	9.41E+04	4.80E+02	2.08E+03	9.35E+06
B2110HLL	1.33E+04	1.05E+02	4.95E+02	4.64E+06	5.98E+05	1.14E+06	2.25E+05	4.50E+04	6.24E+04	4.64E+08
B211HLL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E+00	1.00E+00	1.33E+04	1.63E+08
B211HLL	1.33E+02	1.05E+00	4.95E+02	4.64E+06	5.98E+05	1.14E+06	2.25E+05	4.50E+04	6.24E+04	4.64E+08
B211HLL	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B211HLL	1.32E+04	1.04E+02	4.95E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.07E+07
B211HLL	1.32E+04	1.04E+02	0.00E+00	0.00E+00	0.00E+00	1.45E+02	0.00E+00	0.00E+00	0.00E+00	7.28E+07

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 54 of 56)

File: C:\ASPRUNSCLEAN41.INP (CLEAN OPTION WITH CPUS, SST&DST BLEND, HEEL = 96% DST + 64% SST)

Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	TOTAL (kg)
B2120U	1.34E+00	1.06E-02	1.55E-08	1.55E-06	1.55E-06	1.59E+04	1.55E-06	1.55E-06	1.14E+05	1.55E+08
B212ARCY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+05	6.78E+05
B212CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.67E+04	1.00E-14	1.00E-14	1.35E+04	8.24E+07
B212COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.87E+02	0.00E+00	0.00E+00	0.00E+00	1.44E+08
B212ML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E+04	2.17E+06
B212ORCY	1.34E+00	1.06E-02	0.00E+00	0.00E+00	0.00E+00	1.51E+04	0.00E+00	0.00E+00	0.00E+00	6.85E+06
B212U	0.00E+00	0.00E+00	1.55E-06	1.55E-06	1.55E-06	0.00E+00	1.55E-06	1.55E-06	0.00E+00	1.69E+06
B2210HLL	1.35E+02	1.07E+00	5.03E+02	6.47E-06	6.09E+05	1.14E+06	2.29E+05	4.58E+04	7.30E+05	6.47E+08
B221AMLN	1.35E+02	5.36E-01	5.03E+02	0.00E+00	0.00E+00	1.07E+05	0.00E+00	0.00E+00	0.00E+00	2.04E+08
B221CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.81E+04	1.00E-14	1.00E-14	7.09E+05	3.31E+08
B221HLL	1.35E-02	5.36E-01	5.03E-02	0.00E+00	6.09E+05	1.03E+06	2.29E+05	4.58E+04	3.28E+04	3.61E+08
B221ML	1.35E-02	5.36E-05	5.03E-02	6.47E-06	0.00E+00	3.22E+02	0.00E+00	0.00E+00	6.97E+05	8.18E+07
B2220HLL	1.36E+02	5.37E-01	5.05E+02	2.44E-06	2.44E-06	1.14E+05	2.44E-06	2.44E-06	2.44E-06	2.44E+08
B222ALML	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.37E+03	0.00E+00	0.00E+00	0.00E+00	3.67E+07
B222AMLN	0.00E+00	0.00E+00	5.05E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.56E+05
B222BLML	1.36E+02	5.37E-01	5.05E+02	2.44E-06	2.44E-06	1.12E+05	2.44E-06	2.44E-06	2.44E-06	2.07E+08
B222CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.49E+03	1.00E-14	1.00E-14	1.00E-14	3.95E+07
B2310HLL	1.37E-02	5.42E-01	5.09E+02	1.16E-05	6.16E+05	1.26E+06	2.31E+05	4.64E+04	6.86E+05	1.16E+09
B231CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.20E+05	1.00E-14	1.00E-14	6.56E+05	7.96E+08
B231HLL	1.37E-02	5.42E-01	5.09E+02	0.00E+00	6.16E+05	1.19E+06	2.31E+05	4.64E+04	3.31E+04	5.09E+08
B231ML	0.00E+00	0.00E+00	0.00E+00	1.16E-05	0.00E+00	1.10E+04	0.00E+00	0.00E+00	1.52E+05	4.26E+07
B231SRCT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.16E+05	6.14E+04	0.00E+00	0.00E+00	0.00E+00	6.06E+08
B2320HLL	1.20E-05	1.20E-05	1.20E-05	1.20E-05	6.16E+05	7.27E+04	1.20E-05	1.20E-05	1.20E-05	1.20E+09
B232CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.12E+04	1.00E-14	1.00E-14	1.00E-14	5.89E+08
B232ML	1.20E-05	1.20E-05	1.20E-05	1.20E-05	5.89E+05	1.10E+03	1.20E-05	1.20E-05	1.20E-05	5.38E+08
B232SRCT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.83E+04	7.16E+04	0.00E+00	0.00E+00	0.00E+00	6.58E+08
B240HLL	1.37E-02	5.42E-01	5.09E+02	5.09E-06	6.16E+05	1.19E+06	2.68E+05	4.64E+04	3.32E+04	5.09E+08
B24CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	3.71E+04	1.00E-14	3.97E+01	4.56E+05
B24CS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.69E+04	0.00E+00	1.16E+01	1.65E+05
B24ML	1.37E-02	5.42E-01	5.09E+02	5.09E-06	6.16E+05	1.19E+06	2.31E+05	4.64E+04	3.32E+04	5.09E+08
B310HLL	2.32E+01	2.11E-01	3.52E-01	1.54E+07	5.94E+04	4.49E+03	3.42E+06	1.43E+04	1.88E+06	5.78E+08
B31CM	1.00E-14	1.00E-14	1.00E-14	9.27E+04	1.00E-14	9.04E+03	1.00E-14	1.00E-14	1.00E-14	1.65E+07
B31COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.48E+04	1.48E+04
B31CS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.75E+06
B31HLL	2.32E+01	2.11E-01	3.52E-01	1.54E+07	5.94E+04	0.00E+00	3.42E+06	1.43E+04	1.88E+06	5.73E+08
B320ML	2.35E+01	2.14E-01	3.57E-01	1.56E+07	6.02E+04	2.49E+03	3.46E+06	1.45E+04	89E+06	5.89E+08
B32CM	1.00E-14	1.00E-14	1.00E-14	9.34E+04	1.00E-14	8.43E+03	1.00E-14	1.00E-14	0.00E+00	1.59E+07
B32COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.35E+06
B32ML	2.35E+01	2.14E-01	3.57E-01	1.56E+07	0.00E+00	0.00E+00	3.46E+06	1.45E+04	1.89E+06	5.84E+08
B32SR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.02E+04	2.49E+03	0.00E+00	0.00E+00	1.18E+06
B330ML	3.05E+01	2.77E-01	4.63E-01	2.47E+07	1.10E-05	1.82E+04	4.49E+06	1.88E+04	2.45E+06	1.10E+09
B33CM	1.00E-14	1.00E-14	1.00E-14	6.82E+06	1.00E-14	2.74E+04	1.00E-14	1.00E-14	1.00E-14	5.14E+08
B33ML	3.05E+01	2.77E-01	4.63E-01	2.47E+07	1.10E-05	1.26E+04	4.49E+06	1.88E+04	2.45E+06	1.10E+09
B33TC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.58E+03	0.00E+00	0.00E+00	0.00E+00	1.41E+06
B3CM	1.00E-14	1.00E-14	1.00E-14	2.33E+05	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.29E+07
B3GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B3HRCY	0.00E+00	0.00E+00	0.00E+00	2.33E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.83E+07
B410LLW	1.43E+02	1.17E+00	6.63E-01	5.51E+07	4.61E+05	1.98E-05	1.00E+07	5.84E+04	8.35E+07	1.98E+09
B41CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.13E+07	1.13E+07
B41COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.31E+09
B41GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.98E-05	0.00E+00	0.00E+00	7.96E+07	7.96E+07
B41NACR	1.43E+02	1.17E+00	6.63E-01	5.51E+07	4.61E+05	0.00E+00	1.00E+07	5.84E+04	3.94E+06	5.86E+08
B420ML	1.44E+02	1.18E+00	6.66E-01	5.52E+07	4.63E+05	6.01E-06	1.01E+07	5.87E+04	4.07E+06	6.01E+08
B42CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.46E+07
B42CR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.43E+05
B42ML	1.15E+02	9.45E-01	5.33E-01	4.42E+07	3.71E+05	6.01E-06	8.08E+06	4.70E+04	3.26E+06	4.81E+08
B42NAOH	2.87E+01	2.36E-01	1.33E-01	1.10E+07	9.24E+04	0.00E+00	2.01E+06	1.17E+04	8.13E+05	1.20E+08
B430HNO3	1.53E-05	1.53E-05	1.53E-05	1.53E-05	1.53E-05	1.36E+06	1.53E-05	1.53E-05	5.00E+07	1.53E+09
B43CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	4.31E+07	6.05E+07
B43GAS	1.53E-05	1.53E-05	1.53E-05	1.53E-05	1.53E-05	0.00E+00	1.53E-05	1.53E-05	5.00E+07	5.00E+07
B43HNO3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.79E+03	0.00E+00	0.00E+00	0.00E+00	1.33E+09
B43HRCY	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E+06	0.00E+00	0.00E+00	0.00E+00	1.53E+08
B440HLS	1.08E+04	8.51E+01	4.04E+02	1.76E-07	2.24E+04	7.39E+03	1.76E-07	1.76E-07	5.25E+05	1.76E+07
B44CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.00E+05

H-61

MHC-EP-0791

Table H3. ASPEN PLUS Global Model Mass Balance Output Results. (sheet 56 of 56)

File: C:\ASPRUNSCLEAN41.INP (CLEAN OPTION WITH CPU: SST&DST BLEND, HEEL = 96% DST + 64% SST)

Streams	TH	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	TOTAL (kg)
B44CONO	0.00E+00	0.00E+00	0.00E+00	1.76E-07	0.00E+00	0.00E+00	1.76E-07	1.76E-07	5.35E+05	1.32E+06
B44HLS	1.08E+04	8.51E+01	4.04E+02	0.00E+00	2.24E+04	7.39E+03	0.00E+00	0.00E+00	0.00E+00	1.63E+07
B45OLML	1.37E+02	1.08E+00	1.02E-01	9.15E-06	6.16E+01	5.43E+05	6.09E+06	4.63E+04	2.80E+07	9.15E+08
B45CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.90E+06	1.00E-14	1.00E-14	1.99E+08
B45CONO	0.00E+00	0.00E+00	0.00E+00	9.15E-06	0.00E+00	4.66E+05	0.00E+00	0.00E+00	2.80E+07	7.48E+08
B45LML	1.37E+02	1.08E+00	1.02E-01	0.00E+00	6.16E+01	7.69E+04	6.09E+06	4.63E+04	3.31E+04	1.67E+08
B46HLL	1.35E+04	1.07E+02	5.09E+02	7.30E-06	2.82E+04	1.29E+05	7.30E-06	7.30E-06	7.30E-06	7.30E+08
B46CONO	0.00E+00	0.00E+00	0.00E+00	7.30E-06	0.00E+00	9.42E+04	7.30E-06	7.30E-06	7.30E-06	7.18E+08
B46HLL	1.35E+04	1.07E+02	5.09E+02	0.00E+00	2.82E+04	3.51E+04	0.00E+00	0.00E+00	0.00E+00	1.27E+07
B4CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	7.31E+04
C11CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.44E+05	1.00E-14	9.98E+05
C12CM	1.00E-14	1.00E-14	1.00E-14	4.38E+08	1.00E-14	4.38E+07	1.00E-14	1.00E-14	4.39E+08	9.21E+08
C12HLS	1.56E+04	1.23E+02	5.94E+02	4.38E+08	3.19E+04	4.38E+07	3.98E+04	3.75E+04	4.39E+08	9.22E+08
C13HLS	1.56E+04	1.23E+02	5.94E+02	0.00E+00	3.19E+04	0.00E+00	3.98E+04	3.75E+04	0.00E+00	2.39E+05
CBUSTSL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	3.07E+08
COST304A	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.27E+04
COST318A	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.31E+04
COST336A	0.00E+00	0.00E+00	0.30E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.18E+05
COST450	4.59E+01	4.17E-01	6.96E-01	3.03E-07	1.17E+05	1.15E+03	6.75E+06	2.83E+04	3.68E+06	1.12E+09
COST59A	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.49E+03	0.00E+00	0.00E+00	0.00E+00	7.79E+04
COST85A	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.12E+04	0.00E+00	0.00E+00	0.00E+00	1.27E+06
DSTTRKW	8.26E+02	6.40E+01	1.11E+02	1.03E+07	1.76E+03	6.57E-05	2.20E+06	6.00E+04	1.73E+06	1.85E+08
NOBUSTS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.15E+08
OFFGAS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.05E+05
S10BUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.50E+08
S10GRT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.50E+08
S10LEACH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.59E+08
S1CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.29E+08
S20ASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.92E+08
S20GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.54E+07
S2CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.10E+13
S30CONC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.43E+08
S30CONO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.08E+08
S3CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	7.36E+07
S40FILT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.59E+07
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.59E+03
S40LIQ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.59E+04
S4CM	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.10E+13
SSTRTRKW	1.30E+04	4.54E+01	4.02E+02	9.14E+06	5.00E+05	1.00E-14	2.20E+06	1.00E-14	1.90E+06	5.72E+08
STR304A	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.27E+04
STR318A	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.31E+04
STR336A	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	5.18E+05
STR450	4.59E+01	4.17E-01	6.96E-01	3.03E-07	1.17E+05	1.15E+03	6.75E+06	2.83E+04	3.68E+06	1.12E+09
STR59A	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	6.49E+03	1.00E-14	1.00E-14	1.00E-14	7.79E+04
STR85A	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.12E+04	1.00E-14	1.00E-14	1.00E-14	1.27E+06
T100HLL	4.71E+03	1.89E+01	1.45E+02	3.70E+06	1.80E+05	2.63E-06	8.80E+05	2.40E+03	7.53E+05	2.13E+08
VAQUELLW	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VCBUSTSL	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VNCBUSTS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13
VOFFGAS	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	1.00E-14	2.50E-13

H-63

WMC-EP-0791

This page intentionally left blank.

APPENDIX I

RELATIVE HEALTH RISK ESTIMATES

LIST OF TERMS

ALARA	as low as reasonably achievable
DF	decontamination factor
DOE	U.S. Department of Energy
DST	double-shell tank
GTCC	Greater than Class C
HHI	Health Hazard Index
HLW	high-level waste
HSA	Hanford Strategic Analysis
LANH	heavy lanthanides
LANL	light lanthanides
LLW	low-level waste
PUREX	Plutonium-Uranium Extraction (Plant)
SST	single-shell tank
TRU	transuranic
TRUEX-C	Transuranic Extraction Option C

RELATIVE HEALTH RISK ESTIMATES

11.0 RELATIVE HEALTH RISKS

Systems analyses of radioactive waste handling systems require safety performance measures in evaluating alternative processes. Absolute health risks in terms of dose or deaths are not necessary for the purpose of this study. Only ratios of health risks of the same kind are calculated for the processes to be compared. Health risks of each kind can be stated as ratios to a standard or a regulation, and the values for each process can be compared with each other.

The various kinds of health risks can be subdivided into short term and long term with the time of decay of ^{137}Cs and ^{90}Sr to insignificant values as the transition point. In waste repository risk calculations, the range 300 to 1,000 years after reactor discharge was taken as a transition range, but here 500 years will be used as the dividing time between short term and long term.

A second kind of subdivision of health risks is between onsite and offsite risks. As used here "onsite risks" refer to radionuclides or chemicals in question that remain onsite usually in solid form and undisturbed unless man intrudes and releases them into the biosphere, exposing himself or carrying them offsite to expose others. As used here, offsite risk refers to radionuclides or chemicals that migrate offsite with geochemical agents, such as water after barriers are breached. The onsite risk is directly related to the concentration in the waste at the onsite sample point, while offsite risk also depends on the solubility in water and the rate of transport to a remote sample point where the material is released to the biosphere.

A preliminary division of the safety performance measures into five categories has been made, and a relative health risk estimate for each of them has been developed. The categories are given below:

1. **Long-Term Offsite Safety:** This measure is confined to radionuclides that can be transported by water from the waste site and measured by an adjusted health hazard index (HHI). The important nuclides on our time scale are ^{99}Tc and ^{129}I .
2. **Long-Term Onsite Safety:** This measure assumes that human or animal intrusion will introduce mixed wastes directly into the biosphere. This measure is represented by the ratio of radionuclide concentration to Hanford cleanup residential soil standards. The important nuclides are alpha emitters, such as ^{238}U , ^{239}Pu , ^{241}Am , ^{243}Am , and their decay chains.
3. **Short-Term Offsite Safety:** This measure is confined to radionuclides that can be transported to the biosphere within 300 to 500 years by water or air after unusual events, or which are already present in the groundwater. It is measured by the ratio of concentration to potable water limits. The important radionuclides should be ^3H , ^{137}Cs , and ^{90}Sr .

4. **Short-Term Onsite Safety:** This measure assumes human or animal intrusion will introduce mixed wastes directly into the biosphere within 300 to 500 years. This measure is represented by the ratio of radionuclide concentration to Hanford Site cleanup residential soil standards. The important nuclides should be ^{137}Cs , ^{90}Sr , and ^{239}Pu .
5. **Occupational Exposure:** This measure accounts for exposure to workers operating the processing plants who are taking samples and cleaning up spills. It is directly proportional to and measured by the volume and activity level of tertiary nonprocess wastes, such as special work permit clothing, laboratory samples, gloves, removed equipment, decontamination solutions. The important radionuclides should be ^{137}Cs , ^{90}Sr , and ^{239}Pu . These may be classified as gamma fields, alpha emitters, and beta emitters with low energy gamma fields, and indexes can be calculated separately for each category.

12.0 PROBABILITY AND RISK

It is certainly desirable to evaluate all five of these relative performance measures separately. However, after this step is taken, one cannot combine them into a single safety performance measure without calculating the risk from each (i.e., the product of probability of occurrence and the dose consequences).

It may be possible to come up with a useful relative measure of risk without computing the doses if the limits for delivery to man are consistent among the five performance measures. For this, one would also need the set of probabilities for each of the five types of exposure (i.e., the probability distribution that each will occur). In the absence of much experience, this probability set might be in the form of uniform probability, log uniform probability, or a triangular distribution for each of the five consequences.

Although we have not estimated health risks here, some idea of the values of the probability sets is as follows.

1. **Long-Term Offsite Safety:** Barrier degradation followed by nuclide transport will have a high probability, near unity, because the process is already described by the calculation of transport through the barrier. Only the probability of water contact during a very long time period needs to be added. Additional disruptive events, such as those that shorten the flow path for water to and from the waste, will have lower probabilities; but the consequences will be greater because the barrier is less formidable.
2. **Long-Term Onsite Safety:** The probability of human intrusion is the subject of much debate. However, over a long period of time, it is very likely. Then, the exposure of the intruder and quantity of waste removed to the biosphere by human transport may become an important quantity.

3. **Short-Term Offsite Safety:** The very low probability of release by disruptive events during the first 300 to 500 years should be evaluated because the consequences resulting from the release of high inventories of ^{137}Cs and ^{90}Sr could be very great. Materials already released would need a transport calculation but would have a release probability of unity.
4. **Short-Term Onsite Safety:** The probability of human intrusion during the first 300 to 500 years can be made very low by administrative controls of the surrounding area. The consequences resulting from intrusion into high inventories of ^{137}Cs and ^{90}Sr may still be very large.
5. **Occupational Exposure:** Estimated exposures would have a probability of unity. Occupational exposure of workers resulting from accidents would have to be included, and each accident will have its own probability of a given dose exposure.

If the probability distribution part of each of the five consequences were estimated, the corresponding risks could be put on a common basis. The first four can be ratioed to concentration or inventory limits that have been derived from an allowable dose; therefore, the dose for the consequence is available by simple ratio. The occupational exposure is already ratioed to a dose limit. Proper attention should also be given to the important matter of whether each of the five risks are in terms of maximum individuals or the population as a whole. The ratio of the worker population to the total population may also be needed. Only then can we calculate and sum all five risks in dose units to estimate a single performance measure of radiological risk.

The measurement of health risk in terms of dose units would bypass the secondary concentration and inventory limits that have been derived from them to set regulatory controls on releases from waste sites. This would allow one to determine the effect on health risk of setting the concentration limits at one value or another. One could then do cost-benefit analyses on the regulations themselves and influence the setting of reasonable limits. This has not been done in this analysis, and only five separate HHIs have been estimated.

13.0 EVALUATION OF RELATIVE HEALTH HAZARDS

13.1 LONG-TERM OFFSITE HEALTH HAZARD

The long-term offsite radiological safety performance measure was evaluated by combining transport through a barrier to a 100 meter distant well with the concentration limit for potable water. The resultant adjusted HHI was then used to compare the waste separation alternatives. This long-term performance measure is confined to radionuclides that can be transported by water from the waste site and measured by the adjusted HHI. The important nuclides are ^{99}Tc and ^{129}I .

The relative long-term health hazard model developed below evaluates the long-term health hazard to the public. The health hazard estimates included the following assumptions.

