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Technical Support for Authorization of 242-A Evaporator Campaign 97-2, Hanford Site, Richland, Washington

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July 1997

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EXECUTIVE SUMMARY

An analysis was performed to determine the acceptability of processing 242-A Evaporator/Crystallizer Campaign 97-2 feed. Inhalation unit liter doses (ULDs) were calculated using the methods and data described in the *Tank Waste Remediation System Basis for Interim Operation* (TWRS BIO) and *242-A Evaporator/Crystallizer Safety Analysis Report*. The ULD calculated for the Campaign 97-2 slurry was found to be less than the TWRS BIO Evaporator slurry ULD and so would be within the analyzed safety envelope defined in the TWRS BIO. The Evaporator slurry ULD established in the TWRS BIO and supporting documents was calculated using the bounding source strength defined in the 242-A Evaporator SAR. Consequently, the risks and consequences associated with the Campaign 97-2 slurry would be lower than those already accepted by DOE and documented in the TWRS BIO and the 242-A Evaporator SAR.

The direct radiation exposures from formation of a liquid pool of Campaign 97-2 slurry were demonstrated to be less than the exposures from a pool formed by bounding source strength evaporator slurry as defined in the 242-A Evaporator SAR. This was demonstrated via a comparison of the Campaign 97-2 slurry composition and the 242-A Evaporator SAR bounding source strength. It was concluded that the direct radiation exposures from Campaign 97-2 slurry would be within the analyzed safety envelope in the 242-A Evaporator SAR.

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1.0 INTRODUCTION AND BACKGROUND

The 242-A Evaporator/Crystallizer (Evaporator), located in the 200 East Area of the Hanford Site, concentrates and reduces the volume of liquid radioactive wastes generated at the Hanford Site. The liquid wastes are transferred via an encased underground piping system from radioactive waste storage tanks to the 241-AW-102 (AW-102) double shell tank (DST), also referred to as the Evaporator Feed Tank. From AW-102, the liquid wastes are transferred via encased underground piping to the 242-A Evaporator facility for volume reduction. Following volume reduction, the slurry product is transferred via encased underground piping to the DST system for interim storage pending final disposition.

In preparation for an Evaporator campaign, samples of feed are collected and analyzed to determine, among other things, their acceptability with respect to the facility's authorization basis and their compatibility with liquid wastes already in interim storage in the DST system. Feed samples taken to support Evaporator Campaign 97-2 were discovered to have concentrations of Pu-238 that were above the limits specified in the facility authorization basis. As a result, the operator of the 242-A Evaporator facility, Waste Management Services Hanford, Inc., contracted with the Pacific Northwest National Laboratory (PNNL) to help resolve this issue.

This document provides the technical basis for comparing the slurry compositions expected to be generated in Evaporator Campaign 97-2 to the safety envelopes represented in the *242-A Evaporator/Crystallizer Safety Analysis Report* (Evaporator SAR; WHC 1997) and the *Tank Waste Remediation System Basis for Interim Operation* (TWRS BIO; LMHC 1997). These documents represent the authorization bases for these two facilities. This document also develops a Unit Liter Dose (ULD) value for the bounding source strength Evaporator slurry to compare against the Campaign 97-2 slurry ULD.

The slurry produced by the 242-A Evaporator is transferred to the DST system where it is stored pending final disposition. Thus, there is a direct relationship between the source term limits for slurries produced by the Evaporator and the source term limits represented in the TWRS BIO for slurries allowed in the DST system. A supporting document for the BIO (Cowley 1996) developed the basis for the source terms used in the BIO. This document provided source terms for, among other things, composite DST liquids, composite DST solids, and evaporator slurries. The evaporator source term in Cowley (1996) is the same as the bounding source strength given in the Evaporator SAR, Table 9-2. This source term also forms the basis for the Evaporator's inventory control program. There has been a consistent application of this source term in both the Evaporator and TWRS authorization basis documents.

Cowley (1996) used the Evaporator source terms to calculate ULD values for evaporator slurry and then compared the Evaporator slurry ULD to the DST composite liquid and solid ULDs used in the BIO accident analyses. The DST liquids and solids ULDs represent part of the TWRS authorization basis. Cowley (1996) concluded that the slurry ULD for DSTs, comprised of 30% DST solids and 70% DST liquids, was far greater than the ULD calculated for Evaporator slurry. Therefore, as long as the radionuclide concentrations in Evaporator slurries are below the limits specified in the Evaporator's inventory control program, the Evaporator slurry would not conflict with the ULDs established for the DST system. This means the Evaporator slurry would be within the analyzed safety envelope established in the TWRS BIO.