1. All time periods are equally important when evaluating health hazard. However, this model is directed at the time period from 500 to 10^5 years or essentially long-term health hazard.
2. Waste is disposed of in dry form, with nuclide migration to groundwater and then into drinking water as the dominant hazard pathway from the waste disposal site to biological receptors.
3. Assessment of health hazard from beneficial use of nuclear materials is not considered.
4. The radiological health hazard to a receptor is proportional to the quantity of radioactive material disposed of. This proportionality relies on the following. First, health hazard is proportional to the dose to a receptor by a dose response constant, d_r (endpoints/mrem). Second, dose is a linear function of disposed waste mass. To relate dose to source mass, a dose factor, d_f , and a waste disposal package/barrier attenuation factor, a_f , are used. These factors account for far - field and near - field barrier effects, respectively. The dose factor, d_f , relates liquid concentration at the biosphere (e.g., drinking water from a well) to the disposed waste mass source and also characterizes the receptor's rate and period of ingestion. It is adjusted to support incorporation of a package/barrier attenuation factor, a_f , which is normalized to unity for unimpeded migration in soil (mrem/kg). The package/barrier attenuation factor, a_f , depends on diffusivity and path to soil regions without drainage barriers. This factor is normalized to unity for unimpeded migration in soil. For groundwater, it is normalized to unimpeded groundwater flow ($a_f \leq 1$, dimensionless). As an example, the health hazard, r_k , from technetium mass (kg) in output waste stream k, T_{c_k} , would be:

$$r_k = d_r * d_{fk} * a_{fkTc} * T_{c_k}$$

Thus, the relative long-term health hazard to the public, r_{rel} , may be characterized by the following equation:

$$r_{rel} = (r_{llw} + r_{lmw} + r_{tru} + r_{hlw}) / r_0$$

where:

- r_{llw} = Health hazard due to low-level waste.
- r_{lmw} = Health hazard due to low-level mixed waste (hazardous and radioactive).
- r_{tru} = Health hazard due to transuranic waste.
- r_{hlw} = Health hazard due to high-level waste.
- r_0 = Health hazard from current inventory in its existing configuration.

5. Material in current inventories would in time migrate in soil without any impediment, except for materials in Facilities and Nuclear Material. For the purpose of normalizing health hazard estimates, it is assumed that the period of initially impeded migration resulting from tanks, etc., is negligible.
6. For an initial approximation, assume all d_{fk} are equal. Thus, r_{rel} is only a function of a_{fk} and Tc_k (or I_k). The following represent the main waste disposal product streams considered in the relative health hazard estimates.

Waste Disposal Product Stream	⁹⁹ Tc Package/Barrier Attenuation Factor, a_{fkTc}
In Situ Vitrification Monolith: 3110HLWS	5.1 E-11
Salt Grout: 3400LMWS, LLWS	6.6 E-5
In-situ Grout: 3530LMWS	1.5 E-5
Dome Fill Tank: 3200HLWS	1.7 E-4

To estimate the iodine (I) attenuation factors, a_{fi} , it was assumed that 1 kg of I is 1.5 times as dangerous as 1 kg of technetium, based on a relative dose contribution basis (e.g., iodine concentrates in the thyroid once in the human body, while technetium distributes among many organs). Thus, $a_{fi} = 1.5 * a_{fkTc}$. The basis for this factor is the following calculation:

$$^{129}I / (^{127}I + ^{129}I) = 0.67$$

Use 50-year committed dose equivalent factors from DOE/EH-0071(7/88):

$$CEDE_I * (kg/Ci)_{Tc} / (CEDE_{Tc} * (kg/Ci)_I) = 0.28 * 0.059 / 1.3e-3 * 5.66/0.67$$

$$= 1.5$$

The iodine attenuation factors were also multiplied by a conservative 0.8 factor to account for the ratio of radiogenic iodine from nuclear reactors in the stream flows (Pajunen et al. 1992).

The above stream technetium and iodine masses along with the relative long-term health hazard estimates for the CLEAN Option, Transuranic Extraction Option C (TRUEX-C), and Sludge Wash C process strategies are shown in Table II

for the 0% heel (i.e., unretrieved waste remaining in tank) case. Figure I1 shows the same health hazard data. The comparison results show that the relative long-term offsite health hazard for the CLEAN Option process strategy is within 1% of the health hazard for the TRUEX-C and Sludge Wash C process strategies for the 0% tank waste heel case. Based on previous analyses of the TRUEX-C and Sludge Wash C process strategies (Knutson et al. 1993) these relative health hazards will increase by a factor of approximately 2.4 if the heel percentage increases from zero to 5%. This health hazard increase is associated with more radioactive waste products left behind in the tanks that will be immobilized in place (stream 3200HLWS would reflect this health hazard increase). Thus, the data suggest that the relative long-term offsite health hazard is comparable for all of the process strategies.

These results should not be used in an absolute sense but only for comparative value in considering the various waste treatment processes.

13.2 LONG-TERM ONSITE HEALTH HAZARD

A preliminary set of coefficients for long-term onsite health hazard is given in Table I2 for the 25 lumped components used in the global models. These coefficients are derived from the drilling and excavation scenarios given in *Dose and Risk Assessment for Intrusion Into Mixed Waste Disposal Sites* (Kennedy and Aaberg 1991). For all situations, the dose from the excavation scenario predominated over the drilling scenario. Their results are presented in Table I3 in terms of rems per person per drilling or excavation event for individual radionuclides present at unit concentrations in the solid waste. They represent the worst-case scenario with pathways to the highest exposed individual. The final column in Table I3 shows their health hazard data in units of dose (millirem) per exposure concentration (Ci/m³) convenient for HHI calculations made in this report.

To calculate the long-term onsite HHI (mrem per person) associated with a particular component in a specific waste stream, the HHI coefficient (mrem/[Ci/m³]) for that component was multiplied by the radioactivity level (or concentration) (Ci/m³) of the component in that specific waste stream. The radioactivity level calculations are discussed in Section I5.0.

The long-term onsite HHIs in mrem per person are shown in Table I4 for the Clean Option, TRUEX-C, and Sludge Wash C process strategies. The data in Table I4 were normalized to the value for the total tank waste feedstreams (SSTTNKW and DSTTNKW). Cesium and strontium were excluded because of their short half-lives compared to the assumed long-term time frame of greater than 500 years. The normalized HHIs are compared in Figure I2 by waste stream for the three pretreatment process strategies with 0% tank heels.

As shown in Figure I2, the greatest long-term onsite waste health hazard would be in the high-level waste (HLW) glass stream (3110HLWS) if the environment were not protected from it by formidable barriers around the repository. The uranium product stream (B212U for Clean, B24U for TRUEX-C and Sludge Wash C) has the highest HHI for the Sludge Wash C process because it is highly concentrated. However, it is assumed that the uranium product does not remain onsite but is added to the U.S. national stockpile. Thus, the tank heel (requiring dome fill) stream (3200HLWS) dominates the onsite health

hazard. Otherwise, the primary low-level waste (LLW) grout stream (3400LLWS+3400LMWS) contains the only significant variation between pretreatment process strategies, where the TRUEX-C process strategy value was a factor of approximately 5 and 7 higher than for the Clean Option and Sludge Wash C process strategies, respectively. Note that while no estimate of the primary LLW glass HHI is included, it is expected to be lower than that resulting from primary LLW grout because the glass represents a more stable long-term waste form than grout.

The contributions of each component to the normalized long-term onsite HHI for the HLW glass and primary LLW grout are compared in Figures 13 and 14, respectively. Figure 13 shows that the Clean Option HLW glass has substantially more contribution to the long-term onsite HHI (compared to the original total feedstream value) from plutonium, technetium, americium, thorium, neptunium, and heavy lanthanides (LANH), because of the more extensive separation processing performed for these elements. This greater processing in the CLEAN Option also produced less contribution to HLW glass from uranium, fission products (FP2), and ^{63}Ni (OTH3) compared to the other process strategies.

Overall, the Clean Option long-term onsite HHI was more than an order of magnitude greater for the HLW glass product than the TRUEX-C and Sludge Wash C process strategies because of the greater HLW concentration. However, it is highly unlikely that any excavation would uncover a deep repository. The drilling scenario with different controlling components would produce more health hazard from the repository than the excavation scenario.

The contributions of each component to the normalized long-term onsite HHI for primary LLW grout show that the CLEAN Option had larger contributions from the iodine, fission products (FP2), ^{63}Ni (OTH3), thorium, and neptunium than the TRUEX-C and Sludge Wash C process strategies because of the greater primary LLW concentration. However, the overall long-term onsite HHI for primary LLW grout is substantially lower when compared to the initial feedstream.

These results should not be used in an absolute sense but only for comparative value in considering the various waste treatment processes.

13.3 SHORT-TERM ONSITE AND OFFSITE HEALTH HAZARD

The offsite health hazard for the short term (less than 500 years) was nearly nil because the barriers to migration would be expected to be intact and unbreached for 500 years unless man intruded. Therefore, the offsite health hazard was included in the onsite health hazard. The short-term onsite health hazard was calculated in the same way as the long-term onsite health hazard, except that the age of the waste was assumed to be only 10 years so that ^{137}Cs and ^{90}Sr were still the dominant radiation dose inventories.

The HHI coefficients for short-term and long-term onsite health hazards are given in Table I2. It is apparent that the two indexes have the same values for many components. This does not mean that the two health hazards are the same because the probabilities of release are not included. While a framework has been laid for future calculations, much work needs to be done in

estimating or finding input information to calculate these HHIs and in estimating probability sets before they can be combined to give a single index.

The short-term onsite and offsite HHIs in mrem per person are shown in Table I5 for the Clean Option, TRUEX-C, and Sludge Wash C process strategies. The data in Table I5 were normalized to the value for the total tank waste feedstreams (SSTTNKW and DSTTNKW) and compared in Figure I5 by waste stream for the three pretreatment process strategies with 0% tank heels.

As shown in Figure I5, the greatest short-term onsite waste health hazard would be in the HLW glass stream (3110HLWS) if the environment were not protected from it by formidable barriers around the repository. Excluding the HLW glass product, the tank heel (requiring dome fill) stream (3200HLWS) dominates the short-term onsite health hazards. Otherwise, the only significant variations in the short-term onsite health hazards between the pretreatment process strategies occurs for the primary LLW grout product stream (3400LLWS+3400LMWS) and the uranium product stream (B212U for CLEAN and B24U for TRUEX-C and Sludge Wash C). Assuming that the uranium product does not remain onsite but is added to the U.S. national stockpile, only the primary LLW grout product health hazards are compared. As shown in Figure I5 the Clean Option process strategy has a primary LLW grout product health hazard value that is more than an order of magnitude less than the TRUEX-C and Sludge Wash C process strategy values. Note that while no estimate of the primary LLW glass HHI is included it is expected to be lower than that resulting from primary LLW grout because the glass represents a more stable short-term (up to 500 years) waste form than grout.

The contributions of each component to the normalized short-term onsite HHI for the HLW glass and primary LLW grout are compared in Figures I6 and I7, respectively. Figure I6 shows that the CLEAN Option HLW glass has substantially more contribution to the short-term onsite HHI (compared to the original total feedstream value) from plutonium, cesium, strontium, technetium, americium, thorium, neptunium, and LANTH, because of the more extensive separation processing performed for these elements. This greater processing in the CLEAN Option also produced less contribution to HLW glass from uranium, fission products (FP2), and ⁶³Ni (OTH3) compared to the other process strategies.

Overall, the CLEAN Option short-term onsite HHI was more than an order of magnitude greater for the HLW glass product than the TRUEX-C and Sludge Wash C process strategies because of the greater HLW concentration. However, it is highly unlikely that any excavation would uncover a deep repository in the first 500 years after closure. The drilling scenario with different controlling components would probably produce more health hazard from the repository than the excavation scenario during the first 500 years.

The contributions of each component to the normalized short-term onsite HHI for primary LLW grout show that the CLEAN Option had larger contributions from the iodine, fission products (FP2), ⁶³Ni (OTH3), thorium, and neptunium than the TRUEX-C and Sludge Wash C process strategies because of the greater primary LLW concentration. However, the CLEAN Option had substantially smaller contributions from cesium and strontium because of the more extensive

separation processing performed for these elements. Overall, the short-term onsite HHI for primary LLW grout is substantially lower when compared to the initial feedstream.

These results should not be used in an absolute sense but only for comparative value in considering the various waste treatment processes.

13.4 OCCUPATIONAL EXPOSURE

The dose to workers operating a plant may be an important health hazard. In general, with similar designs, one would expect that more highly radioactive streams result in greater worker exposure, even though the processes themselves are shielded. This is because sampling and equipment repair usually have some doses associated with them. It was arbitrarily assumed that the occupational exposure was proportional to the volume of tertiary nonprocess waste from a particular process multiplied by the curie concentration of the lumped component in the feedstream to a process. This does NOT result in the curies in the tertiary waste or in an HHI in terms of dose but does leave the possibility that the index could be calibrated by data from an operating plant.

There are essentially two types of occupational exposure. They are as follows.

1. Gamma radiation (primarily ^{137}Cs) emanating from equipment, processes, or contamination, which acts through a distance and perhaps requires shielding.
2. Contamination by alpha and beta particles where the radionuclide gets on the clothing, skin, or inside the person. The alpha contamination is quite significant in occupational exposure (e.g., uranium, plutonium, neptunium, thorium, americium). The beta contamination will be unimportant unless a low-energy gamma accompanies the beta decay.

The previous report (Knutson et al 1993) considered occupational exposure resulting from ^{137}Cs weighted by the feedstream and tertiary waste flows to particular processes, along with the relative alpha contamination from ^{238}U and ^{239}Pu and beta contamination from ^{90}Sr . To increase the accuracy and detail of the occupational exposure calculations more components were evaluated in this report. Because the lumped or pseudo components of FP2, OHAZ2, and OTH3 contained a mix of isotopes, the isotope with the major exposure impact was chosen to represent the pseudo component. This impact was evaluated, based on the particular isotope radioactive inventory, half-life compared to expected processing time frames, and decay particle energies and their relative exposure importance. Isotopes with more than one decay particle emission were classified based on the decay particle energies. The following is a list of the radionuclides considered in this report and their subsequent contamination classification used in calculating the occupational exposure impact.

<u>Pseudo Component</u>	<u>Isotope and Decay Particle Emitted</u>
H2O:	H-3 (β)
PU:	Pu-239 (α), Pu-241 (α)
U:	U-238 (α)
LANL:	Ce-144 ($\beta\gamma$)
CS:	Cs-137 ($\beta\gamma$)
SR:	Sr-90 (β)
TC:	Tc-99 (β)
I:	I-129 ($\beta\gamma$)
FP2:	Ru-106 (β), Se-79 (β), Sn-126 ($\beta\gamma$), Zr-93 ($\beta\gamma$)
AP1:	C-14 (β)
OHAZ2:	Ag-108m (γ), Cd-113m (IT), Te-127m (γ)
OTH3:	Fe-55 (β), Nb-93m (β), Ni-63 (β), Rh-106 (γ), Sb-125 (γ), Co-60 (γ)
AM:	Am-241 (α)
TH:	Th-232 (α)
NP:	Np-237 (α)
LANH:	Sm-151 ($\beta\gamma$)

14.0 CLASSIFICATION FOR OCCUPATIONAL EXPOSURE CALCULATION

Gamma Contamination: Cs (Cs-137)

Alpha Contamination: U (U-238) + Pu (Pu-239) + Am (Am-241) + Th (Th-232) + Np (Np-237)

Beta Contamination: Sr (Sr-90) + Tc (Tc-99) + I (I-129) + FP2 (Zr-93 + Sn-126) + AP1 (C-14) + OTH3 (Ni-63) + LANH (Sm-151)

Note that H₂O, light lanthanides (LANL), and OHAZ2 were not included because the radioactive inventories for their respective isotopes were ignored, based on their short half-lives compared to expected processing time frames or simply from having zero radioactive inventories. Table J1 of Appendix J shows the isotopes that were ignored in the radioactive inventory calculations.

Thus, the occupational exposure HHI was calculated for each major process within each process strategy using three separate indexes for gamma, alpha, and beta contamination. These indexes represent the process feedstream radioactive inventory concentration (Ci/kg) weighted to represent tertiary waste "curies" by multiplying by the process tertiary waste stream inventory (kg). Assuming an arbitrary 1 kg/m³ density for comparison purposes, the resulting HHIs are in units of curies times kilograms per cubic meter. Note that by calculating the HHIs for each process, due credit is given to flowsheets in which high-dose radionuclides are taken out of streams in the earlier processes, leaving lower potential for exposure in downstream processes.

The occupational exposure HHIs are given in Tables I6 through I8, for the CLEAN Option, TRUEX-C, and Sludge Wash C process strategies, respectively, with a summary shown in Table I9. Figures I8 through I11 show the same table information for the respective process strategies. As shown in Table I9 the plant designs for the CLEAN Option flowsheets result in about 3 and 24% more occupational gamma exposure, a factor of 2.3 and 12.1 more occupational alpha exposure, and a factor of 2.2 and 19.2 more occupational beta exposure, than the TRUEX-C and Sludge Wash C plant designs, respectively. These larger indexes for the CLEAN Option result from its greater processing requirements.

Figures I6 through I8 show how the occupational exposure distributes among the various processes in each process strategy. Note that in the flowsheets the ion exchange processes are weighted more heavily in terms of exposure than the solid separation steps because they are assumed to have the same amount of tertiary waste as a single cycle of solvent extraction who was a plant engineer in the Hanford Plutonium-Uranium Extraction (PUREX) Plant for many years). The solid separation steps are only assumed to generate 0.25 as much tertiary waste as one solvent extraction cycle judged from equipment floor space in the Savannah River PUREX F and H canyons (see Appendix E).

Generally, more efficient removal of major exposure-causing components in the first process elements to contact the tank waste would lower the occupational exposure in all process strategies. For example, the CLEAN Option process strategy has alkaline-side cesium removal before strontium and technetium removal, thereby reducing gamma exposure in these subsequent removal operations (Figure I8). However, cesium removal follows after other removal operations in the acid-side processing. If the acid-side cesium removal could also be placed before the other acid-side removal operations, it would reduce the gamma exposure in those subsequent removal operations.

These results should not be used in an absolute sense but only for comparative value in considering the various waste treatment processes.

15.0 WASTE CLASSIFICATION AND RADIONUCLIDE CONCENTRATIONS

The radioactivity level (or concentration) of each component in each waste stream was determined by making a global level model run using the radioactive curie inventories (Appendices H and J) in place of the kg mass inventories for the two tank waste feedstreams. Multiplying the component curies (Ci) in a specific waste stream by the waste stream density (kg/m^3 kilograms per cubic meter) and dividing by the total waste stream kg yields the desired component radioactivity levels (Ci/m^3). These stream radioactivity levels for each process strategy are shown in Table I12.

A detailed discussion of the Hanford waste tank inventories is given in the Hanford Strategic Analysis (HSA) (Pajunen et al. 1992). In that report the TNKW inventory was divided into SSTTNKW, DSTTNKW, and UGTNKSTR and the concentrations of each of the radioactive components was shown by inventory category in bar graphs with waste classifications as shaded backgrounds. A portion of the tank heels that could not be recovered was included in UGTNKSTR. The DSTTNKW is usually highly concentrated, but the concentration

in SSTTNKW varies widely from tank to tank although the total volume of SSTTNKW is much larger than DSTTNKW. The discussion of waste concentrations and classifications here is similar to that in the HSA with a breakdown between the SSTTNKW and DSTTNKW categories. However, this breakdown cannot apply to a single tank or a single tank farm. Also, because large quantities of inert strontium, LANHs, and, perhaps, iodine were added to parts of the SSTTNKW, the concentrations of radionuclides in these components vary widely between SSTTNKW and DSTTNKW.

The LLW classification criteria used for individual radionuclides are given in Table I10, expanded from those used in the HSA. Existing regulations do not explicitly contain criteria for all of the radionuclides desired and extrapolation methods (Kocher and Croff 1988) may be in dispute. These values were converted into the component LLW classification criteria shown in Table I11 by using only the controlling radionuclide in each component. Only 12 out of the 25 components were actually evaluated because the radioactivity level of the remaining components were considered zero or no limits were established.

In the LLW classification system only the HLW glass stream (3110HLWS) for the CLEAN Option and TRUEX-C process strategies qualified as Greater than Class C (GTCC). The single-shell tank (SST) and double-shell tank (DST) tank waste feedstreams (SSTTNKW and DSTTNKW, respectively), the HLW glass stream for Sludge Wash C, and the tank residual waste stream (3200HLWS) qualified as LLW-C. All of these streams require deep burial by virtue of their ^{137}Cs and ^{90}Sr content. As a whole the SSTTNKW has low concentrations of radionuclides, but some individual tanks contain GTCC because of their ^{137}Cs , ^{90}Sr , or transuranic (TRU) content. The U.S. Department of Energy (DOE) LLW classifications, such as Category 2, derived from the above system, have an upper limit identical to Class C but Category 1 reduces the equivalent to Class A to even lower values, which would place fewer SSTTNKW tanks into Category 1 than into Class A.

The LLW waste classifications for the process strategies are shown in Table I13 based on the radioactive concentrations shown in Table I12. The concentrations of total radioactivity and of components plutonium, uranium, cesium, strontium, technetium, iodine, fission products (FP2), activation products (AP1), other (OTH3), americium, neptunium, and LANH in the feed and waste streams for the 0% heel option are compared with the LLW classifications in Figures I12 through I24, respectively. The waste product streams may deviate from the target designations for some components because the LLW classifications involve setting multiple individual radionuclide (or component) limits. Modification of the process decontamination factors (DFs) to agree with all target classifications could result in minor changes in capital or operating costs. Also the flowsheet results are always subject to as low as reasonably achievable (ALARA) considerations so that lower LLW concentrations and classifications are preferred over higher values. Higher HLW radionuclide concentrations are usually preferred because they lower HLW disposal costs.

The complexity of using the LLW individual radionuclide limits as multiple performance measures (applying only to the first 500 years after disposal) is evident. The method of applying these limits is that if any individual radionuclide exceeds its limit for a particular LLW classification, then the waste is a higher class, and there is a specially prescribed additivity rule.

The need for process screening methods has led us to the development of a simpler set of HHIs discussed above, which are tailored to the periods of risk. However, meeting the waste classifications are regulatory requirements and no lower bound has been set for Class A except for ALARA.

Figure I12 shows the concentration of total radioactivity. The radiological limits applied to each feedstream or waste product stream were those for a component that controlled the final classification of that stream for all process strategies (Table I13). For example, because the HLW glass stream (3110HLWS) classification was controlled by plutonium, cesium, strontium, and technetium limits, the plutonium limits were used because they were consistently controlling in all process strategies. Thus, the intent of Figure I12 is to show a comparison of the final stream classifications for each process strategy.

As shown in Figure I12, the tank waste feedstreams (SSTTNKW and DSTTNKW), the HLW glass stream (3110HLWS) destined for a HLW repository, and the tank heel (3200HLWS) stream are GTCC. The LLW grout (3400LLWS+3400LMWS) streams are LLW Class A for the CLEAN Option process strategy, while the TRUEX-C and Sludge Wash C process strategies were LLW Class B because of the strontium limits. Using uranium LLW classification limits proposed by Kocher and Croff (Kocher and Croff 1988), the uranium product stream was also GTCC for the CLEAN and Sludge Wash C process strategies, while the TRUEX-C process strategy uranium stream was LLW Class C. Higher DFs may be needed for the atmospheric release of the vitrification offgas (VITRW-GAS) where different limits apply than for solid LLW. The uranium product stream was also GTCC for the CLEAN and Sludge Wash C process strategies, while the TRUEX-C process strategy uranium stream was LLW Class C.

Figure I13 shows the concentration of the plutonium (e.g., ^{239}Pu) component radioactivity. The HLW glass and tank heel streams were classified as TRU. The Clean Option and TRUEX-C process strategies had grout streams classified as LLW Class A while the Sludge Wash C process strategy grout stream was below LLW Class A (note that the CLEAN Option was nearly below Class A). The TRUEX-C vitrification offgas was LLW Class A and may need further cleanup as discussed above. Summarizing, the HLW was more concentrated in the CLEAN Option process strategy because of its more extensive plutonium separation processing. The HLW was above LLW Class C, while the LLW was reduced to nearly industrial limits by the CLEAN Option and Sludge Wash C process strategies.

Figure I14 shows the concentration of the uranium (e.g., ^{238}U) component radioactivity. The HLW glass and tank heel streams were classified as LLW Class A while the grout streams were classified as less than LLW Class A. Using uranium LLW classification limits proposed by Kocher and Croff (Kocher and Croff 1988), the uranium product stream was also GTCC for the CLEAN and Sludge Wash C process strategies, while the TRUEX-C process strategy uranium stream was LLW Class C.

Figure I15 shows the concentration of the cesium (e.g., ^{137}Cs) component radioactivity. Both the HLW glass and the tank heel are LLW-C, with the CLEAN Option process strategy HLW glass qualifying as GTCC. The grout streams for the TRUEX-C and Sludge Wash C process strategies were LLW Class A while the

CLEAN Option grout stream qualified for industrial use. The vitrification offgas stream for the TRUEX-C and Sludge Wash C process strategies were LLW Class A and B, respectively.

Figure I16 shows the concentration of the strontium (e.g., ^{90}Sr) component radioactivity. Both the HLW glass and the tank heel are LLW-C, with the CLEAN Option process strategy HLW glass qualifying as GTCC. The grout streams for the TRUEX-C and Sludge Wash C process strategies were LLW Class B, while the CLEAN Option grout stream qualified as LLW Class A. The vitrification offgas stream for the TRUEX-C process strategy was LLW Class B.

Figure I17 shows the concentration of the technetium (e.g., ^{99}Tc) component radioactivity. The HLW glass stream for the CLEAN Option process strategy was classified as GTCC while the TRUEX-C and Sludge Wash C process strategies were LLW Class C. The tank heel is below the LLW Class A limit and the grout is below the industrial soil limit. The vitrification offgas stream for the TRUEX-C and Sludge Wash C process strategies qualified as residential and industrial, respectively.

Figure I18 shows the concentration of the iodine (e.g., ^{129}I) component radioactivity. All streams are well below the LLW Class A limit.

Figure I19 shows the concentration of the fission product (e.g., ^{93}Zr , ^{126}Sn) component radioactivity. All streams qualify as LLW Class A. The vitrification offgas stream for the TRUEX-C process strategy was below the LLW Class A limit.

Figure I20 shows the concentration of the activation product (e.g., ^{14}C) component radioactivity. All streams qualified as LLW Class A. The vitrification offgas stream for the CLEAN Option and TRUEX-C process strategies were below residential limits. Note that the industrial limit exceeds the LLW class limits for ^{14}C .

Figure I21 shows the concentration of the "Other" (e.g., ^{63}Ni) component radioactivity. Most streams qualified as LLW Class A or below. The in situ grout stream (3530LMWS) was below the industrial soil limit. The vitrification offgas stream for the CLEAN Option and TRUEX-C process strategies were below residential and industrial limits, respectively.

Figure I22 shows the concentration of the americium (e.g., ^{241}Am) component radioactivity. Both the HLW glass and the tank heel are classified as TRU. The grout streams were LLW Class A. The vitrification offgas stream for the TRUEX-C process strategy was LLW Class A.

Figure I23 shows the concentration of the neptunium (e.g., ^{237}Np) component radioactivity. All streams were LLW Class A except for the CLEAN Option HLW glass stream, which was LLW Class C.

Figure I24 shows the concentration of the LANH (e.g., ^{151}Sm) component radioactivity. Both the HLW glass and the tank heel streams were classified as LLW Class A except the CLEAN Option HLW glass stream, which was GTCC. The TRUEX-C process strategy grout stream was LLW Class A while the CLEAN Option and Sludge Wash C process strategy grout streams were classified as industrial-soil. The vitrification offgas stream for the TRUEX-C process strategy was LLW Class A.

16.0 REFERENCES

- Kennedy, Jr., W. E., and R. L. Aaberg, 1991, *Dose and Risk Assessment For Intrusion Into Mixed Waste Disposal Sites*, PNL-SA-20032, Pacific Northwest Laboratory, Richland, Washington.
- Knutsen, B. J., et al., 1993, "Advanced Chemical Separation Study: TRUEX Strategy Compared To Sludge Wash Ion Exchange," Letter report, Westinghouse Hanford Company, Richland, Washington.
- Kocher, D. C., and A. G. Croff, 1988, *A Proposed Classification System For High-Level And Other Radioactive Wastes*, Research Sponsored by DOE Contract DE-AC05-84OR21400, *Radioactive Waste Management and the Nuclear Fuel Cycle*, Vol. LL(3), Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Pajunen, A. L., et al., 1992, *Hanford Strategic Analysis Study*, WHC-EP-0549, Westinghouse Hanford Company, Richland, Washington.

Figure I1. Comparison of Relative Long-Term Offsite Health Hazard.

Figure I2. Long-Term Onsite Health Hazard Index.

Figure I3. Long-Term Onsite Health Hazard Index for High-Level Waste Glass Stream.

Figure I4. Long-Term Onsite Health Hazard Index for Low-Level Waste Grout Stream.

Figure I5. Short-Term Onsite and Offsite Health Hazard Index.

Figure 16. Short-Term Onsite and Offsite Health Hazard Index for High-Level Waste Glass Stream.

Figure 17. Short-Term Onsite and Offsite Health Hazard Index for Low-Level Waste Grout Stream.

Figure 18. Occupational Health Hazard Index for Clean Option.

PROCESS BLOCK

Figure I9. Occupational Health Hazard Index for Transuranic Extraction Option C.

Figure 110. Occupational Health Hazard Index for Sludge Wash C.

Figure I11. Total Occupational Health Hazard Index.

Figure 112. Total Radioactivity Level.

Figure I13. Plutonium Radioactivity Level.

Figure I14. Uranium Radioactivity Level.

Figure I15. Cesium Radioactivity Level.

Figure I16. Strontium Radioactivity Level.

Figure I17. Technetium Radioactivity Level.

Figure I18. Iodine Radioactivity Level.

Figure I19. Fission Product Radioactivity Level.

Figure I20. Activation Product Radioactivity Level.

Figure I21. Other (e.g., Nickel) Radioactivity Level.

Figure I22. Americium Radioactivity Level.

Figure I23. Neptunium Radioactivity Level.

Figure I24. Heavy Lanthanide Radioactivity Level.

Table II. Relative Long-Term Health Hazard Comparison Between Process Strategies.

Waste Disposal Product Stream	MODEL:	Mass Inventories (KG)			Pkg/barrier Atten Fact. af	Relative Health Risk For Tc and I		
		CLEANG31 CLEAN OPTION	TRUG31 TRUEX-C W/ NEUTRAL.	SLUG31 SLUDWC W/ NEUTRAL.		CLEANG31 CLEAN OPTION	TRUG31 TRUEX-C W/ NEUTRAL.	SLUG31 SLUDWC W/ NEUTRAL.
		0% HEEL	0% HEEL	0% HEEL		0% HEEL	0% HEEL	0% HEEL
3110HLWS	Tc	3.67E+03	3.66E+03	3.67E+03	5.10E-11	1.87E-07	1.87E-07	1.87E-07
3200HLWS	Tc	7.77E-11	7.77E-11	7.77E-11	1.70E-04	1.30E-14	1.30E-14	1.30E-14
3400LLWS	Tc	1.08E+01	1.88E+01	1.32E+01	6.60E-05	7.13E-04	1.24E-03	8.68E-04
3400LMWS	Tc	1.08E+01	1.88E+01	1.32E+01	6.60E-05	7.13E-04	1.24E-03	8.68E-04
3530LMWS	Tc	1.00E-14	1.00E-14	1.00E-14	1.50E-05	1.50E-19	1.50E-19	1.50E-19
TOTALS	Tc					1.43E-03	2.49E-03	1.74E-03
3110HLWS	I	0.00E+00	0.00E+00	0.00E+00	6.12E-11	0.00E+00	0.00E+00	0.00E+00
3200HLWS	I	2.49E-11	2.49E-11	2.49E-11	2.04E-04	5.00E-15	5.00E-15	5.00E-15
3400LLWS	I	6.22E+02	6.22E+02	6.15E+02	7.92E-05	4.93E-02	4.92E-02	4.87E-02
3400LMWS	I	6.22E+02	6.22E+02	6.15E+02	7.92E-05	4.93E-02	4.92E-02	4.87E-02
3530LMWS	I	1.00E-14	1.00E-14	1.00E-14	1.80E-05	1.80E-19	1.80E-19	1.80E-19
TOTALS	I					9.85E-02	9.85E-02	9.73E-02
GRAND TOTAL	Tc and I					1.00E-01	1.01E-01	9.91E-02
CLEAN/"MODEL"							9.90E-01	1.01E+00

Table I2. Health Hazard Index Coefficients by Component.

COMPONENT	SHORT TERM ONSITE (mrem/person)/ (Ci/m3)	LONG TERM ONSITE (mrem/person)/ (Ci/m3)
H2O	3.00E+01	0.00E+00
PU	5.80E+04	5.80E+04
U	2.20E+04	2.20E+04
LANL	0.00E+00	0.00E+00
CS	1.40E+04	0.00E+00
SR	2.20E+02	0.00E+00
TC	5.30E+00	5.30E+00
I	4.40E+02	4.40E+02
FP2	4.40E+02	4.40E+02
AP1	5.00E+00	5.00E+00
NANO3	0.00E+00	0.00E+00
OHAZ2	0.00E+00	0.00E+00
SOI	0.00E+00	0.00E+00
OTH3	1.30E+00	1.30E+00
CR2O3	0.00E+00	0.00E+00
AM	8.90E+04	8.90E+04
TH	5.00E+04	5.00E+04
NP	5.00E+04	5.00E+04
LANH	4.40E+02	4.40E+02
NAOH	0.00E+00	0.00E+00
BA	0.00E+00	0.00E+00
HNO3	0.00E+00	0.00E+00
AL2O3	0.00E+00	0.00E+00
SIO2	0.00E+00	0.00E+00
NOX	0.00E+00	0.00E+00

Table I3. Calculated Radiation Dose and Cancer Risk to Individuals, Ranked by Risk, Assuming Exposure to a Buried Waste Concentration of 1 mCi/m³ (PNL-SA-20032 [Kennedy and Aaberg 1991]).

Scenario Nuclide	Ingestion (rems)	Inhalation (rems)	External (rems)	Total (rems)	Risk of Fatal Cancer(a)	New Units mrem/Ci/m ³
Drilling:						
Co-60	1.2E-06	1.6E-09	2.6E-03	2.6E-03	1E-06	2.60E+03
Cs-137	5.7E-06	2.3E-10	6.2E-04	6.3E-04	3E-07	6.30E+02
Am-241	4.4E-04	3.5E-06	4.7E-06	4.5E-04	2E-07	4.50E+02
I-129	3.0E-05	1.2E-09	1.8E-06	3.2E-05	1E-08	3.20E+01
Sr-90	1.5E-05	1.6E-09	1.2E-07	1.5E-05	6E-09	1.50E+01
Pu-239	6.0E-06	2.4E-06	4.6E-08	8.4E-06	3E-09	8.40E+00
U-238	2.8E-06	9.2E-07	2.8E-08	3.7E-06	2E-09	3.70E+00
Tc-99	2.7E-07	6.7E-11	1.7E-08	2.9E-07	1E-10	2.90E-01
Ni-63	6.6E-08	1.7E-11	6.3E-11	6.6E-08	3E-11	6.60E-02
Excavation:						
Am-241	5.4E-03	8.4E-02	1.0E-04	8.9E-02	4E-05	8.90E+04
Co-60	1.5E-05	3.8E-05	5.8E-02	5.8E-02	2E-05	5.80E+04
Pu-239	7.5E-05	5.8E-02	1.0E-06	5.8E-02	2E-05	5.80E+04
U-238	3.5E-05	2.2E-02	6.3E-07	2.2E-02	9E-06	2.20E+04
Cs-137	7.1E-05	5.7E-06	1.4E-02	1.4E-02	6E-06	1.40E+04
I-129	3.7E-04	2.9E-05	4.1E-05	4.4E-04	2E-07	4.40E+02
Sr-90	1.8E-04	3.9E-05	2.6E-06	2.2E-04	9E-08	2.20E+02
Tc-99	3.3E-06	1.6E-06	3.7E-07	5.3E-06	2E-09	5.30E+00
Ni-63	8.3E-07	4.2E-07	1.4E-09	1.3E-06	5E-10	1.30E+00

(a) Risk for workers, as given in ICRP Publication 60, is based on the conversion factor 4E-04 fatal cancers per rem.

Table I4. Long-Term Onsite Health Hazard Index (mrem/person) by Component. (sheet 2 of 2)

Input Streams	NP	LAN1	NACH	BA	HNO3	AL2O3	SiO2	NOX	Tot(mrem/per)
DSTTNKW	1.96E+01	8.57E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E+05
SSTTNKW	4.47E+00	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.44E+04
MODEL CLEG31 LONG TERM ONSITE HEALTH HAZARD INDEX									
Output Streams									
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E-10
3110HLWS	3.09E+03	3.89E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.69E+07
3200HLWS	1.03E+01	1.21E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.52E+04
3400LLWS	4.38E-02	6.20E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.42E+01
3400LMWS	4.38E-02	6.20E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.42E+01
3530LMWS	4.00E-15	3.49E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.76E-05
B212U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E+04
3400GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ALLGAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.08E-05
S10GRT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.87E-23
S10BUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.74E-23
S20ASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.30E-19
S30COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.26E-23
S30CONC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-18
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.70E-21
Tot(mrem/per)	3.10E+03	3.70E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.69E+07
MODEL TRUG31 LONG TERM ONSITE HEALTH HAZARD INDEX									
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E-09
3110HLWS	2.62E+02	3.09E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E+06
3200HLWS	1.03E+01	1.21E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.52E+04
3400LLWS	3.18E-02	3.88E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E+02
3400LMWS	3.18E-02	3.88E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E+02
3530LMWS	1.10E-14	9.51E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.50E-04
B24U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.14E+03
3110GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.48E-07
3400GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B112GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B13GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B21GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E-03
B22GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27E-05
B23GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B24GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.44E-07
B311GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B312GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C14GAS	5.16E-02	6.02E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.75E+02
S10GRT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.91E-23
S10BUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-22
S20ASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.12E-18
S30COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.03E-23
S30CONC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.56E-18
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-20
Tot(mrem/per)	2.72E+02	3.21E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.47E+06
MODEL SLUG31 LONG TERM ONSITE HEALTH HAZARD INDEX									
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E-10
3110HLWS	5.65E+01	6.68E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.05E+05
3200HLWS	1.03E+01	1.21E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.52E+04
3400LLWS	4.29E-03	3.30E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.44E+01
3400LMWS	4.29E-03	3.30E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.44E+01
3530LMWS	1.80E-14	1.80E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.78E-05
B24U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E+05
3110GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.79E-07
3400GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B112GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.51E-05
B13GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-03
B21GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E-03
B22GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.98E-04
B23GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B24GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.26E-06
B311GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B312GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C14GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.66E-01
S10GRT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.40E-23
S10BUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.88E-22
S20ASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.77E-18
S30COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-22
S30CONC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E-18
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.63E-20
Tot(mrem/per)	6.68E+01	7.89E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.35E+05

(sheet 1 of 2)

Insect Streams	Density kg/m ² /yr	NZO	RJ	U	LANL	CS	SR	TC	I	FPZ	AP1	NANC3	CMAZ2	SCT	OTW3	CRD3	AM	TH
ESTIMAY	1.80E+03	0.00E+00	2.74E+04	4.49E-01	0.00E+00	3.89E+06	2.17E+04	1.00E+00	1.03E-01	1.90E+00	1.02E-01	0.00E+00	0.00E+00	0.00E+00	2.72E-02	0.00E+00	7.71E+04	4.00E-15
SSTINWAY	1.80E+03	0.00E+00	1.19E+04	2.99E+01	0.00E+00	6.28E+05	3.09E+04	2.37E-01	2.93E-02	1.26E+01	4.78E-02	0.00E+00	0.00E+00	0.00E+00	1.10E+00	0.00E+00	1.14E+04	1.40E-01
MODEL CLE3C3 SHORT TERM ONSITE HEALTH HAZARD INDEX																		
Outfall		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Z200H2O	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E-10	0.00E+00	0.00E+00	0.00E+00
B110HLWS	1.00E+03	0.00E+00	5.90E-08	1.48E+01	0.03E+00	0.25E+08	1.09E+07	1.88E-02	0.00E+00	2.95E-01	7.80E-02	0.00E+00	0.00E+00	0.00E+00	8.41E-02	0.00E+00	1.05E+07	4.00E+01
3200L LWS	2.00E+03	0.00E+00	1.98E+04	2.81E+01	0.00E+00	1.72E+08	3.57E+04	5.53E-01	0.00E+00	1.26E+01	7.80E-02	0.00E+00	0.00E+00	0.00E+00	1.04E+00	0.00E+00	3.43E+04	1.98E-01
3400LLWS	2.00E+03	0.00E+00	7.97E+00	2.18E-02	0.00E+00	0.00E+00	1.15E+00	1.19E-03	2.29E-02	4.82E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.00E-01	0.00E+00	2.09E+01	5.44E-04
3400LLWS	2.00E+03	0.00E+00	7.97E+00	2.18E-02	0.00E+00	0.00E+00	1.15E+00	1.19E-03	2.29E-02	4.82E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.00E-01	0.00E+00	2.09E+01	5.44E-04
3530LLWS	1.00E+03	0.00E+00	0.00E+00	2.00E-15	0.00E+00	1.00E+15	1.74E-17	4.20E-19	3.49E-17	3.49E+17	3.98E+19	0.00E+00	0.00E+00	0.00E+00	2.79E-05	0.00E+00	7.00E+15	4.00E-15
B121U	3.00E+03	0.00E+00	0.00E+00	1.84E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3400GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ALLGAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SHOGRIT	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SHOGRIT	2.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SHOGRIT	2.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SPRASH	2.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SZ30CND	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SZ30CNC	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SZ40GAS	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SZ40GAS	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Totl(mrem/yr)																		
		0.00E+00	8.01E+06	1.85E+04	0.00E+00	5.27E+08	1.09E+07	1.89E+02	1.08E-01	4.28E+01	7.80E-02	0.00E+00	0.00E+00	0.00E+00	1.93E+00	0.00E+00	1.05E+07	4.02E+01
MODEL TUC3C3 SHORT TERM ONSITE HEALTH HAZARD INDEX																		
Outfall		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Z200H2O	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.29E-09	0.00E+00	0.00E+00	0.00E+00
B110HLWS	1.00E+03	0.00E+00	5.00E-08	1.07E+02	0.00E+00	4.39E+07	9.17E+05	1.43E-01	0.00E+00	4.11E-01	7.80E-02	0.00E+00	0.00E+00	0.00E+00	3.04E+00	0.00E+00	8.77E+04	3.39E+01
3200H LWS	2.00E+03	0.00E+00	1.98E+04	2.81E+01	0.00E+00	1.72E+08	3.57E+04	5.53E-01	0.00E+00	1.26E+01	7.80E-02	0.00E+00	0.00E+00	0.00E+00	1.04E+00	0.00E+00	3.43E+04	1.98E-01
3400LLWS	2.00E+03	0.00E+00	8.11E+01	5.52E-02	0.00E+00	7.29E-03	1.12E+02	1.76E-03	1.85E-02	3.58E+00	2.53E-02	0.00E+00	0.00E+00	0.00E+00	1.79E-01	0.00E+00	1.06E+02	4.12E-04
3400LLWS	2.00E+03	0.00E+00	8.11E+01	5.52E-02	0.00E+00	7.29E-03	1.12E+02	1.76E-03	1.85E-02	3.58E+00	2.53E-02	0.00E+00	0.00E+00	0.00E+00	1.79E-01	0.00E+00	1.06E+02	4.12E-04
3530LLWS	1.00E+03	0.00E+00	1.30E-14	5.00E-15	0.00E+00	3.00E-15	4.79E-17	1.15E-18	9.51E-17	9.51E-17	1.08E-18	0.00E+00	0.00E+00	0.00E+00	8.50E-04	0.00E+00	1.90E-14	1.10E-14
B121U	3.00E+03	0.00E+00	0.00E+00	4.14E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3110GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.12E-07	0.00E+00	0.00E+00	0.00E+00
3400GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B112GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B112GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B112GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B212GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B222GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B232GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B242GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B311GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B312GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B312GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C14GAS	1.00E+00	0.00E+00	9.78E+01	2.11E+02	0.00E+00	8.53E+03	1.78E+02	2.79E-03	0.00E+00	8.21E-03	5.91E-07	0.00E+00	0.00E+00	0.00E+00	8.29E-04	0.00E+00	1.71E+02	0.00E+00
SHOGRIT	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SHOGRIT	2.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SHOGRIT	2.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SZ30CND	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SZ30CNC	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SZ30CNC	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SZ40GAS	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SZ40GAS	1.00E+00	0.00E+00	0.00E+00															