Sampling data indicates that the concentration of Pu-238 in the 241-AY-101 (AY-101) feed stream to the Evaporator exceeds the Pu-238 limit specified in the Evaporator SAR. Since Cowley (1996) and the TWRS BIO (LMHC 1997) used the same source terms as the Evaporator SAR to conclude the Evaporator slurry source term would be bounded by slurry ULDs calculated using the DST liquids and solids source terms, the Pu-238 concentration in the AY-101 feed stream would be higher than the Pu-238 concentration used to calculate these slurry ULDs. However, the accident analyses in the TWRS BIO used composite ULDs in the accident analyses. Individual radionuclide concentrations were not used in the accident analyses and thus controls were not established at the individual radionuclide level. Rather, controls are established at the ULD level. This means that activities would be within the analyzed safety envelope as long as the composite ULD from Campaign 97-2 slurry is less than the composite ULD presented in the BIO.

The ULDs discussed above represent the total effective dose equivalent (Sieverts or Sv) per liter of material inhaled. This means that inhalation was the only pathway considered in this analysis. The Evaporator SAR also addresses the direct radiation dose rate emitted from a pool of liquid formed by failure of a transfer line. The Evaporator SAR concluded that the direct radiation doses from a spill of material with the radionuclide composition specified in the SAR would be acceptable, although precautions should be taken during spill cleanup to maintain exposures As Low As Reasonably Achievable (ALARA). Consequently, as long as the Campaign 97-2 slurry concentrations are below those specified in the Evaporator SAR, the direct radiation exposures would also be acceptable. A comparison of the Campaign 97-2 and Evaporator SAR source terms is performed later to examine direct radiation exposures.

2.0 APPROACH

An analysis was performed to determine a composite ULD for the slurry to be produced in Evaporator campaign 97-2 and a ULD for the bounding source strength given in the Evaporator SAR. The 97-2 slurry ULD was calculated using the same approach and data that was used in Cowley (1996). One minor difference between the calculations performed here and those in Cowley (1996) is the additional radionuclides included in the Campaign 97-2 slurry ULD calculations that were not included in Cowley (1996).

Unit Liter Doses calculated in this study represent the total effective dose equivalent (in units of Sieverts or Sv) from inhalation of a unit volume (units of liters or L) of radioactive material. The ULDs are calculated according to the following formula:

$$ULD_{Composite} = \sum_i SC_i * DCF_i$$

where: ULD = Unit liter dose, Sv/L
 SC = Source concentration of radionuclide I, Bq/L
 DCF = Inhalation dose conversion factor for radionuclide I, Sv/Bq

In practice, the ULDs are calculated in a two-step process: 1) individual radionuclide ULDs are calculated by multiplying together the source concentration of each radionuclide and its respective inhalation dose conversion factor; and 2) the composite source ULD is calculated by summing the individual radionuclide ULDs. A spreadsheet was developed and verified to perform the calculations.

Additional bases for the ULD calculations are as follows:

- The sampling results on the 101-AY used in the calculations are averaged values from as few as 3 to as many as 8 samples.
- The characterization information developed for Evaporator campaign 97-2 also included a combined feed source term that included wastes from tanks AY-101, AW-106 and AN-106. The higher of the radionuclide-specific source term values from the AY-101 sample analysis or the combined source term from the three tanks was used in the slurry ULD calculations.
- The slurry compositions were calculated by multiplying the feed compositions by a factor of 4 to account for volume reduction provided by the evaporator.

- Uranium isotopic compositions were not provided in the sample data. Rather, a total mass-based U concentration was given in units of $\mu\text{g/mL}$. This was converted to radionuclide-specific activity-based concentrations ($\mu\text{Ci/mL}$) by multiplying the total U concentration by approximate mass fractions of each U isotope and then by specific activities taken from 10 CFR 71, Table A-1.
- The source of the inhalation dose conversion factors used in the ULD calculations is EPA (1988), the same source used by Cowley (1996).

3.0 RESULTS

The results of the inhalation ULD analyses are shown in Table 1. The table includes the AY-101 feed composition, combined AY-101, AW-106, and AN-106 feed composition, bounding feed composition determined by selecting the higher radionuclide concentration from AY-101 alone or the combined source term, slurry source term, inhalation dose conversion factors for each radionuclide, and radionuclide ULDs for the slurry. The total ULD for the Campaign 97-2 slurry is also shown in the table.