Table I5. Short-Term Onsite Health Hazard Index (mrem/person) by Component. (sheet 2 of 2)

Input Streams	NP	LANH	NAOH	BA	HNO3	AL2O3	SiO2	NOX	Tot(mrem/per)
DSTTNKW	1.98E+01	8.57E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.81E+08
SSTTNKW	4.47E+00	1.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.82E+05
MODEL CLE331 SHORT TERM ONSITE HEALTH HAZARD INDEX									
Output Streams									
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E-10
3110HLWS	3.08E+03	3.89E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.53E+08
3200HLWS	1.03E+01	1.21E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.81E+08
3400LLWS	4.38E-02	8.20E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.53E+02
3400LMWS	4.38E-02	8.20E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.53E+02
3530LMWS	4.00E-15	3.49E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.76E-05
B212U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E+04
3400GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ALLGAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.08E-05
S10GRT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.87E-23
S10BUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.74E-23
S20ASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.30E-19
S30COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.26E-23
S30CONC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-18
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.70E-21
Tot(mrem/per)	3.10E+03	3.70E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.55E+08
MODEL TRUG31 SHORT TERM ONSITE HEALTH HAZARD INDEX									
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E-09
3110HLWS	2.82E+02	2.09E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.81E+07
3200HLWS	1.03E+01	1.21E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.81E+08
3400LLWS	3.18E-02	3.88E-00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.57E+03
3400LMWS	3.18E-02	3.88E-00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.57E+03
3530LMWS	1.10E-14	9.51E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.50E-04
B24U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.14E+03
3110GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.48E-07
3400GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B112GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B13GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E-03
B21GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.24E-04
B22GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27E-05
B23GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B24GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B311GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B312GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C14GAS	5.18E-02	8.02E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.98E+03
S10GRT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.91E-23
S10BUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-22
S20ASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.12E-18
S30COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.03E-23
S30CONC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.58E-18
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-20
Tot(mrem/per)	2.72E+02	3.21E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.80E+07
MODEL SLUG31 SHORT TERM ONSITE HEALTH HAZARD INDEX									
2200H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E-10
3110HLWS	5.85E+01	8.88E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.88E+08
3200HLWS	1.03E+01	1.21E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.81E+08
3400LLWS	4.29E-03	3.30E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E+04
3400LMWS	4.29E-03	3.30E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E+04
3530LMWS	1.80E-14	1.80E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.78E-05
B24U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E+05
3110GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.79E-07
3400GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B112GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.51E-05
B13GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-03
B21GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.57E-03
B22GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.98E-04
B23GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B24GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B311GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B312GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C14GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.94E+05
S10GRT	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.40E-23
S10BUR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.88E-22
S20ASH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.77E-18
S30COND	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-22
S30CONC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.49E-18
S40GAS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.63E-20
Tot(mrem/per)	8.68E+01	7.89E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.25E+07

Table I6. Occupational Health Hazard Index for Model CLEANG31.

GAMMA CONTAMINATION					
BLOCK	GAMMA FLOW (CI)	TOTAL FLOW (KG)	CONCENTRATION (CI/KG)	TERTIARY STREAM FLOWS (KG)	OCCUP. HEALTH HAZ INDEX (CI-KG/M3)
SEPSOLQ	4.65E+07	7.57E+08	6.13E-02	4.49E+07	2.76E+06
DESTORG	4.12E+07	7.97E+08	5.17E-02	4.63E+07	2.39E+06
CAUSLEAC	1.04E+07	2.47E+08	4.21E-02	2.91E+07	1.22E+06
CSIX	5.16E+07	1.12E+09	4.59E-02	5.33E+08	2.44E+07
SRIX	5.16E+03	1.13E+09	4.56E-06	5.34E+08	2.43E+03
TCIX	5.16E+03	1.14E+09	4.53E-06	5.35E+08	2.42E+03
DISOLVA	5.16E+06	6.30E+07	8.20E-02	7.41E+06	6.08E+05
DISOLVF	5.20E+05	1.53E+07	3.40E-02	1.80E+06	6.11E+04
EXTRUFU	5.11E+06	3.17E+08	1.61E-02	1.49E+08	2.40E+06
PURIFYU	0.00E+00	7.53E+07	0.00E+00	3.59E+07	0.00E+00
EXTRAMLN	5.11E+06	3.28E+08	1.56E-02	1.55E+08	2.42E+06
AMLANIX	0.00E+00	2.08E+08	0.00E+00	9.86E+07	0.00E+00
SPEX	5.11E+06	3.67E+08	1.39E-02	1.73E+08	2.40E+06
SRBAIX	0.00E+00	6.09E+08	0.00E+00	2.88E+08	0.00E+00
APMCSIX	5.11E+06	5.12E+08	9.98E-03	1.21E+08	1.20E+06
RCOVACID	0.00E+00	7.62E+08	0.00E+00	9.03E+07	0.00E+00
DNITRL	5.11E+03	7.22E+08	7.07E-06	8.50E+07	6.01E+02
CALCINE	1.03E+04	2.52E+09	4.07E-06	2.97E+08	1.21E+03
FEVCR	1.03E+04	7.52E+08	1.37E-05	8.82E+07	1.20E+03
EVAPORH	0.00E+00	7.35E+08	0.00E+00	4.26E+07	0.00E+00
DNITRH	5.16E+07	2.22E+07	2.33E+00	2.61E+06	6.08E+06
TOTALS	2.27E+08	1.32E+10	2.70E+00	3.36E+09	4.60E+07

ALPHA CONTAMINATION					
BLOCK	ALPHA FLOW (CI)	TOTAL FLOW (KG)	CONCENTRATION (CI/KG)	TERTIARY STREAM FLOWS (KG)	OCCUP. HEALTH HAZ INDEX (CI-KG/M3)
SEPSOLQ	2.75E+05	7.57E+08	3.63E-04	4.49E+07	1.63E+04
DESTORG	1.05E+04	7.97E+08	1.31E-05	4.63E+07	6.07E+02
CAUSLEAC	2.89E+05	2.47E+08	1.17E-03	2.91E+07	3.40E+04
CSIX	3.75E+02	1.12E+09	3.33E-07	5.33E+08	1.78E+02
SRIX	3.75E+02	1.13E+09	3.31E-07	5.34E+08	1.77E+02
TCIX	3.75E+02	1.14E+09	3.29E-07	5.35E+08	1.76E+02
DISOLVA	2.88E+05	6.30E+07	4.58E-03	7.41E+06	3.39E+04
DISOLVF	2.93E+04	1.53E+07	1.91E-03	1.80E+06	3.44E+03
EXTRUFU	2.74E+05	3.17E+08	8.64E-04	1.49E+08	1.29E+05
PURIFYU	5.79E+02	7.53E+07	7.69E-06	3.59E+07	2.76E+02
EXTRAMLN	1.46E+05	3.28E+08	4.44E-04	1.55E+08	6.89E+04
AMLANIX	1.46E+05	2.08E+08	7.00E-04	9.86E+07	6.90E+04
SPEX	1.49E+01	3.67E+08	4.07E-08	1.73E+08	7.04E+00
SRBAIX	0.00E+00	6.09E+08	0.00E+00	2.88E+08	0.00E+00
APMCSIX	1.49E+01	5.12E+08	2.92E-08	1.21E+08	3.52E+00
RCOVACID	0.00E+00	7.62E+08	0.00E+00	9.03E+07	0.00E+00
DNITRL	4.27E+01	7.22E+08	5.92E-08	8.50E+07	5.03E+00
CALCINE	4.47E+02	2.52E+09	1.77E-07	2.97E+08	5.26E+01
FEVCR	4.47E+02	7.52E+08	5.94E-07	8.82E+07	5.24E+01
EVAPORH	2.73E+05	7.35E+08	3.71E-04	4.26E+07	1.58E+04
DNITRH	2.73E+05	2.22E+07	1.23E-02	2.61E+06	3.22E+04
TOTALS	2.00E+06	1.32E+10	2.27E-02	3.36E+09	4.04E+05

BETA CONTAMINATION					
BLOCK	BETA FLOW (CI)	TOTAL FLOW (KG)	CONCENTRATION (CI/KG)	TERTIARY STREAM FLOWS (KG)	OCCUP. HEALTH HAZ INDEX (CI-KG/M3)
SEPSOLQ	6.28E+07	7.57E+08	8.29E-02	4.49E+07	3.73E+06
DESTORG	8.12E+05	7.97E+08	1.02E-03	4.63E+07	4.71E+04
CAUSLEAC	6.34E+07	2.47E+08	2.57E-01	2.91E+07	7.47E+06
CSIX	4.36E+05	1.12E+09	3.88E-04	5.33E+08	2.07E+05
SRIX	4.36E+05	1.13E+09	3.86E-04	5.34E+08	2.06E+05
TCIX	3.71E+05	1.14E+09	3.26E-04	5.35E+08	1.74E+05
DISOLVA	6.32E+07	6.30E+07	1.00E+00	7.41E+06	7.44E+06
DISOLVF	6.42E+06	1.53E+07	4.20E-01	1.80E+06	7.54E+05
EXTRUFU	6.25E+07	3.17E+08	1.97E-01	1.49E+08	2.94E+07
PURIFYU	1.26E+01	7.53E+07	1.67E-07	3.59E+07	6.00E+00
EXTRAMLN	6.25E+07	3.28E+08	1.90E-01	1.55E+08	2.96E+07
AMLANIX	1.04E+06	2.08E+08	4.99E-03	9.86E+07	4.93E+05
SPEX	6.14E+07	3.67E+08	1.67E-01	1.73E+08	2.89E+07
SRBAIX	6.14E+07	6.09E+08	1.01E-01	2.88E+08	2.90E+07
APMCSIX	6.42E+04	5.12E+08	1.26E-04	1.21E+08	1.51E+04
RCOVACID	0.00E+00	7.62E+08	0.00E+00	9.03E+07	0.00E+00
DNITRL	6.49E+04	7.22E+08	8.99E-05	8.50E+07	7.64E+03
CALCINE	4.03E+05	2.52E+09	1.60E-04	2.97E+08	4.75E+04
FEVCR	3.98E+05	7.52E+08	5.28E-04	8.82E+07	4.66E+04
EVAPORH	6.24E+07	7.35E+08	8.49E-02	4.26E+07	3.62E+08
DNITRH	6.24E+07	2.22E+07	2.82E+00	2.61E+06	7.36E+06
TOTALS	5.72E+08	1.32E+10	5.33E+00	3.36E+09	1.48E+08

Table I7. Occupational Health Hazard Index for Model TRUG31.

GAMMA CONTAMINATION

BLOCK	GAMMA FLOW (CI)	TOTAL FLOW (KG)	CONCENTRATION (CI/KG)	TERTIARY STREAM FLOWS (KG)	OCCUP. HEALTH HAZ INDEX (CI-KG/M3)
WASHSLUD	4.65E+07	7.57E+08	6.13E-02	4.49E+07	2.76E+06
DESTORG	4.13E+07	7.98E+08	5.17E-02	4.64E+07	2.40E+06
FILTADBS	4.12E+07	8.05E+08	5.12E-02	1.89E+08	9.68E+06
CSIX	4.59E+07	1.02E+09	4.50E-02	4.85E+08	2.18E+07
TCIX1	5.71E+05	1.93E+09	2.96E-04	9.03E+08	2.67E+05
DISSOLVA	5.21E+06	8.55E+07	6.09E-02	1.01E+07	6.14E+05
TRUEX	4.69E+06	5.01E+08	9.36E-03	2.35E+08	2.20E+06
SREX	4.69E+06	2.50E+08	1.87E-02	1.18E+08	2.20E+06
UTCSTRIP	0.00E+00	3.05E+08	0.00E+00	7.27E+07	0.00E+00
TCIX2	0.00E+00	6.96E+07	0.00E+00	3.28E+07	0.00E+00
PURIFYU	0.00E+00	1.07E+08	0.00E+00	4.99E+07	0.00E+00
NEUTDCAN	5.24E+05	7.40E+07	7.08E-03	4.36E+06	3.09E+04
NEUTRAL	4.53E+07	1.24E+06	3.66E+01	7.29E+04	2.67E+06
TOTALS	2.36E+08	6.70E+09	3.69E+01	2.19E+09	4.46E+07

ALPHA CONTAMINATION

BLOCK	ALPHA FLOW (CI)	TOTAL FLOW (KG)	CONCENTRATION (CI/KG)	TERTIARY STREAM FLOWS (KG)	OCCUP. HEALTH HAZ INDEX (CI-KG/M3)
WASHSLUD	2.75E+05	7.57E+08	3.63E-04	4.49E+07	1.63E+04
DESTORG	1.05E+04	7.98E+08	1.31E-05	4.64E+07	6.07E+02
FILTADBS	1.05E+02	8.05E+08	1.30E-07	1.89E+08	2.45E+01
CSIX	6.92E+02	1.02E+09	6.79E-07	4.85E+08	3.29E+02
TCIX1	6.92E+02	1.93E+09	3.59E-07	9.03E+08	3.24E+02
DISSOLVA	2.75E+05	8.55E+07	3.21E-03	1.01E+07	3.24E+04
TRUEX	2.34E+05	5.01E+08	4.67E-04	2.35E+08	1.10E+05
SREX	1.17E+03	2.50E+08	4.67E-06	1.18E+08	5.49E+02
UTCSTRIP	1.57E+03	3.05E+08	5.15E-06	7.27E+07	3.75E+02
TCIX2	1.57E+03	6.96E+07	2.26E-05	3.28E+07	7.41E+02
PURIFYU	1.57E+03	1.07E+08	1.47E-05	4.99E+07	7.32E+02
NEUTDCAN	2.72E+05	7.40E+07	3.67E-03	4.36E+06	1.60E+04
NEUTRAL	0.00E+00	1.24E+06	0.00E+00	7.29E+04	0.00E+00
TOTALS	1.07E+06	6.70E+09	7.77E-03	2.19E+09	1.78E+05

BETA CONTAMINATION

BLOCK	BETA FLOW (CI)	TOTAL FLOW (KG)	CONCENTRATION (CI/KG)	TERTIARY STREAM FLOWS (KG)	OCCUP. HEALTH HAZ INDEX (CI-KG/M3)
WASHSLUD	6.28E+07	7.57E+08	8.29E-02	4.49E+07	3.73E+06
DESTORG	8.13E+05	7.98E+08	1.02E-03	4.64E+07	4.72E+04
FILTADBS	1.96E+05	8.05E+08	2.44E-04	1.89E+08	4.61E+04
CSIX	1.97E+05	1.02E+09	1.93E-04	4.85E+08	9.35E+04
TCIX1	2.04E+05	1.93E+09	1.06E-04	9.03E+08	9.55E+04
DISSOLVA	6.26E+07	8.55E+07	7.32E-01	1.01E+07	7.38E+06
TRUEX	5.62E+07	5.01E+08	1.12E-01	2.35E+08	2.64E+07
SREX	5.50E+07	2.50E+08	2.20E-01	1.18E+08	2.58E+07
UTCSTRIP	1.11E+05	3.05E+08	3.63E-04	7.27E+07	2.64E+04
TCIX2	1.24E+04	6.96E+07	1.79E-04	3.28E+07	5.87E+03
PURIFYU	4.87E+03	1.07E+08	4.54E-05	4.99E+07	2.27E+03
NEUTDCAN	6.19E+07	7.40E+07	8.36E-01	4.36E+06	3.65E+06
NEUTRAL	3.82E+04	1.24E+06	3.09E-02	7.29E+04	2.25E+03
TOTALS	3.00E+08	6.70E+09	2.02E+00	2.19E+09	6.72E+07

Table 18. Occupational Health Hazard Index for Model SLUG31.

GAMMA CONTAMINATION

BLOCK	GAMMA FLOW (CI)	TOTAL FLOW (KG)	CONCENTRATION (CI/KG)	TERTIARY STREAM FLOWS (KG)	OCCUP. HEALTH HAZ INDEX (CI-KG/M3)
WASHSLUD	4.65E+07	7.57E+08	6.13E-02	4.49E+07	2.76E+06
DESTORG	4.13E+07	7.98E+08	5.17E-02	4.64E+07	2.40E+06
FILTADBS	4.12E+07	8.04E+08	5.13E-02	1.89E+08	9.69E+06
CSIX	4.12E+07	8.04E+08	5.13E-02	3.75E+08	1.92E+07
TCIX1	5.13E+05	1.50E+09	3.41E-04	7.05E+08	2.41E+05
DISSOLVA	5.17E-07	9.75E-06	5.30E-02	1.15E-06	6.11E-08
TRUEX	4.65E-07	9.53E-06	4.87E-02	4.59E-06	2.24E-07
SREX	4.65E-07	2.05E-06	2.27E-01	9.56E-07	2.17E-07
UTCSTRIP	0.00E+00	2.49E-06	0.00E+00	5.94E-07	0.00E+00
TCIX2	0.00E+00	4.67E-07	0.00E+00	2.19E-07	0.00E+00
PURIFYU	0.00E+00	3.24E-07	0.00E+00	1.52E-07	0.00E+00
NEUTDCAN	5.21E+06	2.18E+08	2.39E-02	1.29E+07	3.08E+05
NEUTRAL	4.07E+07	9.59E+05	4.25E+01	5.69E+04	2.42E+06
TOTALS	2.17E+08	4.88E+09	4.30E+01	1.37E+09	3.71E+07

ALPHA CONTAMINATION

BLOCK	ALPHA FLOW (CI)	TOTAL FLOW (KG)	CONCENTRATION (CI/KG)	TERTIARY STREAM FLOWS (KG)	OCCUP. HEALTH HAZ INDEX (CI-KG/M3)
WASHSLUD	2.75E+05	7.57E+08	3.63E-04	4.49E+07	1.63E+04
DESTORG	1.05E+04	7.98E+08	1.31E-05	4.64E+07	6.09E+02
FILTADBS	1.05E+02	8.04E+08	1.30E-07	1.89E+08	2.46E+01
CSIX	8.95E+01	8.04E+08	1.11E-07	3.75E+08	4.18E+01
TCIX1	8.95E+01	1.50E+09	5.96E-08	7.05E+08	4.20E+01
DISSOLVA	5.49E-09	9.75E-06	5.63E-04	1.15E-06	6.50E-10
TRUEX	4.68E-09	9.53E-06	4.91E-04	4.59E-06	2.25E-09
SREX	2.34E-11	2.05E-06	1.14E-05	9.56E-07	1.09E-11
UTCSTRIP	3.14E-11	2.49E-06	1.26E-05	5.94E-07	7.48E-12
TCIX2	3.15E-11	4.67E-07	6.73E-05	2.19E-07	1.48E-11
PURIFYU	3.15E-11	3.24E-07	9.73E-05	1.52E-07	1.48E-11
NEUTDCAN	2.75E+05	2.18E+08	1.26E-03	1.29E+07	1.63E+04
NEUTRAL	0.00E+00	9.59E+05	0.00E+00	5.69E+04	0.00E+00
TOTALS	5.60E+05	4.88E+09	2.88E-03	1.37E+09	3.33E+04

BETA CONTAMINATION

BLOCK	BETA FLOW (CI)	TOTAL FLOW (KG)	CONCENTRATION (CI/KG)	TERTIARY STREAM FLOWS (KG)	OCCUP. HEALTH HAZ INDEX (CI-KG/M3)
WASHSLUD	6.28E+07	7.57E+08	8.29E-02	4.49E+07	3.73E+06
DESTORG	8.14E+05	7.98E+08	1.02E-03	4.64E+07	4.73E+04
FILTADBS	1.97E+05	8.04E+08	2.45E-04	1.89E+08	4.63E+04
CSIX	1.96E+05	8.04E+08	2.44E-04	3.75E+08	9.16E+04
TCIX1	1.96E+05	1.50E+09	1.31E-04	7.05E+08	9.21E+04
DISSOLVA	1.25E-06	9.75E-06	1.29E-01	1.15E-06	1.48E-07
TRUEX	1.13E-06	9.53E-06	1.18E-01	4.59E-06	5.42E-07
SREX	1.10E-06	2.05E-06	5.37E-01	9.56E-07	5.13E-07
UTCSTRIP	3.47E-09	2.49E-06	1.39E-03	5.94E-07	8.25E-10
TCIX2	4.98E-10	4.67E-07	1.07E-03	2.19E-07	2.34E-10
PURIFYU	1.00E-10	3.24E-07	3.10E-04	1.52E-07	4.72E-11
NEUTDCAN	6.26E+07	2.18E+08	2.87E-01	1.29E+07	3.71E+06
NEUTRAL	3.00E+04	9.59E+05	3.13E-02	5.69E+04	1.78E+03
TOTALS	1.27E+08	4.88E+09	1.19E+00	1.37E+09	7.71E+06

Table 19. Summary of Occupational Health Hazard Index (Ci-kg/m³) Results.

MODEL:	CLEANG31 CLEAN	TRUG31 TRUEX-C	SLUG31 SLUDGE WASH C
TYPE OF CONTAMINATION			
GAMMA	4.60E+07	4.46E+07	3.71E+07
ALPHA	4.04E+05	1.78E+05	3.33E+04
BETA	1.48E+08	6.72E+07	7.71E+06
CLEAN/"MODEL"			
GAMMA		1.03	1.24
ALPHA		2.27	12.14
BETA		2.21	19.25

Table I10. Waste Concentration Upper Limits.

		CLASS							
		Groundwater pCi/L	Residential pCi/gm	Industrial pCi/gm	LLW A Ci/m3	LLW B Ci/m3	LLW C Ci/m3	TRU	GTOC
H2O	tritium	2.00E+04	3.50E+04	1.00E+07	4.00E+01	4.00E+01	4.00E+01	na	on up
PU	Pu-239	1.00E+00	7.50E+01	7.50E+01	10*	10*	100*	on up	na
U	U-238	2.00E+01	5.00E+01	5.00E+01	5.00E-02	5.00E-02	5.00E-01**	na	on up
CS	Cs-137	1.00E+01	3.00E+00	2.00E+04	1.00E+00	4.40E+01	4.60E+03	na	on up
SR	Sr-90	8.00E+00	1.30E+01	6.00E+02	4.00E-02	1.50E+02	7.00E+03	na	on up
TC	Tc-99	4.00E+03	1.80E+03	1.00E+05	3.00E-01	3.00E-01	3.00E+00	na	on up
I	I-129	1.00E+00	5.00E+01	4.00E+03	8.00E-03	8.00E-03	8.00E-02	na	on up
FP2	Ru-106	3.00E+01	1.50E+01	1.50E+01	7.00E+02	7.00E+02	7.00E+02	na	on up
AP1	C-14	7.00E+03	8.70E+02	3.00E+07	8.00E-01	8.00E-01	8.00E+00	na	on up
OTH3	Ni-63	1.20E+04	3.90E+03	1.00E+05	3.50E+00	7.00E+01	7.00E+02	na	on up
AM	Am-241	1.00E+00	2.00E+01	2.00E+01	10*	10*	100*	on up	na
TH	Th-232	no limit	no limit	no limit	no limit	no limit	no limit	no limit	no limit
NP	Np-237	no limit	no limit	no limit	10*	10*	100*	on up	na
LANH	Eu-152	8.00E+02	3.00E+00	3.00E+03	7.00E+02	7.00E+02	7.00E+02	na	on up
Totals		8.00E+00	3.00E+00	6.00E+02	4.00E-02	4.40E+01	4.60E+03	na	on up

* nCi/gm

** From reference Kocher and Croff, 1988.

Table I11. Waste Concentration Upper Limits (Ci/m³).

		CLASS							
		Groundwater Ci/m3	Residential Ci/m3	Industrial Ci/m3	LLW A Ci/m3	LLW B Ci/m3	LLW C Ci/m3	TRU	GTOC
H2O	tritium	2.00E-05	5.25E-02	1.50E+01	4.00E+01	4.00E+01	4.00E+01	na	on up
PU	Pu-239	1.00E-09	1.13E-04	1.13E-04	1.50E-02	1.50E-02	1.50E-01	on up	na
U	U-238	2.00E-08	7.50E-05	7.50E-05	5.00E-02	5.00E-02	5.00E-01	na	on up
CS	Cs-137	1.00E-08	4.50E-06	3.00E-02	1.00E+00	4.40E+01	4.60E+03	na	on up
SR	Sr-90	8.00E-09	1.95E-05	9.00E-04	4.00E-02	1.50E+02	7.00E+03	na	on up
TC	Tc-99	4.00E-06	2.70E-03	1.50E-01	3.00E-01	3.00E-01	3.00E+00	na	on up
I	I-129	1.00E-09	7.50E-05	6.00E-03	8.00E-03	8.00E-03	8.00E-02	na	on up
FP2	Ru-106	3.00E-08	2.25E-05	2.25E-05	7.00E+02	7.00E+02	7.00E+02	na	on up
AP1	C-14	7.00E-06	1.31E-03	4.50E+01	8.00E-01	8.00E-01	8.00E+00	na	on up
OTH3	Ni-63	1.20E-05	5.85E-03	1.50E-01	3.50E+00	7.00E+01	7.00E+02	na	on up
AM	Am-241	1.00E-09	3.00E-05	3.00E-05	1.50E-02	1.50E-02	1.50E-01	on up	na
TH	Th-232	no limit	no limit	no limit	no limit	no limit	no limit	no limit	no limit
NP	Np-237	no limit	no limit	no limit	1.50E-02	1.50E-02	1.50E-01	on up	na
LANH	Eu-152	8.00E-07	4.50E-06	4.50E-03	7.00E+02	7.00E+02	7.00E+02	na	on up
Totals		8.00E-09	4.50E-06	9.00E-04	4.00E-02	4.40E+01	4.60E+03	na	on up

Conversion Factors:

Density =	1.50E+03	kg/m3
pCi/L =	1.00E-09	Ci/m3
pCi/gm =	1.50E-06	Ci/m3
nCi/gm =	1.50E-03	Ci/m3

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

6 of 6

Table 112. Stream Curie Concentration (Ci/m³) by Component.

Input Streams	Density	H2O	PU	U	CS	SR	TC	I	FP2	AP1	OTH3	AM	NP	LAM4	Total Chl(a+b)
3110H1 WS	1.00E+03	8.65E-20	4.73E-01	2.04E-05	2.63E-02	9.66E-01	2.03E-01	2.33E-04	4.31E-03	2.03E-02	2.09E-02	8.67E-01	3.92E-04	1.95E+00	3.65E-02
320H1 WS	1.00E+03	2.80E-20	2.05E-01	1.34E-03	4.47E+01	1.40E+02	4.47E-02	6.71E-05	2.87E-02	0.51E-03	8.44E-01	1.29E-01	8.95E-05	2.29E+00	1.98E-02
340H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
360H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
380H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
400H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
420H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
440H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
460H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
480H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
500H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
520H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
540H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
560H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
580H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
600H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
620H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
640H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
660H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
680H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
700H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
720H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
740H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
760H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
780H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
800H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
820H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
840H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
860H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
880H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
900H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
920H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
940H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
960H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
980H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1000H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1020H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1040H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1060H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1080H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1100H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1120H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1140H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1160H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1180H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1200H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1220H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1240H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1260H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1280H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1300H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1320H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1340H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1360H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1380H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1400H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1420H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1440H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.40E-03	5.23E-03	2.25E-04	5.21E-05	1.10E-02	1.00E-30	3.07E-01	2.32E-04	8.73E-07	1.41E-03	3.34E-01
1460H1 WS	2.00E+03	1.35E-20	1.32E-04	8.92E-07	8.										

[illegible]

[illegible][illegible]

MODEL SLUG31 LOW LEVEL WASTE CLASSIFICATIONS					
2200H2O	1.00E+03	LLWA	LLWA	LLWC	LLWA
110H4WS	1.00E+03	LLWA	LLWC	LLWC	LLWA
2200H4WS	2.00E+03	LLWA	TRU	LLWA	LLWA
400L4WS	2.00E+03	LLWA	LLWA	LLWB	LLWA
400L4WS	2.00E+03	LLWA	LLWA	LLWB	LLWA
530L4WS	1.00E+03	LLWA	LLWA	LLWA	LLWA
B24J	3.00E+03	LLWA	GTOC	LLWA	LLWA
3170GAS	1.00E+00	LLWA	LLWA	LLWA	LLWA
3400GAS	1.00E+00	LLWA	LLWA	LLWA	LLWA
B112GAS	1.00E+00	LLWA	LLWA	LLWA	LLWA
B13GAS	1.00E+00	LLWA	LLWA	LLWA	LLWA
B21GAS	1.00E+00	LLWA	LLWA	LLWA	LLWA
B22GAS	1.00E+00	LLWA	LLWA	LLWA	LLWA
B23GAS	1.00E+00	LLWA	LLWA	LLWA	LLWA
B24GAS	1.00E+00	LLWA	LLWA	LLWA	LLWA
B311GAS	1.00E+00	LLWA	LLWA	LLWA	LLWA
B312GAS	1.00E+00	LLWA	LLWA	LLWA	LLWA
C14GAS	1.00E+00	LLWA	LLWB	LLWA	LLWA
S10GBT	1.00E+03	LLWA	LLWA	LLWA	LLWA
S10BUR	2.00E+03	LLWA	LLWA	LLWA	LLWA
S20ASH	2.00E+03	LLWA	LLWA	LLWA	LLWA
S30CONC	1.00E+03	LLWA	LLWA	LLWA	LLWA
S30CONC	1.00E+03	LLWA	LLWA	LLWA	LLWA
S40GAS	1.00E+00	LLWA	LLWA	LLWA	LLWA

This page intentionally left blank.

APPENDIX J

TANK WASTE INVENTORIES

LIST OF TERMS

DST
SST

dcuble-shell tank
single-shell tank

TANK WASTE INVENTORIES

As part of this study a review of the Hanford tank waste inventories (mass and radiological) was made based on several published documents to ensure that the most up-to-date data was used. Based on the data provided in the references listed below, tank waste inventories were determined as given in Table J1. Table J2 shows a summary of the actual radiological (i.e., curie) data provided in the following references. Actual N Reactor fission yield distribution data shown in Tables J2 and J3 were used to supplement the existing radiological information to provide a better estimate of existing element inventories. Note that in establishing radiological (curie) inventories several elements were ignored because of their short half-lives relative to expected processing times as noted on Table J1.

Table J4 shows the tank waste feedstream curie inventory data by radionuclide. Table J5 shows the tank waste feedstream mass inventory calculated using the curie data only.

Note that the representation of all Hanford tank waste in two feedstreams, single-shell tanks (SST) and double-shell tanks (DST), will not apply to a single tank or a single tank farm. Also, because large quantities of inert strontium, lanthanides, and perhaps iodine were added to parts of the SST tanks, the concentrations of radionuclides in these components vary widely between SST and DST.

REFERENCES

Designated "O'Toole" or "O'Toole-Ci" in Table J1:

O'Toole, S. M., 1993, "Tank Waste Inventory Revision," WHC Internal Memo 01140-93-005, from Integrated Planning Function, Westinghouse Hanford Company, Richland, Washington.

Designated "TRAC" in Table J1:

Garfield, J. S., 1993, "TWRS Systems Engineering Study Double Shell Tank Waste Inventories, Revision 1," WHC Internal Memo 25900-92-29, Westinghouse Hanford Company, Richland, Washington.

Golberg, C. E., 1993, "Technical Options Report Bases And Assumptions," WHC Internal Memo 22170-93-021, Waste Management Engineering, Westinghouse Hanford Company, Richland, Washington.

Designated "Swanson" in Table J1:

Swanson, J. L., 1993, *Clean Option: An Alternative Strategy For Hanford Tank Waste Remediation*, PNL-8388, Vol. 2, Pacific Northwest Laboratory, Richland, Washington.

Designated "IDB93-96" or "IDB-96 Ci" in Table J1:

Integrated Data Base for 1989: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, November 1989, DOE/RW-0006, Rev. 5, Updated for 1993, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Designated "NEW ASPEN" in Table J1:

Boomer, K. D., et al., 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Table J1. Study Tank Waste Inventory Summary.

ASPEN COMPONENTS	STUDY INVENTORY Total kg	DATA SOURCE SST	STUDY INVENTORY SST kg	DATA SOURCE DST	STUDY INVENTORY DST kg	ASPEN COMPONENTS	STUDY INVENTORY SST 1/1/96 Ci	STUDY INVENTORY DST 1/1/96 Ci
Ag+	4.41E+02	O'Toole	0.00E+00	O'Toole	4.41E+02	Ag+ **	0.00E+00	7.84E-01
Al+3	4.40E+06	O'Toole	2.20E+06	O'Toole	2.20E+06	Al+3		
Am+3	4.27E+01	O'Toole	1.40E+01	O'Toole	2.87E+01	Am+3	4.57E+04	9.87E+04
As+5	8.42E+02	O'Toole	0.00E+00	O'Toole	8.42E+02	As+5		
B+3	2.56E+03	O'Toole	0.00E+00	O'Toole	2.56E+03	B+3		
Ba+2	5.02E+05	Swanson	5.00E+05	O'Toole	1.76E+03	Ba+2 **	1.50E+07	2.87E+07
Be+2	9.95E+00	O'Toole	0.00E+00	O'Toole	9.95E+00	Be+2		
Bi+3	2.61E+05	TRAC	2.61E+05	O'Toole	0.00E+00	Bi+3		
C14	1.29E+00	O'Toole-Ci	7.63E-01	O'Toole-Ci	5.27E-01	C14	3.40E+03	2.35E+03
C2H2O4	0.00E+00	O'Toole	0.00E+00	O'Toole	0.00E+00	C2H2O4		
Ca+2	1.47E+05	O'Toole	1.30E+05	O'Toole	1.67E+04	Ca+2		
CANCRINI	2.70E+06	O'Toole	2.70E+06	O'Toole	0.00E+00	CANCRINI		
Cd+2	1.07E+04	O'Toole	4.00E+03	O'Toole	6.74E+03	Cd+2 **	0.00E+00	3.25E+03
Ce+3	2.36E+05	TRAC	2.35E+05	TRAC	8.44E+02	Ce+3 **	0.00E+00	3.20E+04
Cl-	4.87E+05	O'Toole	4.00E+04	O'Toole	4.47E+05	Cl-		
CM+3	2.03E-02	O'Toole-Ci	1.73E-03	O'Toole-Ci	1.86E-02	CM+3	1.40E+02	1.55E+03
Co+3	8.14E+02	O'Toole	0.00E+00	O'Toole	8.14E+02	Co+3 **	9.40E+04	6.96E+03
CO3-2	2.82E+06	O'Toole	1.70E+06	O'Toole	1.12E+06	CO3-2		
Cr+3,+6	1.83E+05	Swanson	1.15E+05	O'Toole	6.83E+04	Cr+3,+6		
Cs+	1.88E+03	O'Toole-Ci	6.46E+02	O'Toole-Ci	1.23E+03	Cs+	1.60E+07	3.05E+07
Cu+2	1.23E+03	O'Toole	0.00E+00	TRAC	1.23E+03	Cu+2		
F-	1.19E+06	O'Toole	8.10E+05	O'Toole	3.82E+05	F-		
Fe+3	7.32E+05	O'Toole	6.30E+05	O'Toole	1.02E+05	Fe+3 **	0.00E+00	2.13E+03
FeCN6-3	3.54E+03	NEW ASPEN	0.00E+00	O'Toole	3.54E+03	FeCN6-3		
H+	6.57E-05	NEW ASPEN	0.00E+00	NEW ASPEN	6.57E-05	H+		
H2O	5.17E+08	NEW ASPEN	3.86E+08	NEW ASPEN	1.31E+08	H2O		
Hg+2	1.28E+03	O'Toole	1.00E+03	O'Toole	2.80E+02	Hg+2		
I-	1.24E+03	O'Toole-Ci	6.19E+02	O'Toole-Ci	6.25E+02	I-	2.40E+01	2.70E+01
K+	1.84E+06	Swanson	4.00E+05	O'Toole	1.44E+06	K+		
La+3	3.87E+04	NEW ASPEN	2.79E+04	TRAC	1.08E+04	La+3		
Li+	4.11E+01	O'Toole	0.00E+00	TRAC	4.11E+01	Li+		
Mg+2	5.40E+03	O'Toole	0.00E+00	O'Toole	5.40E+03	Mg+2		
MnO2	2.12E+05	O'Toole	1.90E+05	O'Toole	2.23E+04	MnO2		
Mo+6	8.42E+03	O'Toole	0.00E+00	O'Toole	8.42E+03	Mo+6		
Na+	6.86E+07	TRAC	5.17E+07	O'Toole	1.69E+07	Na+		
Nb+5	5.41E+00	O'Toole	0.00E+00	O'Toole	5.41E+00	Nb+5 **	8.41E+03	1.44E+02
Ni+3	1.06E+04	NEW ASPEN	0.00E+00	O'Toole	1.06E+04	Ni+3	3.02E+05	2.42E+03
N12FECN6	4.98E+05	NEW ASPEN	4.98E+05	O'Toole	0.00E+00	N12FECN6		
NO2-	9.85E+06	O'Toole	4.80E+06	O'Toole	5.05E+06	NO2-		
NO3-	1.11E+08	O'Toole	9.70E+07	O'Toole	1.40E+07	NO3-		
Np+4	1.09E+02	O'Toole-Ci	4.54E+01	IDB-96 Ci	6.40E+01	Np+4	3.20E+01	4.54E+01
OH-	1.94E+07	TRAC	9.14E+06	O'Toole	1.03E+07	OH-		
P2O5:24W	2.01E+04	NEW ASPEN	2.01E+04	O'Toole	0.00E+00	P2O5:24W		
Pb+4	4.40E+05	TRAC	4.36E+05	O'Toole	3.69E+03	Pb+4		
PO4-3	9.02E+06	O'Toole	8.80E+06	O'Toole	2.17E+05	PO4-3		
Pu+4	5.38E+02	O'Toole	3.80E+02	O'Toole	1.58E+02	Pu+4	7.33E+04	5.47E+04
Rb+	6.49E+01	O'Toole	0.00E+00	NEW ASPEN	6.49E+01	Rb+		
Re+7	4.30E+01	O'Toole	0.00E+00	NEW ASPEN	4.30E+01	Re+7		
Rh+3	4.42E+02	O'Toole	0.00E+00	O'Toole	4.42E+02	Rh+3 **	1.25E+00	3.87E+04
Ru+3	5.53E+02	O'Toole	0.00E+00	O'Toole	5.53E+02	Ru+3 **	1.25E+00	3.87E+04
SB+5	1.86E+03	O'Toole	0.00E+00	O'Toole	1.86E+03	SB+5 **	0.00E+00	1.40E+05
SE+6	1.39E+03	O'Toole-Ci	1.31E+00	O'Toole	1.39E+03	SE+6 **	1.00E+01	8.15E+02
Si+4	6.00E+04	O'Toole	0.00E+00	O'Toole	6.00E+04	Si+4		
Sm+3	5.13E+02	O'Toole-Ci	4.02E+02	O'Toole-Ci	1.11E+02	Sm+3	8.14E+05	2.25E+05
SN+4	6.72E+01	O'Toole-Ci	5.68E+01	O'Toole-Ci	1.04E+01	SN+4	5.70E+02	1.78E+02
SO4-2	2.03E+06	TRAC	1.65E+06	O'Toole	3.80E+05	SO4-2 **		
Sr+2	4.71E+04	O'Toole-Ci	4.69E+04	O'Toole	2.47E+02	Sr+2	5.00E+07	1.14E+07
TcO4-	3.89E+03	O'Toole	1.55E+03	O'Toole	2.34E+03	TcO4-	1.60E+04	2.35E+04
Te+6	2.51E+02	O'Toole	0.00E+00	TRAC	2.51E+02	Te+6 **	0.00E+00	3.41E+04
Th+4	1.38E+04	Swanson	1.30E+04	O'Toole	8.26E+02	Th+4	1.00E+00	0.00E+00
Ti+4	4.47E+02	O'Toole	0.00E+00	O'Toole	4.47E+02	Ti+4		
TL+3	5.49E+03	O'Toole	0.00E+00	NEW ASPEN	5.49E+03	TL+3		
TOC	8.15E+05	O'Toole	2.00E+05	O'Toole	6.15E+05	TOC		
UO2+2	1.63E+06	O'Toole	1.59E+06	TRAC	4.35E+04	UO2+2	4.80E+02	2.36E+00
V+5	4.81E+01	O'Toole	0.00E+00	NEW ASPEN	4.81E+01	V+5		
W+6	3.87E+03	TRAC	6.02E+02	NEW ASPEN	3.27E+03	W+6		
Zn+2	2.35E+03	O'Toole	0.00E+00	O'Toole	2.35E+03	Zn+2		
ZrO2:2H2O	9.83E+05	O'Toole	4.36E+05	O'Toole	5.46E+05	ZrO2:2H2O	9.70E+03	3.21E+02
Pd (Pd not currently in model)	2.10E+03 Swanson		2.00E+03	O'Toole-Ci	9.87E+01	Pd (Pd not currently in model)	3.00E+01	8.21E+00
Tot. Rare Earths	2.75E+05		2.63E+05		1.17E+04	Y **	5.00E+07	1.14E+07
						Eu **	0.00E+00	1.19E+05
						Pm **	0.00E+00	2.80E+06
						Pr **	0.00E+00	3.23E+04
						Light Lan. **	0.00E+00	0.00E+00
						Heavy Lan.	8.14E+05	2.25E+05

** Ignored in final ASPEN+ Curie Inventory

Table J2. Study of Curie Inventory Data and Mass Inventory Estimates Based on the Curie Data.