The ULD for the bounding source strength Evaporator slurry is shown in Table 2. The bounding source strength was taken from Table 9-2 of the Evaporator SAR and is the same as the source strength used by Cowley (1996) in support of the TWRS BIO.

A comparison of source terms was performed to examine the direct radiation exposures calculated in the Evaporator SAR accident analysis that result from transfer line failure followed by formation of a liquid pool. The comparison determined that two radionuclides, Pu-238 and Ra-226, were larger in the Campaign 97-2 slurry concentrations than those presented in Table 9-2 of the Evaporator SAR. The concentrations of all other radionuclides are smaller in Campaign 97-2 than those listed in the Evaporator SAR. Both Pu-238 and Ra-226 are alpha-emitters with long half-lives (about 88 and 1600 yr, respectively) and would not contribute significantly to the dose rate emitted from a pool of liquid. The dominant contributors to the external dose rate are in significantly lower concentrations in Campaign 97-2 slurry than in the Evaporator SAR, including Cs-137 - about 27% of the SAR concentration; Cs-134 - 2%; Sr-90 - 3%; Co-60 - 9%; Y-90 - 3%; Eu-154 - 49%; and Eu-155 - 9%. As a result, the external dose rate emitted from a liquid pool of Campaign 97-2 slurry would be less than that from a spill of slurry at the radionuclide concentrations given in the Evaporator SAR. Therefore, the external exposures from a spill of Campaign 97-2 slurry would be lower than those previously accepted in the Evaporator SAR.

Table 1. 242-A Evaporator Campaign 97-2 Waste Compositions and Unit Liter Dose Calculations

Radionuclide	Evaporator Feed Composition, $\mu\text{Ci/mL}$			Composite Slurry Composition, $\mu\text{Ci/mL}^{(b)}$	Inhalation dose conversion factor, Sv/Bq	Unit Liter Dose (Sv/L inhaled)
	AY-101 Source Term	Combined ^(a) Source Term	Composite Source Term			
H-3	8.29E-03	9.20E-03	9.20E-03	3.68E-02	1.73E-11	2.36E-05
C-14	3.03E-04	2.92E-04	3.03E-04	1.21E-03	5.64E-10	2.53E-05
Co-60	2.69E-02	2.49E-02	2.69E-02	1.08E-01	5.91E-08	2.35E-01
Se-79	3.42E-04	2.76E-04	3.42E-04	1.37E-03	2.66E-09	1.35E-04
Sr-90	1.90E+00	1.43E+00	1.90E+00	7.60E+00	6.47E-08	1.82E+01
Y-90	1.90E+00	1.43E+00	1.90E+00	7.60E+00	2.28E-09	6.41E-01
Nb-94	1.11E-02	9.42E-05	1.11E-02	4.44E-02	1.12E-07	1.84E-01
Tc-99	3.31E-02	3.80E-02	3.80E-02	1.52E-01	2.25E-09	1.27E-02
Ru-106	8.29E-01	9.60E-01	9.60E-01	3.84E+00	1.29E-07	1.83E+01
I-129	5.17E-06	2.12E-05	2.12E-05	8.48E-05	4.69E-08	1.47E-04
Cs-134	4.18E-02	8.67E-02	8.67E-02	3.47E-01	1.25E-08	1.60E-01
Cs-137	9.33E+01	9.94E+01	9.94E+01	3.98E+02	8.63E-09	1.27E+02
Ce-144	5.37E-01	6.16E-01	6.16E-01	2.46E+00	1.01E-07	9.21E+00
Eu-154	2.78E-02	3.44E-02	3.44E-02	1.38E-01	7.73E-08	3.94E-01
Eu-155	1.45E-01	1.55E-01	1.55E-01	6.20E-01	1.12E-08	2.57E-01
Ra-226	1.11E+00	1.45E-04	1.11E+00	4.44E+00	2.32E-06	3.81E+02
Np-237	1.15E-03	9.31E-04	1.15E-03	4.60E-03	1.46E-04	2.48E+01
Pu-238	8.84E-03	6.36E-03	8.84E-03	3.54E-02	1.06E-04	1.39E+02
Pu-239	3.58E-02	2.65E-02	3.58E-02	1.43E-01	1.16E-04	6.15E+02
Pu-241	1.47E+00	1.09E+00	1.47E+00	5.88E+00	2.23E-06	4.85E+02
Am-241	3.94E-03	6.47E-03	6.47E-03	2.59E-02	1.20E-04	1.15E+02
Cm-244	1.62E-03	1.21E-03	1.62E-03	6.48E-03	6.70E-05	1.61E+01
U-233	2.81E-05	2.25E-05	2.81E-05	1.12E-04	3.66E-05	1.52E-01
U-234	1.53E-04	1.23E-04	1.53E-04	6.12E-04	3.58E-05	8.11E-01
U-235	4.61E-06	3.69E-06	4.61E-06	1.84E-05	3.32E-05	2.26E-02
U-236	9.45E-06	7.58E-06	9.45E-06	3.78E-05	3.39E-05	4.74E-02
U-238	9.92E-05	7.95E-05	9.92E-05	3.97E-04	3.20E-05	4.70E-01
TOTAL ULD, Sv/L						1.95E+03