ASPEN+ COMPONENTS	Study INVENTORY SST CI	Study INVENTORY DST CI	Study INVENTORY SST kg	Study INVENTORY DST kg	Study INVENTORY Total kg	Estimates Using N-Reactor Fuel 30y Decay Data SST kg	DST kg	Reactor Yield Distribution Data
Ag+ **	0.00E+00	7.84E-01	0.00E+00	1.65E-07	1.65E-07			N-Reactor Fuel Based on BNWL-B-350 Apr74 Origin Results Decay Date: 20y 30y 50y Ba(kgs) 1.56E+02 1.71E+02 1.91E+02 Ba-137m(Ci) 5.75E+06 4.57E+06 2.88E+06 kg/Ci 2.71E-05 3.73E-05 6.64E-05 Ba+2 (kg SST) 4.07E+02 5.60E+02 9.96E+02 Ba+2 (kg DST) 7.79E+02 1.07E+03 1.91E+03
Al+3								
Am+3	4.57E+04	9.87E+04	1.34E+01	2.88E+01	4.22E+01			
As+5								
B+3								
Ba+2 **	1.50E+07	2.87E+07	2.79E-05	5.34E-05	8.12E-05	5.60E+02	1.07E+03	
Be+2								
Bi+3								
C14	3.40E+03	2.35E+03	7.63E-01	5.27E-01	1.29E+00			
C2H2O4								
Ca+2								Wodrich Report Data: Radiogenic/NonRadiogenic Iodine I-129 (Ci) I-129 (kg) Total I (kg) SST 24 123 560 DST 32 181 740 Radiogenic Ratio (I-129/I-127): SST 0.277 DST 0.319
CANCRINI								
Cd+2 **	0.00E+00	3.25E+03	0.00E+00	1.45E-02	1.45E-02			
Ce+3 **	0.00E+00	3.20E+04	0.00E+00	1.00E-02	1.00E-02			
Cl-								
CM+3	1.40E+02	1.55E+03	1.73E-03	1.86E-02	2.04E-02			
Co+3 **	9.40E+04	6.96E+03	8.31E-02	6.15E-03	8.92E-02			
CO3-2								
Cr+3.+6								
Cs+	1.60E+07	3.05E+07	2.48E+02	4.03E+02	6.51E+02	6.46E+02	1.23E+03	
Cu+2								PWR React. Fuel Based on BM/ONWI-655 Origin Results Decay Date: 20y 30y 60y Cs(kgs) 2.15E+00 2.00E+00 1.71E+00 Cs-137(Ci) 6.47E+04 5.14E+04 2.57E+04 kg/Ci 3.33E-05 3.89E-05 6.64E-05 Cs+ (kg SST) 5.33E+02 6.23E+02 1.06E+03 Cs+ (kg DST) 1.01E+03 1.18E+03 2.02E+03
F-								
Fe+3 **	0.00E+00	2.13E+03	0.00E+00	8.95E-04	8.95E-04			
FeCN6-3								
H+								
H2O								
Hg+2								
I-	2.40E+01	2.70E+01	1.36E+02	1.53E+02	2.89E+02	6.19E+02	6.25E+02	
K+								
La+3								N-Reactor Fuel Based on BNWL-B-350 Apr74 Origin Results Decay Date: 20y 30y 50y Cs(kgs) 2.12E+02 1.97E+02 1.76E+02 Cs-137(Ci) 6.15E+06 4.88E+06 3.08E+06 kg/Ci 3.44E-05 4.03E-05 5.72E-05 Cs+ (kg SST) 5.50E+02 6.46E+02 9.15E+02 Cs+ (kg DST) 1.05E+03 1.23E+03 1.74E+03
Li+								
Mg+2								
MnO2								
Mo+6								
Na+								
Nb+5 **	8.41E+03	1.44E+02	3.52E-02	6.02E-04	3.58E-02			
Ni+3	3.02E+05	2.42E+03	5.31E+00	1.56E-01	5.47E+00			
Ni2FeCN6								
NO2-								N-Reactor Fuel Based on BNWL-B-350 Apr74 Origin Results Decay Date: 20y 30y 50y Sn(kgs) 3.15E+00 3.15E+00 3.15E+00 Sn-126(Ci) 3.16E+01 3.16E+01 3.16E+01 kg/Ci 9.97E-02 9.97E-02 9.97E-02 Sn+4 (kg SST) 5.68E+01 5.68E+01 5.68E+01 Sn+4 (kg DST) 1.04E+01 1.04E+01 1.04E+01
NO3-								
Np+4	3.20E+01	4.54E+01	4.54E+01	6.40E+01	1.09E+02			
OH-								
P2O5:24W								
Pb+4								
PO4-3								
Rb+								
Re+7								
Rh+3 **	1.25E+00	3.87E+04	3.51E-13	1.09E-08	1.09E-08			PWR React. Fuel Based on BM/ONWI-655 Origin Results * Decay Date: 20y 30y 60y Sr(kgs) 6.76E-01 6.06E-01 4.74E-01 Sr-90(Ci) 4.48E+04 3.53E+04 1.73E+04 kg/Ci 1.51E-05 1.72E-05 2.74E-05 Sr+2 (kg SST) 4.32E+04 4.91E+04 7.85E+04 Sr+2 (kg DST) 1.95E+02 2.22E+02 3.55E+02 *Note: factor of 57.24 added for SST and DSSF to account for addition of stable Sr (Wodrich Report)
Ru+3 **	1.25E+00	3.87E+04	3.78E-07	1.17E-02	1.17E-02			
SB+5 **	0.00E+00	1.40E+05	0.00E+00	1.35E-01	1.35E-01			
SE+6 **	1.00E+01	8.15E+02	1.44E-01	1.17E+01	1.18E+01	1.31E+00	1.07E+02	
Si+4								
Sm+3	8.14E+05	2.25E+05	3.09E+01	8.55E+00	3.95E+01	4.02E+02	1.11E+02	
SN+4	5.70E+02	1.78E+02	2.01E+01	3.66E+00	2.37E+01	5.08E+01	1.04E+01	
S04-2 **								
Sr+2	5.00E+07	1.14E+07	3.66E+02	8.34E+01	4.49E+02	4.69E+04	2.12E+02	
TcO4-	1.60E+04	2.35E+04	9.43E+02	1.38E+03	2.33E+03			N-Reactor Fuel Based on BNWL-B-350 Apr74 Origin Results Decay Date: 20y 30y 50y Sr(kgs) 7.39E+01 6.59E+01 5.49E+01 Sr-90(Ci) 5.15E+06 4.02E+06 2.46E+06 kg/Ci 1.43E-05 1.64E-05 2.23E-05 Sr+2 (kg SST) 4.11E+04 4.69E+04 6.39E+04 Sr+2 (kg DST) 1.86E+02 2.12E+02 2.89E+02 *Note: factor of 57.24 added for SST and DSSF to account for addition of stable Sr (Wodrich Report)
Te+6 **	0.00E+00	3.41E+04	0.00E+00	1.89E-03	1.89E-03			
Th+4	1.00E+00	0.00E+00	9.08E+03	0.00E+00	9.08E+03			
Ti+4								
Tl+3								
TOC								
UO2+2	4.80E+02	2.36E+00	1.38E+06	2.85E+03	1.38E+06			
V+5								
W+6								
Zn+2								N-Reactor Fuel Based on BNWL-B-350 Apr74 Origin Results Decay Date: 20y 30y 50y Pd(kgs) 6.07E+01 6.07E+01 6.07E+01 Pd-107(Ci) 5.05E+00 5.05E+00 5.05E+00 kg/Ci 1.20E+01 1.20E+01 1.20E+01 Pd+2 (kg SST) 3.61E+02 3.61E+02 3.61E+02 Pd+2 (kg DST) 9.87E+01 9.87E+01 9.87E+01
ZrO2:2H2O	9.70E+03	3.21E+02	3.78E+03	1.25E+02	3.91E+03	4.22E+03	1.17E+03	
Pd	3.00E+01	8.21E+00	3.09E+01	1.19E+01	4.28E+01			
(Pd not currently in model)			5.83E+01	1.60E+01	7.43E+01	3.61E+02	9.87E+01	
Y **	5.00E+07	1.14E+07	9.20E-02	2.10E-02	1.13E-01			
Eu **	0.00E+00	1.19E+05	0.00E+00	3.31E-01	3.31E-01			
Pm **	0.00E+00	2.80E+06	0.00E+00	3.01E+00	3.01E+00			
Pr **	0.00E+00	3.23E+04	0.00E+00	4.24E-07	4.24E-07			
LANL **	0.00E+00	0.00E+00	0.00E+00	3.02E+00	3.02E+00	3.77E+03	1.04E+03	
LANH	8.14E+05	2.25E+05	3.09E+01	8.89E+00	3.98E+01	4.48E+02	1.24E+02	

** Ignored in final ASPEN+ Curie Inventory

**Table J3. N Reactor Yield Distribution Data for Rare Earths Based on
BNWL-B-350 Apr74 ORIGEN Results.**

Assume 1966 As Avg Year for Decay

For Sm151= 2.25E+05 Ci (1/1996)
8.55E+00 kg (1/1996)

Isotope	Decayed 30y grams	kg-specie/ kg-Sm151	AW	kg (1/1996)	Ci (1/1996)	Element	kgs	kgs	fraction	Ci	Ci	fractions
La139	1.21E+05	1.71E+01	139	1.46E+02	3.76E-17	La	1.46E+02	1.05E+03	0.8940	3.76E-17	1.27E+04	0.0485
Ce140	1.23E+05	1.74E+01	140	1.49E+02	3.80E-17	Ce	2.84E+02	(light)		3.06E-04		(light)
Pr141	1.17E+05	1.65E+01	141	1.41E+02	3.59E-17	Pr	1.41E+02			3.07E-04		
Ce142	1.12E+05	1.58E+01	142	1.35E+02	3.41E-17	Nd	4.76E+02			1.53E-07		
Nd142	1.15E+02	1.62E-02	142	1.39E-01	3.50E-20	Pm	1.37E-02			1.27E+04		
Nd143	1.02E+05	1.44E+01	143	1.23E+02	3.08E-17	Sm	1.12E+02	1.24E+02	0.1060	2.25E+05	2.49E+05	0.9515
Ce144	7.94E-08	1.12E-11	144	9.59E-11	3.06E-04	Eu	8.69E+00	(heavy)		2.33E+04		(heavy)
Pr144	3.36E-12	4.75E-16	144	4.00E-15	3.07E-04	Gd	3.74E+00			6.48E-11		
Nd144	1.07E+05	1.51E+01	144	1.29E+02	1.53E-07	Tb	1.16E-01			2.60E-20		
Nd145	7.45E+04	1.05E+01	145	9.00E+01	2.22E-17	Dy	3.39E-02			7.51E-21		
Nd146	6.05E+04	8.55E+00	146	7.31E+01	1.79E-17	Ho	7.12E-04			3.15E-04		
Pm147	1.13E+01	1.60E-03	147	1.37E-02	1.27E+04	Er	2.60E-04			5.61E-23		
Sm147	4.43E+04	6.26E+00	147	5.35E+01	1.23E-03	Tm						
Nd148	3.48E+04	4.92E+00	148	4.20E+01	1.02E-17	Yb						
Sm148	2.22E+03	3.14E-01	148	2.68E+00	9.26E-10	Lu				2.61E+05	2.61E+05	
Sm149	3.25E+03	4.59E-01	149	3.93E+00	9.43E-19	Total (kg)	1.17E+03	1.17E+03				
Nd150	1.49E+04	2.10E+00	150	1.80E+01	4.29E-18	Ratios Used To Estimate Rare Earths Based On Sm151 Data						
Sm150	2.38E+04	3.36E+00	150	2.88E+01	6.86E-18							
Sm151	7.08E+03	1.00E+00	151	8.55E+00	2.25E+05							
Eu151	2.00E+03	2.82E-01	151	2.42E+00	5.73E-19							
Sm152	9.14E+03	1.29E+00	152	1.10E+01	2.60E-18	LANL(light)/Sm151=	kg/kg	1.22E+02		Ci/Ci	5.62E-02	
Eu152	5.06E-01	7.15E-05	152	6.11E-04	1.07E+02	LANH(heavy)/Sm151=		1.45E+01			1.10E+00	
Gd152	2.48E+00	3.50E-04	152	3.00E-03	6.41E-11	Sm/Sm151=		1.30E+01			1.00E+00	
Eu153	5.12E+03	7.23E-01	153	6.19E+00	1.45E-18							
Gd153	1.53E-16	2.16E-20	153	1.85E-19	6.53E-13							
Sm154	2.53E+03	3.57E-01	154	3.06E+00	7.10E-19							
Eu154	7.11E+01	1.00E-02	154	8.59E-02	2.32E+04							
Gd154	2.05E+02	2.90E-02	154	2.48E-01	5.75E-20							
Eu155	3.15E-03	4.45E-07	155	3.81E-06	1.87E+00							
Gd155	4.79E+02	6.77E-02	155	5.79E-01	1.34E-19							
Gd156	1.74E+03	2.46E-01	156	2.10E+00	4.82E-19							
Gd157	1.33E+01	1.88E-03	157	1.61E-02	3.66E-21							

Table J4. Tank Waste Feedstream Curie Inventory.

Data Source:	-0616 REYC-0616 REVC	IOB 93	IOB 93	O'Toole	Jansen	Swanson	Study	DATA	-0616 REYC-0616 REVC	IOB 93	IOB 93	O'Toole	Jansen	Study	DATA
Decay Date:	Bases Rep. Tab. 4-5	Tab. A1-3	Tab. A1-3	Waste Inv	Est.	Est.	INVENTORY	SOURCE	Bases Rep. Tabs. 4-5	Tab. A4	Tab. A4	Waste Inv	Est.	INVENTORY	SOURCE
Radionuclide	SST 1/91	SST 1/91	SST 1/91	SST 1/96	SST 1/96	SST	SST	SST	DST 1/91	DST 1/91	DST 1/91	DST 1/96	DST	DST	DST
Ag110m								IOB93-96			1.242E+02	7.839E-01		7.839E-01	IOB93-96
Am241	4.05E+04	4.60E+04	4.608E+04	4.569E+04	4.60E+04	3.57E+04	4.569E+04	IOB93-96	9.86E+04	9.90E+04	5.243E+04	5.856E+04	9.86E+04	9.86E+04	O'Toole
Am242	6.39E+01							IOB93-96			4.350E+01	4.252E+01		4.252E+01	IOB93-96
Am242m	6.43E+01							IOB93-96			4.375E+01	4.276E+01		4.276E+01	IOB93-96
Am243	3.21E+01	1.90E+01			1.90E+01		1.90E+01	O'Toole			7.165E+00	7.162E+00	0.00E+00	7.162E+00	IOB93-96
Ba137m	2.77E+07		1.740E+07	1.061E+07	1.50E+07		1.50E+07	O'Toole			1.550E+07	1.871E+07	2.87E+07	2.87E+07	O'Toole
Cl14	1.64E+04	3.00E+03	4.464E+03	3.402E+03	3.00E+03	1.40E+02	3.402E+03	IOB93-96	2.35E+03	2.30E+03	5.693E+02	1.628E+03	2.35E+03	2.35E+03	O'Toole
Cd113m								IOB93-96			4.116E+03	3.246E+03		3.246E+03	IOB93-96
Cd115m								IOB93-96			1.734E-05	0.000E+00			IOB93-96
Ce144								IOB93-96			2.746E+06	3.198E+04	2.11E+03	3.198E+04	IOB93-96
Cm242	5.36E+01							IOB93-96			4.349E+01	3.567E+01		3.567E+01	IOB93-96
Cm244	1.62E+02	1.60E+02	1.693E+02	1.398E+02	6.90E+01		1.398E+02	IOB93-96			1.387E+03	1.145E+03	1.51E+03	1.51E+03	O'Toole
Co60			4.188E+03	2.11E+03	9.40E+04		9.40E+04	O'Toole			1.343E+04	6.958E+03	4.65E+03	6.958E+03	IOB93-96
Cs134								IOB93-96			2.749E+05	5.121E+04		5.121E+04	IOB93-96
Cs135					7.30E+01		7.30E+01	O'Toole			5.915E+01	5.915E+01	0.00E+00	5.915E+01	IOB93-96
Cs137	2.93E+07	3.50E+07	1.840E+07	1.121E+07	1.50E+07	9.50E+06	8.47E+06	O'Toole	6.63E+07	6.60E+07	1.639E+07	1.979E+07	3.04E+07	3.04E+07	O'Toole
Eu152								IOB93-96			5.994E+02	4.646E+02		4.646E+02	IOB93-96
Eu154								IOB93-96			7.934E+04	5.302E+04	5.27E+04	5.302E+04	IOB93-96
Eu155								IOB93-96			1.309E+05	6.509E+04	4.32E+04	6.509E+04	IOB93-96
Fe55								IOB93-96			8.089E+03	2.133E+03		2.133E+03	IOB93-96
I129	4.26E+01	2.40E+01			2.40E+01	2.40E+01	2.40E+01	O'Toole	2.70E+01	2.70E+01	2.652E-01	2.652E-01	2.70E+01	2.70E+01	O'Toole
Nb93m	2.95E+03		8.059E+03	8.406E+03			8.406E+03	IOB93-96			9.783E+01	1.438E+02		1.438E+02	IOB93-96
Ni59								IOB93-96			9.057E+00	9.057E+00		9.057E+00	IOB93-96
Ni63	3.03E+05	3.00E+05	3.122E+05	3.016E+05	2.90E+05	2.90E+05	3.016E+05	IOB93-96			1.064E+03	1.025E+03	2.41E+03	2.41E+03	O'Toole
Np237	5.96E+01	3.20E+01	2.153E-03	1.606E-03	3.20E+01	3.10E+01	3.20E+01	O'Toole			4.509E+01	4.513E+01	2.98E+01	4.518E+01	IOB93-96
Np238	3.22E-01							IOB93-96			2.188E-01	2.12E-01		2.138E-01	IOB93-96
Pd107						3.00E+01	3.00E+01	Swanson			8.210E+00	8.210E+00		8.210E+00	IOB93-96
Pm147								IOB93-96			1.048E+07	2.797E+06	1.13E+06	1.797E+06	IOB93-96
Pr144								IOB93-96			2.739E+06	3.189E+04		3.189E+04	IOB93-96
Pr144m								IOB93-96			3.288E+04	3.828E+02		3.828E+02	IOB93-96
Pu238	1.15E+03	4.50E+02			4.40E+02		4.40E+02	O'Toole			3.724E+02	4.449E+02	4.17E+02	4.449E+02	IOB93-96
Pu239	2.14E+04	2.20E+04	2.199E+04	2.199E+04	2.20E+04	2.70E+04	2.199E+04	IOB93-96	2.32E+04	2.30E+04	3.277E+03	4.412E+03	9.12E+03	9.12E+03	O'Toole
Pu240	5.05E+03	5.40E+03	5.296E+03	5.293E+03	5.40E+03		5.40E+03	O'Toole			8.850E+02	1.173E+03	2.58E+03	2.58E+03	O'Toole
Pu241	5.24E+04	5.70E+04	5.784E+04	4.547E+04	4.50E+04		4.547E+04	IOB93-96			3.689E+04	4.259E+04	5.02E+03	4.259E+04	IOB93-96
Pu242	2.03E-04							IOB93-96			8.677E-02	1.058E-01		1.058E-01	IOB93-96
Rh103m								IOB93-96			5.831E-04	0.000E+00			IOB93-96
Rh106	1.86E+01		3.884E+01	1.250E+00	7.40E-01		1.250E+00	IOB93-96			1.203E+06	3.865E+04	1.89E+04	3.865E+04	IOB93-96
Ru103								IOB93-96			6.470E-04				IOB93-96
Ru106	1.86E+01	2.30E+01	3.884E+01	1.250E+00	7.40E-01		1.250E+00	IOB93-96			1.203E+06	3.865E+04	1.89E+04	3.865E+04	IOB93-96
Sb124								IOB93-96			2.012E-04	1.490E-13		1.490E-13	IOB93-96
Sb125								IOB93-96			4.881E+05	1.397E+05	6.94E+04	1.397E+05	IOB93-96
Sb126								IOB93-96			1.458E+01	1.458E+01		1.458E+01	IOB93-96
Sb126m								IOB93-96			1.151E+02			1.151E+02	IOB93-96
Se79						1.00E+01	1.00E+01	Swanson			6.582E+01	6.582E+01	8.15E+02	8.15E+02	O'Toole
Sm151	7.00E+05	6.80E+05	8.462E+05	8.142E+05	6.50E+05	3.85E+05	8.142E+05	IOB93-96			2.340E+05	2.252E+05	1.45E+05	2.252E+05	IOB93-96
Sn119m								IOB93-96			2.306E+03	1.316E+01		1.316E+01	IOB93-96
Sn121m								IOB93-96			6.572E+01	6.131E+01		6.131E+01	IOB93-96
Sn123								IOB93-96			8.880E+01	4.922E-03		4.922E-03	IOB93-96
Sn126		5.70E+02			5.70E+02	4.00E+02	5.70E+02	O'Toole			1.039E+02	1.039E+02	0.00E+00	1.039E+02	IOB93-96
Sr89								IOB93-96			2.048E-01	2.658E-12		2.658E-12	IOB93-96
Sr90	5.53E+07	1.13E+08	5.630E+07	4.965E+07	5.00E+07	4.50E+07	3.99E+07	O'Toole	2.58E+07	2.60E+07	1.144E+07	1.037E+07	1.14E+07	1.14E+07	O'Toole
Te123m								IOB93-96			4.118E-04	1.051E-08		1.051E-08	IOB93-96
Te125m								IOB93-96			1.191E+05	3.409E+04		3.409E+04	IOB93-96
Te127m								IOB93-96			6.960E+01	6.284E-04		6.284E-04	IOB93-96
Tc99	2.79E+04	1.60E+04	1.890E+04	8.709E+03	1.60E+04	1.60E+04	9.00E+03	O'Toole	2.40E+04	2.50E+04	1.332E+04	2.350E+04	2.40E+04	2.350E+04	IOB93-96
Th232								Swanson							IOB93-96
U233	5.65E-03							IOB93-96			1.232E+00	1.237E+00		1.237E+00	IOB93-96
U234	1.55E-01							IOB93-96			5.177E-02	5.177E-02	7.04E-02	7.04E-02	O'Toole
U235	2.00E+01	2.00E+01			2.00E+01		2.00E+01	O'Toole			1.081E-01	1.081E-01		1.081E-01	IOB93-96
U236								IOB93-96			9.456E-01	9.456E-01	6.60E-01	9.456E-01	IOB93-96
U238	4.74E+02	4.60E+02			4.50E+02	4.20E+02	4.60E+02	O'Toole			1.144E+07	1.038E+07	1.14E+07	1.14E+07	O'Toole
Y90	5.53E+07		5.630E+07	4.965E+07	5.00E+07		5.00E+07	O'Toole			3.828E+00	1.542E-09		1.542E-09	IOB93-96
Y91								IOB93-96			3.206E-02	3.206E-02	0.00E+00	3.206E-02	IOB93-96
Zr93	3.94E+03	4.30E+03	9.700E+03	9.700E+03	4.30E+03	4.00E+03	9.700E+03	IOB93-96							
TOTALS	1.69E+08	1.49E+08	1.50E+08	1.22E+08	1.32E+08	5.45E+07	4.92E+07	1.32E+08	9.22E+07	9.21E+07	7.46E+07	6.291E+07	8.35E+07	2.27E+08	8.56E+07

Table J5. Tank Waste Feedstream Mass Inventory Based Only on Curie Data.

Data Source:			-0616 REVO-0616 REVO IDB 93 IDB 93 O'Toole Jansen Swanson Study DATA										-0516 REVO-0616 REVO IDB 93 IDB 93 O'Toole Jansen Study DATA											
Decay Date:			Bases Rep. Tabs. 4-5 Tab. A1-3 Tab. A1-3 Waste Inv Est. SST 1/96 SST 1/96 SST 1/96 SST 1/96 SST 1/96 SST 1/96 SST 1/96										Bases Rep. Tabs. 4-5 Tab. A4 Tab. A4 Waste Inv Est. SST 1/96 SST 1/96 SST 1/96 SST 1/96 SST 1/96 SST 1/96 SST 1/96											
Radionuclide T1/2 (yrs) AWght			kg kg kg kg kg kg kg kg kg kg kg kg										kg kg kg kg kg kg kg kg kg kg kg kg											
Ag110m	6.84E-01	110																						
Am241	4.33E+02	241	1.18E+01	1.34E+01	1.343E+01	1.332E+01	1.34E+01																	
Am242	1.83E-03	242	7.90E-08																					
Am242m	1.41E+02	242	6.13E-03																					
Am243	7.37E+03	243	1.61E-01	9.51E-02																				
Ba137m	4.86E-06	137	5.15E-05		3.236E-05	1.972E-05	2.79E-05																	
C14	5.73E+03	14	3.68E+00	6.73E-01	1.001E+00	7.627E-01	6.73E-01																	
Cd113m	1.41E+01	113																						
Cd115m	1.22E-01	115																						
Ce144	7.80E-01	144																						
Cm242	4.46E-01	242	1.62E-05																					
Cm244	1.81E+01	244	2.00E-03	1.97E-03	2.090E-03	1.726E-03	8.52E-04																	
Co60	5.27E+00	60			3.702E-03	1.917E-03	8.31E-02																	
Cs134	2.07E+00	134																						
Cs135	2.30E+06	135					6.34E+01																	
Cs137	3.02E+01	137	3.38E+02	4.04E+02	2.126E+02	1.295E+02	1.85E+02	1.10E+02	9.78E+01	1.85E+02														
Eu152	1.35E+01	152																						
Eu154	8.59E+00	154																						
Eu155	4.71E+00	155																						
Fe55	2.73E+00	55																						
I129	1.57E+07	129	2.41E+02	1.36E+02			1.36E+02	1.36E+02	1.36E+02	1.36E+02														
Nb93m	1.61E+01	93	1.23E-02		3.373E-02	3.518E-02				3.52E-02														
Ni59	7.50E+04	59																						
Ni63	1.00E+02	63	5.34E+00	5.28E+00	5.497E+00	5.311E+00	5.11E+00			5.10E+00	5.31E+00													
Np237	2.14E+06	237	8.45E+01	4.54E+01	3.052E-03	2.277E-03	4.54E+01			4.39E+01	4.54E+01													
Np238	5.80E-03	238	1.24E-09																					
Pd107	6.50E+06	107								5.83E+01	5.83E+01													
Pm147	2.62E+00	147																						
Pr144	3.29E-05	144																						
Pr144m	1.37E-05	144																						
Pu238	8.77E-01	238	6.71E-02	2.63E-02			2.57E-02			2.57E-02														
Pu239	2.41E+04	239	3.45E+02	3.54E+02	3.540E+02	3.540E+02	3.54E+02			4.35E+02	3.54E+02													
Pu240	6.56E+03	240	2.22E+01	2.38E+01	2.330E+01	2.329E+01	2.38E+01				2.38E+01													
Pu241	1.44E+01	241	5.08E-01	5.53E-01	5.610E-01	4.410E-01	4.36E-01			4.41E-01														
Pu242	3.75E+05	242	5.15E-05																					
Rh103m	1.07E-04	103																						
Rh106	9.48E-07	106	5.23E-12		1.091E-11	3.510E-13	2.08E-13			3.51E-13														
Ru103	1.08E-01	103																						
Ru106	1.02E+00	106	5.62E-06	6.95E-06	1.174E-05	3.777E-07	2.24E-07			3.78E-07														
Sb124	1.65E-01	124																						
Sb125	2.76E+00	125																						
Sb126	3.40E-02	126																						
Sb126m	3.49E-07	126																						
Se79	6.50E+04	79																						
Sm151	9.00E+01	151	2.66E+01	2.58E+01	3.214E+01	3.093E+01	2.47E+01			1.46E+01	3.09E+01													
Sn119m	8.03E-01	119																						
Sn121m	5.50E+01	121																						
Sn123	3.54E-01	123																						
Sn126	1.00E+05	126	2.01E+01				2.01E+01			1.41E+01	2.01E+01													
Sr89	1.38E-01	89																						
Sr90	2.91E-01	90	4.05E+02	8.27E+02	4.121E+02	3.634E+02	3.66E+02	3.29E+02	2.92E+02	3.66E+02														
Tel23m	3.28E-01	123																						
Tel25m	1.59E-01	125																						
Tel27m	2.99E-01	127																						
Tc99	2.13E+05	99	1.64E+03	9.43E+02	1.114E+03	5.133E+02	9.43E+02	9.43E+02	5.30E+02	9.43E+02														
Th232	1.40E+10	232								9.08E+03	9.08E+03													
U233	1.59E+05	233	5.86E-04																					
U235	2.46E+05	234	2.51E-02																					
U238	7.04E+08	235	9.25E+03	9.25E+03																				
U238m	2.34E+07	236																						
Y88	4.47E+09	238	1.41E+06	1.37E+06			1.37E+06			1.19E+06	1.37E+06													
Y90	7.32E-03	90	1.02E-01		1.036E-01	9.136E-02	9.20E-02				9.20E-02													
Y91	1.60E-01	91																						
Zr93	1.50E+06	93	1.54E+03	1.68E+03	3.782E+03	3.782E+03	1.68E+03			1.56E+03	3.78E+03													
TOTALS			1.42E+06	1.38E+06	5.95E+03	5.22E+03	1.38E+06	1.52E+03	1.20E+06															

MHC-EP-0791

This page intentionally left blank.

APPENDIX K

PROCESS STRATEGY TECHNICAL RISK

LIST OF TERMS

CPU	compact processing unit
DOE	U.S. Department of Energy
HLW	high-level waste
LLW	low-level waste
SREX	strontium extraction
TCIX	Technetium Ion Exchange
TRUEX-C	Transuranic Extraction Option C

PROCESS STRATEGY TECHNICAL RISK

This appendix discusses the development of a process strategy technical risk estimation method based on data contained in *Pretreatment Status Report on the Identification and Evaluation of Alternative Processes* (Sutherland et al. 1993). The reference document presents a status report on the identification and evaluation of alternative processes. It contains an appendix showing various alternative process technology development levels and extents. This data is tabulated using the following categories:

- Maturity of particular process technologies — extent and scale of testing with simple or realistic simulants (e.g., laboratory, bench, pilot plant, full-scale, operating full-scale facility)
- Potential benefit of particular process technologies — activity level and timeliness of testing and development
- Current U.S. Department of Energy (DOE) funding level of particular process technologies — extent of funding and the associated advance of maturity.

To allow an assessment of the technical risk associated with each of the process strategies, weighting factors were assigned to the above process technology development levels and extents as shown below. The weighting factor assignments are considered first approximation using reasonable engineering judgment. Using these weights, numerical estimates of technical risk factor indexes were calculated for particular process technologies using the following formulas:

$$\text{Technical Risk Index} = 1/(\text{Level Weight} * \text{Extent Weight}) \quad (\text{R\&D and DT\&E})$$

$$\text{Technical Risk Index} = 1/(\text{Level Weight}) \quad (\text{Proven Levels})$$

where:

R&D = Research and Development.

DT&E = Demonstration Testing and Experimentation.

Process Development Level	Weight
Research and development	1
Demonstration testing and experimentation	10
Proven in an operating full-scale facility for processing a local high-level waste	50
Proven in an operating full-scale facility for processing Hanford high-level waste	100

Process Development Extent	Weight
Maturity of particular process technologies	
Research and Development:	
High = Bench scale with realistic simulants	1.0
Medium = Laboratory scale with simple simulants	0.3
Low = Little or no testing	0.1
Demonstration Testing and Experimentation:	
High = Full scale with realistic simulants	1.0
Medium = Pilot plant with realistic simulants	0.3
Low = Pilot plant with simple simulants	0.1
Current DOE funding level of particular process technologies	
Either R&D or DT&E:	
High = Significantly advanced maturity	1.0
Medium = Moderately advanced maturity	0.3
Low = Negligible advance of maturity	0.1
Pctential benefit of particular process technologies	
Either R&D or DT&E:	
High = High timely	1.0
Medium = Moderate timely	0.3
Low = Low, untimely or inactive concept	0.1

Table K1 shows the technical risk factor data for various process technologies contained in the reference (Sutherland et al. 1993). These process technologies were related to the various processes represented in each process strategy as shown in Table K2. Table K2 presents the technical risk indexes calculated using the process development level and extent weights applied to the particular process technologies. Note that a low technical risk index value is desirable. The individual process technical risk indexes were summed over each risk category (i.e., maturity, timeliness, and DOE current level of effort) and averaged over each category for each process strategy. The technical risk indexes for the process technologies used in the various process strategies is shown in Figure K1. Figures K2 and K3 show the total and process average technical risk results for each process strategy, respectively.

As shown in Figure K1 the technical risk for the cesium ion exchange for alkaline liquids, the low-level waste (LLW) salt grouting process, and the high-level waste (HLW) or LLW glass vitrification process had the lowest technical risk indexes, because of their essentially fully demonstrated technologies. Note that the DOE current level of effort contributes considerably to the technical risk of many process technologies, representing the slow advance of the process maturity. These processes (e.g., Solids Dissolution, Strontium Extraction [SREX], NaOH/HNO₃ Recycle, Technetium Ion

Exchange [TCIX], and Uranium Separation associated with the TRUEX process) may require renewed or increased levels of effort to provide successful application of a tank waste pretreatment process strategy.

Figure K2 shows that the CLEAN Option process strategy without compact processing units (CPUs) (i.e., Model CLEAN31) had a total combined category technical risk index that was a factor of approximately 2 and 10 times higher than the Transuranic Extraction Option C (TRUEX-C) and Sludge Wash C process strategies, respectively. The contributions of the individual category technical risk indexes to this total combined category technical risk index reflected essentially the same ratio factors, respectively. The exception was for the timeliness category where the CLEAN Option process strategy without CPUs had a total timeliness category technical risk index that was a factor of approximately 14 times higher than the Sludge Wash C process strategy.

The process average combined category technical risk index for the CLEAN Option process strategy without CPUs was nearly the same as the TRUEX-C process strategy and a factor of approximately 3 higher than for the Sludge Wash C process strategy. Again, the contributions of the individual category technical risk indexes to this average combined category technical risk index reflected essentially the same ratio factors, respectively. The exception was for the timeliness category where the CLEAN Option process strategy without CPUs had a total timeliness category technical risk index that was a factor of approximately 4 times higher than the Sludge Wash C process strategy.

The use of CPUs in the CLEAN Option process strategy to provide supernate and salt cake processing outside of a central processing facility will necessarily have significant technical risk because it is a new and developing concept. Thus, the CLEAN Option with CPUs should be considered to have more technical risk than the CLEAN Option based only on a central processing facility concept.

In summary, DOE current level of effort contributes considerably to the technical risk of many process technologies, representing the slow advance of the process maturity. These processes (e.g., Solids Dissolution, SREX, NaOH/HNO₃ Recycle, TCIX, and Uranium Separation associated with the TRUEX process) may require renewed or increased levels of effort to provide successful application of a tank waste pretreatment process strategy. The CLEAN Option process strategy without CPUs had a total combined category technical risk index that was a factor of approximately 2 and 10 times higher than the TRUEX-C and Sludge Wash C process strategies, respectively. The process average combined category technical risk index for the CLEAN Option process strategy without CPUs was nearly the same as the TRUEX-C process strategy and a factor of approximately 3 higher than for the Sludge Wash C process strategy. The CLEAN Option using the new and developing CPU concept should be considered to have more technical risk than the CLEAN Option based only on a central processing facility concept.

REFERENCES

Sutherland, D. G., et al., 1993, *Pretreatment Status Report On The Identification And Evaluation Of Alternative Processes*, WHC-SD-WM-PRS-012, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Figure K1. Technical Risk Index.

Figure K2. Total Technical Risk Index by Process Strategy.

Figure K3. Average Technical Risk Index by Process Strategy.

Table K1. Technical Risk Factor Data for Various Process Technologies.
(sheet 1 of 3)

Process Name	Application Status	Development Stage	Funding Level	Potential Benefit	Confidence/Maturity
Actinide/ Lanthanide Separation	Not Fully Proven	R&D	Medium	Medium	Medium
Actinide/Lanthanide Separation	Not Fully Proven	R&D	Medium	Medium	Medium
AEROJET LLW IN POLYETHYLENE	Not Fully Proven	DT&E	Low	Medium	Medium
Ag II PROCESS	Fully Proven on Local HLW				
Al Precipitation	Not Fully Proven	R&D	Medium	Medium	Medium
Al & Zr Precipitation	Not Fully Proven	R&D	Low	Low	Medium
ALKALI EARTHS ION X CHROMA- TOGRAPHY	Not Fully Proven	R&D	Low	Low	Low
ALKALINE HYDROLYSIS	Fully Proven on Local HLW				
Barium/ Strontium Separation	Not Fully Proven	R&D	Medium	Medium	Medium
Ba/Sr Separation	Not Fully Proven	R&D	Medium	Medium	Medium
BIOLOGICAL DESTRUCTION	Not Fully Proven	R&D	Low	Low	Low
Biological Destructions	Not Fully Proven	R&D	Medium	Medium	Low
BIOLOGICAL SEPARATION	Not Fully Proven	R&D	Low	Low	Low
C14 SEPARATION CAUSTIC SCRUB	Fully Proven on Local HLW				
CALCINATION NITRATE DESTRUCTION	Not Fully Proven	R&D	Medium	High	Medium
CALCINE & LEACH SEPARATION	Not Fully Proven	R&D	Low	High	Low
CC OZONIZATION	Not Fully Proven	R&D	Low	High	Medium
CC PHASE SEPARATION	Not Fully Proven	R&D	Low	Low	Low
CC & FeCN Destruction, Ozonation	Not Fully Proven	R&D	Low	High	Medium
CC/FeCN Destruction	Not Fully Proven	R&D	High	High	Medium
CC/FeCN DESTRUCTION HYDROTHERMAL	Not Fully Proven	R&D	Medium	High	Medium
CC/FeCN DESTRUCTION, CALCINATION	Not Fully Proven	R&D	High	High	Medium
CC/FeCN Destruction, Electrochem	Not Fully Proven	R&D	Low	High	Medium
CENTRIFUGE	Fully Proven for Hanford HLW				
CEPOD	Not Fully Proven	DT&E	Low	Low	Medium
CLEAN SALT PRECIPITATION	Not Fully Proven	R&D	Medium	High	Medium
COBALT DICARPOLITE (Sr)	Not Fully Proven	R&D	Low	Medium	Low
CR LEACH	Not Fully Proven	R&D	Medium	Medium	Low
Cr, Ni, Fe Magnetic Separation	Not Fully Proven	R&D	Medium	Medium	Medium
Cs Acidic Separation	Not Fully Proven	R&D	Medium	Medium	Medium
Cs Acidic Separation (WHC)	Not Fully Proven	R&D	Medium	Medium	Medium
CS CRYSTALLINE SI-TITANATE	Not Fully Proven	R&D	Low	Low	Medium
Cs EXTRACTION w/ChCoDiC	Not Fully Proven	DT&E	Low	Medium	High
Cs Ion X, Cs-100	Not Fully Proven	R&D	Medium	Medium	Medium
Cs ION X, FERROCYANIDE	Not Fully Proven	R&D	Low	Medium	Low
Cs ION X, Fr	Fully Proven on Local HLW				
Cs ION X, GB	Fully Proven on Local HLW				
Cs Ion X, Resourceinol	Not Fully Proven	R&D	Medium	Medium	Medium
Cs ION X, WHC	Fully Proven for Hanford HLW				
Cs MOLECULAR RECOGNITION	Not Fully Proven	R&D	Low	Medium	Medium
Cs PRECIP ULTRAFILTRATION	Fully Proven on Local HLW				
Cs PRECIPITATION	Not Fully Proven	R&D	Medium	Medium	Medium
Cs REMOVAL	Not Fully Proven	R&D	Low	Medium	High
CS REMOVAL, TITANATES	Not Fully Proven	R&D	Medium	High	Medium
Cs SELECTIVE LEACH	Not Fully Proven	R&D	Medium	Medium	Medium
Cs Separation CPU	Not Fully Proven	R&D	Medium	High	Medium
Cs Separation (Acidic)	Not Fully Proven	R&D	Medium	Medium	Medium
Cs Separation (Basic)	Fully Proven for Hanford HLW				
Cs SOLID SORBENT	Not Fully Proven	R&D	Medium	Medium	Medium
CSIX, PNL	Not Fully Proven	R&D	Medium	Medium	Medium
DIDPA (ACID)	Not Fully Proven	R&D	Low	High	Medium
DST SOLIDS DISSOLUTION (PNL)	Not Fully Proven	R&D	Low	High	Medium
DST SOLIDS DISSOLUTION (WHC)	Not Fully Proven	R&D	Low	High	Medium
DST SOL/LIQ SEPARATION (PNL)	Not Fully Proven	R&D	Low	High	High
DST SOL/LIQ SEPARATION (WHC)	Not Fully Proven	R&D	Low	High	High
DWPF	Not Fully Proven	DT&E	High	High	High
ELEC CHEM IX TRACE METAL SEPARATION	Not Fully Proven	R&D	Low	High	High
ELECTROCHEM ION X	Not Fully Proven	DT&E	Low	Low	Medium
ELECTRO- CHEMICAL INCINERATION	Not Fully Proven	DT&E	Low	High	Medium
ELECTRO- CHEMICAL ION X	Not Fully Proven	R&D	Low	High	Medium
ELECTRO- CHEMICAL ORGANICS TO CO2 & H2O	Not Fully Proven	R&D	Low	High	High
ELECTRO- CHEMICAL OXIDATION	Not Fully Proven	R&D	Low	High	Medium
ELECTRO- CHEMICAL Ru DEPOSITION	Not Fully Proven	R&D	Low	Low	High
ELECTRO- CHEMICAL URANIUM SEPARATION	Not Fully Proven	R&D	Low	Medium	High
ELECTRO- FILTRATION	Not Fully Proven	R&D	Low	High	High
F Removal by CaF2 Precipitation	Not Fully Proven	R&D	Low	Low	Medium
FIS PROD ELECTRO- CHEMICAL I X	Not Fully Proven	R&D	Low	Low	High
FREEZE CRYSTALLIZATION	Not Fully Proven	R&D	Low	High	Medium
GROUT	Not Fully Proven	DT&E	High	High	High
GROUT (GB)	Fully Proven on Local HLW				
GROUT (Other)	Not Fully Proven	DT&E	High	High	High
H2O2 CC OXIDATION	Not Fully Proven	R&D	Low	High	Low
H2O2 WET OXIDATION	Not Fully Proven	R&D	Low	High	High
HEAVY METAL EXTRACTION	Not Fully Proven	R&D	Low	Medium	High