(a) Includes wastes from AY-101, AW-106, and AN-106.

(b) To convert from $\mu\text{Ci/mL}$ to Bq/L, multiply by $3.7\text{E}+07$.

Table 2. Inhalation Unit Liter Dose for Evaporator Slurry at Bounding Concentrations Given in the 242-A Evaporator SAR

Radionuclide	SAR-023 Bounding Source Term		Inhalation Dose Conversion Factor, Sv/Bq	Inhalation Unit Liter Dose, Sv/L
	Ci/L	Bq/L		
C-14	2.6E-04	9.6E+06	5.6E-10	5.4E-03
Co-60	1.2E-03	4.4E+07	5.9E-08	2.6E+00
Se-79	7.8E-05	2.9E+06	2.7E-09	7.7E-03
Sr-90	2.2E-01	8.1E+09	6.5E-08	5.3E+02
Y-90	2.2E-01	8.1E+09	2.3E-09	1.9E+01
Nb-94	9.8E-05	3.6E+06	1.1E-07	4.1E-01
Tc-99	2.0E-03	7.4E+07	2.3E-09	1.7E-01
Ru-106	5.3E-02	2.0E+09	1.3E-07	2.5E+02
I-129	2.6E-06	9.6E+04	4.7E-08	4.5E-03
Cs-134	1.5E-02	5.6E+08	1.3E-08	6.9E+00
Cs-137	1.5E+00	5.6E+10	8.6E-09	4.8E+02
Eu-154	5.0E-03	1.9E+08	7.7E-08	1.4E+01
Eu-155	7.0E-03	2.6E+08	1.1E-08	2.9E+00
Ra-226	3.3E-05	1.2E+06	2.3E-06	2.8E+00
Pu-238	1.3E-06	4.8E+04	1.1E-04	5.1E+00
Pu-239	1.6E-04	5.9E+06	1.2E-04	6.9E+02
Pu-241	1.5E-02	5.6E+08	2.2E-06	1.2E+03
Am-241	1.0E-03	3.7E+07	1.2E-04	4.4E+03
Cm-244	1.3E-05	4.8E+05	6.7E-05	3.2E+01
TOTAL ULD, Sv/L				7.7E+03

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4.0 CONCLUSIONS

The composite ULD for the Campaign 97-2 slurry is shown in Table 1 to be about 2,000 Sv/L. This can be directly compared to the bounding source strength evaporator slurry ULD of 7,700 Sv/L shown in Table 2. The bounding source strength evaporator slurry ULD is clearly larger than the Campaign 97-2 composite slurry ULD. Since the bounding source strength evaporator slurry source term, calculated using the bounding source strength defined in the Evaporator SAR, is within the analyzed safety envelope defined in the TWRS BIO, the Campaign 97-2 ULD will also be within the safety envelope. Consequently, the risks and consequences associated with the Campaign 97-2 slurry would be lower than those already accepted by DOE and documented in the TWRS BIO and the 242-A Evaporator SAR.

The direct radiation exposures from formation of a liquid pool of Campaign 97-2 slurry were demonstrated to be less than the exposures from a pool formed by evaporator slurry that has the bounding source strength defined in the Evaporator SAR. This was demonstrated via a comparison of the Campaign 97-2 slurry composition and the Evaporator SAR bounding source strength. It was concluded that the direct radiation exposures from Campaign 97-2 slurry would be within the analyzed safety envelope in the 242-A Evaporator SAR.

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