Table K1. Technical Risk Factor Data for Various Process Technologies.
(sheet 2 of 3)

Process Name	Application Status	Development Stage	Funding Level	Potential Benefit	Confidence/Maturity
HEAVY METAL MAGNETIC FILTER	Not Fully Proven	R&D	Low	High	Medium
HEAVY METALS EXTRACTION CaTiO_4	Not Fully Proven	R&D	Low	Low	Medium
Heavy Metals Separation	Not Fully Proven	R&D	Low	Medium	Low
Heavy Metals Separation (PNL)	Not Fully Proven	R&D	Low	Medium	Low
HLW IN SILICA	Not Fully Proven	R&D	Low	Low	High
HWVP	Not Fully Proven	DT&E	High	High	High
HYDROPULSE FILTER	Fully Proven for Hanford HLW				
Hydropulse Filter Sol/Liq Separation	Fully Proven for Hanford HLW				
I REMOVAL VIA Ag ZEOLITE	Fully Proven on Local HLW				
I REMOVAL WITH Ag MORDENITE	Not Fully Proven	R&D	Low	Medium	High
I Separation	Not Fully Proven	R&D	Low	Medium	Low
Immobilization in Grout	Not Fully Proven	DT&E	High	High	High
Iodine Removal	Not Fully Proven	R&D	Low	Medium	Low
IODINE SEPARATION	Not Fully Proven	R&D	Low	Low	Low
LANTHANIDE EXTRACTION (Fr)	Not Fully Proven	R&D	Low	Low	Low
LANTHANIDE EXTRACTION (Other)	Not Fully Proven	R&D	Low	Low	High
LANTHANIDES EXTRACTION w/ChCoDiC	Not Fully Proven	DT&E	Low	Low	High
LANTHANIDES ION X	Not Fully Proven	R&D	Low	Low	Medium
LANTHANIDES ION X CHROMA- TOGRAPHY	Not Fully Proven	R&D	Low	Low	Low
LLW IN BITUMEN	Fully Proven on Local HLW				
LLW POLY- ETHYLENE ENCAPSU- LATION	Not Fully Proven	R&D	Medium	Medium	High
MACROCYCLE SEPARATIONS	Not Fully Proven	R&D	Low	Low	Low
MOLTEN SALT PYROLYSIS (Ox)	Not Fully Proven	R&D	Medium	High	Medium
MOLTEN SALT PYROLYSIS (Trans)	Not Fully Proven	R&D	Medium	High	Medium
NaNO ₃ Removal	Not Fully Proven	R&D	Medium	High	Medium
NaNO ₃ Removal (PNL)	Not Fully Proven	R&D	Medium	High	Medium
NaOH/HNO ₃ Recycle	Not Fully Proven	R&D	Low	High	Low
NaOH/HNO ₃ Recycle (PNL)	Not Fully Proven	R&D	Low	High	Low
NaTiO ₄ ACIDIC	Not Fully Proven	R&D	Low	High	Medium
NaTiO ₄ ALKALINE	Not Fully Proven	DT&E	Medium	High	Medium
NITRATES DESTRUCTION	Not Fully Proven	R&D	Low	High	High
NITRATES SALT SPLITTING	Not Fully Proven	R&D	Low	High	High
NITRATES SEPARATION	Not Fully Proven	R&D	Low	High	Medium
NITRATES TO N ₂ & H ₂ O ELECTRO CHEM IX	Not Fully Proven	R&D	Low	High	High
NO ₃ Destruction	Not Fully Proven	R&D	High	Medium	Medium
NO ₃ Destruction (PNL)	Not Fully Proven	R&D	High	Medium	Medium
NO ₃ PYROLYSIS MOLTEN SALT (Other)	Not Fully Proven	R&D	Medium	High	Medium
NO ₃ PYROLYSIS MOLTEN SALT (WHC)	Not Fully Proven	R&D	Medium	High	Medium
NO ₃ TO NH ₃ & CERAMIC	Not Fully Proven	R&D	Medium	High	Medium
Noble Metals Separation	Not Fully Proven	R&D	Low	Medium	Low
Noble Metals Separation (PNL)	Not Fully Proven	R&D	Low	Medium	Low
ORGANICS DESTRUCTION (Fr)	Not Fully Proven	R&D	Low	High	High
pH Control Wash	Not Fully Proven	R&D	Medium	Medium	Medium
Pu Am ALKYLDIAMINE EXTRACTION	Not Fully Proven	R&D	Low	Medium	Medium
PuNO ₃ BIOLOGICAL DESTRUCTION	Not Fully Proven	R&D	Medium	Low	Low
Pu Rh Pd RECOVERY	Not Fully Proven	R&D	Low	Medium	High
Pu SEPARATION	Fully Proven on Local HLW				
Selective Tank Analysis	Not Fully Proven	R&D	Medium	High	Medium
SLUDGE DEWATERING ELECTRO- OSMOSIS	Not Fully Proven	R&D	Low	High	High
Sludge Dissolution	Not Fully Proven	R&D	Medium	High	Medium
SLUDGE SEPARATION STE-3	Fully Proven on Local HLW				
Sludge Wash Sol/Liq Separation	Not Fully Proven	R&D	Medium	High	Medium
Solids Dissolution (DST)	Not Fully Proven	R&D	Low	High	Medium
Solids Dissolution (SST)	Not Fully Proven	R&D	Low	High	Medium
Sr Basic Separation	Not Fully Proven	R&D	Medium	Medium	Medium
Sr BaSO ₄ PRECIPITATION	Fully Proven on Local HLW				
Sr EXTRACTION CROWN ETHER	Not Fully Proven	DT&E	Low	High	Medium
Sr EXTRACTION w/ChCoDiC	Not Fully Proven	DT&E	Low	High	High
Sr EXTRACTION (USTID)	Not Fully Proven	R&D	Medium	High	Medium
Sr EXTRACTION (WHC)	Fully Proven for Hanford HLW				
Sr ION X	Fully Proven on Local HLW				
Sr MOLECULAR RECOGNITION	Not Fully Proven	R&D	Low	High	Medium
Sr PRECIPITATE ULTRAFILTRATION	Fully Proven on Local HLW				
Sr PRECIPITATION	Not Fully Proven	R&D	Medium	High	Medium
Sr REMOVAL	Not Fully Proven	R&D	Low	High	High
Sr SELECTIVE LEACH	Not Fully Proven	R&D	Medium	High	Medium
Sr Separation (Acidic)	Not Fully Proven	R&D	Low	High	Medium
Sr Separation (Basic)	Not Fully Proven	R&D	Medium	Medium	Medium
Sr SOLID SORBENTS (PNL)	Not Fully Proven	R&D	Medium	High	Medium
SPEX	Not Fully Proven	R&D	Low	High	Medium
Sr/Cs EIX (Cs)	Not Fully Proven	R&D	Low	Medium	Medium
Sr/Cs EIX (Sr)	Not Fully Proven	R&D	Low	High	Medium
SSR ELECTRO- FLOCCULATION	Not Fully Proven	R&D	Low	High	High
SSR ELECTRO- FLOTATION	Not Fully Proven	R&D	Low	High	High

Table K1. Technical Risk Factor Data for Various Process Technologies.
(sheet 3 of 3)

Process Name	Application Status	Development Stage	Funding Level	Potential Benefit	Confidence/Maturity
SST SOLIDS DISSOLUTION (PNL)	Not Fully Proven	R&D	Low	High	Medium
SST SOLIDS DISSOLUTION (WHC)	Not Fully Proven	R&D	Low	High	High
SST SOL/LIQ SEPARATION (PNL)	Not Fully Proven	R&D	Low	High	High
SST SOL/LIQ SEPARATION (WHC)	Not Fully Proven	R&D	Low	High	High
SUBSTITUTED HALONAMIDES	Not Fully Proven	R&D	Low	Low	Low
SUPER-CRITICAL WATER OXIDATION	Not Fully Proven	R&D	Medium	High	Medium
Tc Acidic Separation	Not Fully Proven	R&D	Medium	Medium	Medium
Tc Acidic Separation (WHC)	Not Fully Proven	R&D	Medium	Medium	Medium
Tc ADSORPTION (PNL)	Not Fully Proven	R&D	Low	Medium	Medium
Tc ADSORPTION (WHC)	Not Fully Proven	R&D	Low	Medium	Medium
Tc Crystalline Si-Titanate	Not Fully Proven	R&D	Low	Low	Medium
Tc EXTRACTION	Fully Proven on Local HLW				
Tc Ion X	Not Fully Proven	R&D	Low	High	Medium
Tc MOLECULAR RECOGNITION (Tc)	Not Fully Proven	R&D	Low	High	Medium
Tc MOLECULAR RECOGNITION (Tc&U)	Not Fully Proven	R&D	Low	Medium	Medium
Tc PRECIPITATION	Not Fully Proven	R&D	Medium	High	Medium
Tc Pre-Separation (Acidic)	Not Fully Proven	R&D	Low	Medium	Medium
Tc SELECTIVE LEACH	Not Fully Proven	R&D	Medium	High	Medium
Tc Separation (Acidic)	Not Fully Proven	R&D	Medium	Medium	Medium
Tc Separation (Basic)	Not Fully Proven	R&D	Low	High	Medium
Tc SEPARATION (Fr)	Not Fully Proven	R&D	Low	High	Low
Tc SEPARATION (Japan)	Not Fully Proven	R&D	Low	High	High
Tc Solid Sorbent	Not Fully Proven	R&D	Medium	High	Medium
TITANATE Sr REMOVAL	Not Fully Proven	R&D	Low	High	Medium
TITANATE TRU SEPARATION	Not Fully Proven	R&D	Low	High	Medium
Ti/Zeolite Separations	Fully Proven on Local HLW				
TRANS Pu EXTRACTION w/ChCoDIC	Not Fully Proven	DT&E	Low	Medium	High
TRANS Pu ION X	Not Fully Proven	R&D	Low	High	Medium
TRANS Pu ION X CHROMA- TOGRAPHY	Not Fully Proven	R&D	Low	Medium	Low
TRANSMUTATION (Japan)	Not Fully Proven	R&D	Low	Low	Medium
TRANSMUTATION (Other)	Not Fully Proven	R&D	Low	Low	Medium
TRANSMUTATION (PNL)	Not Fully Proven	R&D	Low	Low	Medium
TRANSMUTATION (WHC)	Not Fully Proven	R&D	Low	Low	Medium
TRU Basic Separation	Not Fully Proven	R&D	Medium	Medium	Medium
TRU BY EIX + ACT-DE-CON	Not Fully Proven	R&D	Low	High	High
TRU FLOC ULTRA- FILTRATION	Fully Proven on Local HLW				
TRU MOLECULAR RECOGNITION	Not Fully Proven	R&D	Low	High	Medium
TRU PRECIPITATION	Not Fully Proven	R&D	Medium	High	Medium
TRU SELECTIVE LEACH	Not Fully Proven	R&D	Medium	High	Medium
TRU Separation (Acidic)	Not Fully Proven	R&D	Medium	High	High
TRU Separation (Basic)	Not Fully Proven	R&D	Medium	Medium	Medium
TRU SOLID SORBENT	Not Fully Proven	R&D	Medium	High	Medium
TRU Ti(OH) ₄ PRECIPITATION	Fully Proven on Local HLW				
TRUEX (Japan)	Not Fully Proven	R&D	Medium	High	High
TRUEX (USTID)	Not Fully Proven	R&D	Medium	High	High
TRUEX (WHC)	Not Fully Proven	R&D	Medium	High	High
U Magnetic Separation	Not Fully Proven	R&D	Medium	Medium	Medium
U MOLECULAR RECOGNITION	Not Fully Proven	R&D	Low	Medium	Medium
U Separation	Not Fully Proven	R&D	Low	Medium	Low
ULTRAFILT. CENTRIFUGE HM FLOCCU- LATION	Fully Proven on Local HLW				
Uranium Separation	Not Fully Proven	R&D	Low	Medium	Low
Vitrification to Glass	Not Fully Proven	DT&E	High	High	High
VITRIFICATION (GB)	Fully Proven on Local HLW				
VITRIFICATION (Japan)	Fully Proven on Local HLW				
Water Wash	Fully Proven for Hanford HLW				
WATER WASH SETTLE-DECANT	Fully Proven for Hanford HLW				
WATER WASH (Br)	Fully Proven on Local HLW				
WATER WASH (SRS)	Fully Proven on Local HLW				
WET OXIDATION	Not Fully Proven	R&D	Low	High	High

Table K2. Technical Risk Indexes by Process Name and Overall Strategy.

**** Technical Risk Category ****

Process Name	Model Name	Maturity	Timeliness	DOE Current Level of Effort	Combined Categories
TRUEXC31					
WATER WASH SETTLE-DECANT	WASHSLUD	0.01	0.01	0.01	
U Separation	UTCSTRIP	10.00	3.33	10.00	
TRUEX (USTID)	TRUEX	1.00	1.00	3.33	
Tc Ion X	TCIX1	3.33	1.00	10.00	
HWVP	VITRW	0.10	0.10	0.10	
SPEX	SPEX	3.33	1.00	10.00	
SST SOLIDS DISSOLUTION (PNL)	DISSOLVA	3.33	1.00	10.00	
Tc Acidic Separation	TCIX2	3.33	3.33	3.33	
GROUT	GROUTW	0.10	0.10	0.10	
DST SOLIDS DISSOLUTION (WHC)	DISSOLVA	3.33	1.00	10.00	
Cs ION X, WHC	CSIX	0.01	0.01	0.01	
CC/FECN DESTRUCTION, CALCINATION	DESTORG	3.33	1.00	1.00	
TOTAL, (CLEANG31/TRUEXC31):		31.22 (2.1)	12.89 (2.4)	57.89 (1.8)	101.99 (2.0)
AVERAGE, (CLEANG31/TRUEXC31):		2.60 (1.2)	1.07 (1.4)	4.82 (1.0)	8.50 (1.1)
SLUDWC31					
WATER WASH SETTLE-DECANT	WASHSLUD	0.01	0.01	0.01	
Tc Ion X	TCIX1	3.33	1.00	10.00	
HWVP	VITRW	0.10	0.10	0.10	
GROUT	GROUTW	0.10	0.10	0.10	
Cs ION X, WHC	CSIX	0.01	0.01	0.01	
CC/FECN DESTRUCTION, CALCINATION	DESTORG	3.33	1.00	1.00	
TOTAL, (CLEANG31/SLUDWC31):		6.89 (9.5)	2.22 (14.1)	11.22 (9.2)	20.33 (9.8)
AVERAGE, (CLEANG31/SLUDWC31):		1.15 (2.7)	0.37 (4.0)	1.87 (2.6)	3.39 (2.8)
CLEANG31					
U Separation	PURIFYU	10.00	3.33	10.00	
TRUEX (USTID)	EXTRUFU	1.00	1.00	3.33	
TRUEX (USTID)	EXTRAMUN	1.00	1.00	3.33	
Tc Ion X	TCIX	3.33	1.00	10.00	
SST SOLIDS DISSOLUTION (PNL)	DISOLVA	3.33	1.00	10.00	
SST SOLIDS DISSOLUTION (PNL)	DISOLVF	3.33	1.00	10.00	
SPEX	SPEX	3.33	1.00	10.00	
Sr Basic Separation	SPIX	3.33	3.33	3.33	
NO3 Destruction (PNL)	DNITRH	3.33	3.33	1.00	
HWVP	VITRW	0.10	0.10	0.10	
HYDROPULSE FILTER	SEPSOLQ	0.01	0.01	0.01	
NaOH/HNO3 Recycle (PNL)	RCOVACID	10.00	1.00	10.00	
GROUT	GROUTW	0.10	0.10	0.10	
DST SOLIDS DISSOLUTION (WHC)	DISOLVA	3.33	1.00	10.00	
DST SOLIDS DISSOLUTION (WHC)	DISOLVF	3.33	1.00	10.00	
Cs ION X, WHC	CSIX	0.01	0.01	0.01	
Cs Acidic Separation	APMCSIX	3.33	3.33	3.33	
CC/FECN DESTRUCTION, CALCINATION	DESTORG	3.33	1.00	1.00	
CC/FECN DESTRUCTION, CALCINATION	CALCINE	3.33	1.00	1.00	
Ba/Sr Separation	SFBAIX	3.33	3.33	3.33	
Actinide/ Lanthanide Separation	AMLANIX	3.33	3.33	3.33	
TOTAL:		65.55	31.22	103.22	199.99
AVERAGE:		3.12	1.49	4.92	9.52

This page intentionally left blank.

DISTRIBUTION

Number of Copies

OFFSITE

2

Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, New Mexico 87545

Dr. S. F. Agnew
Dr. M. Attrep, Jr.

MS J-586
MS K-514

1

Martin Marietta Energy Systems
P.O. Box 2008
Oak Ridge, Tennessee 37831-6149

Dr. J. Watson

2

U.S. Department of Energy,
Headquarters
Office of Technology Development
Trevion II Building, EM-545
12800 Middlebrook Road
Germantown, Maryland 20874

Dr. T. Fryberger, Program Manager

1

U.S. Department of Energy,
Headquarters
% Dr. T. Fryberger
Trevion II Building, EM-545
12800 Middlebrook Road
Germantown, Maryland 20874

Dr. D. Oakley

1

Waste Policy Institute
Quince Diamond Executive Center
555 Quince Orchard Road
Gaithersburg, Maryland 20878-1437

Dr. I. Tasker

1

Westinghouse Savannah River Company
U.S. Highway 19
Aiken, South Carolina 29802

Dr. M. Thompson

1

Dr. R. Wymer
188A Outer Drive
Oak Ridge, Tennessee 37831

DISTRIBUTION (cont.)

ONSITE

3	<u>U.S. Department of Energy.</u> <u>Richland Operations Office</u>	
	D. E. Trader (3)	K8-50
17	<u>Pacific Northwest Laboratory</u>	
	L. K. Holton, Jr.	P7-43
	M. Hoza	K7-22
	W. L. Kuhn (4)	K2-21
	D. E. Kurath	P7-43
	L. Lauerhass (6)	P8-38
	L. J. Sealock, Jr. (2)	K2-10
	J. I. Straalsund	B1-40
	J. L. Swanson	P7-25
24	<u>Westinghouse Hanford Company</u>	
	J. N. Appel	G3-21
	S. A. Barker	G3-20
	W. B. Barton	L4-75
	J. D. Berger	L0-18
	A. L. Boldt	H5-49
	G. W. Jackson	H6-33
	G. Jansen, Jr. (2)	L0-14
	B. J. Knutson (6)	L0-14
	G. T. Maclean	H5-49
	R. M. Orme	L4-75
	S. E. Seeman	L0-06
	E. J. Slaathaug	H5-49
	D. G. Sutherland	L4-72
	D. J. Washenfelder	L4-75
	B. D. Zimmerman	L0-06
	Information Release	
	Administration (3)	L8-07

DATE

FILMED

10/18/94

END