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POTENTIAL RADIATION DAMAGE - STORAGE TANKS FOR LIQUID RADIOACTIVE WASTE (U)

by

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EXECUTIVE SUMMARY

The low intensity gamma and neutron emissions generated by high level waste do not cause sufficient displacement damage to degrade the mechanical properties of the carbon steel storage tanks. Therefore, structural assessment of tanks for storage of high level waste may be based on mechanical properties of the carbon steels from which the tanks were constructed. The highest estimated damage level is less than 4.0E-7 displacements per atom (dpa) following a 100 year exposure to fresh, "high heat" waste. This damage level is below the limit of 1.0E-5 dpa for measurement of radiation damage to the mechanical properties of carbon steels. Extrapolation of the trend equation relating increase in nil-ductility transition temperature (NDTT) to dpa, projects an increase of less than 5°F (<3°C) in the NDTT for 4.0E-7 dpa. This low dpa has a negligible effect on the mechanical properties of the materials of construction of the tanks.

High level waste at SRS is stored in carbon steel tanks constructed during the period 1951 to 1981. This waste contains radionuclides that decay by alpha, beta, or gamma emission or are spontaneous neutron sources. Thus, a low intensity radiation field is generated that is capable of causing displacement damage to the carbon steel. The potential for degradation of mechanical properties was evaluated by comparing the estimated displacement damage with published data relating changes in Charpy V-notch (CVN) impact energy to neutron exposure. Experimental radiation data was available for three of the four grades of carbon steel from which the tanks were constructed and is applicable to all four steels. Estimates of displacement damage arising from gamma and neutron radiation have been made based on the radionuclide contents for high level waste that are cited in the Safety Analysis Report (SAR) for the Liquid Waste Handling Facilities in the 200-Area. Alpha and beta emissions do not penetrate carbon steel to a sufficient depth to affect the bulk properties of the tank walls but may aggravate corrosion processes. The damage estimates take into account the source of the waste (F- or H-Area), the several types of tank service, and assume water as an attenuating medium. Estimates of displacement damage are conservative because they are based on the highest levels of radionuclide contents reported in the SAR and continuous replenishment of the radionuclides.

INTRODUCTION

High level waste at SRS is stored in carbon steel tanks constructed during the period 1951 to 1981 [1,2]. This waste contains radionuclides that decay by alpha, beta, or gamma emission or are spontaneous neutron sources. Thus, a low intensity radiation field is generated that is capable of causing displacement damage to the carbon steel. Given sufficient time, the accumulated displacement damage could degrade the fracture resistance of the steel and thus reduce the margins on structural stability of the tanks for normal and postulated accident conditions.

The potential for degradation of mechanical properties was evaluated by comparing the estimated displacement damage with published data relating changes in CVN impact energy to neutron exposure. Experimental radiation data was available for three of the four grades of carbon steel from which the tanks were constructed and is applicable to all four steels. Estimates of displacement damage arising from gamma and neutron radiation have been made based on the radionuclide contents for high level waste that are cited in the SAR for the Liquid Waste Handling Facilities in the 200-Area [1]. Alpha and beta emissions do not penetrate carbon steel to a sufficient depth to affect the bulk properties of the tank walls but may aggravate corrosion processes. The damage estimates take into account the source of the waste (F- or H-Area), the several types of tank service, and assume water as an attenuating medium. Estimates of displacement damage are conservative because they are based on the highest levels of radionuclide contents reported in the SAR and continuous replenishment of the radionuclides.

TANKS FOR STORAGE OF HIGH LEVEL WASTE

Materials of Construction

High level waste from the SRS separation operations is stored in carbon steel tanks which were fabricated during the period from 1951 to 1981 [1,2]. There are four tank designs. Types I, II, and III are for storage of high heat waste (5-16 BTU/hr-gal) where supplementary cooling is required and Type IV tanks are for low heat waste (0.2-0.8 BTU/hr-gal) and do not contain cooling coils. Materials of construction of the tanks are listed in Table I for each type of tank [1]. Note that the specification for ASTM A212 Grade B steel, from which the H-area Type IV tanks were constructed, was discontinued in 1966 and has been replaced by ASTM A516. ASTM A516-70 and ASTM A212-B have comparable chemical and mechanical property specifications. Specifications for steel compositions are listed in Table II [3]. The tanks were constructed to the requirements of ASME Section VIII, Div 1 but are not code stamped [1]. Some of the newer Type IIIA tanks are made of A516 and A537 (Table I) and were heat treated after construction to normalize the microstructure and improve the fracture properties of the steel.

Radionuclide Content of High Level Waste

The radionuclide content of the waste depends on the source and age of the waste and prior processing. Effects of waste source (F- or H-Canyons) and processing on the radionuclide content for high heat waste are shown in Tables 4-5 through 4-10 of the SAR, which were compiled as source terms for accident analyses [1]. The radionuclide content of low heat waste is a factor of 100 to 1000 lower than for high heat waste. Estimates of radiation damage to the high heat waste tanks, therefore, bound the radiation damage for the low heat waste tanks. The highest concentrations of radionuclides are in fresh canyon waste (Table 4-10) that is 180 days old. In the high heat waste receiver tanks with 1.5 year old waste (Table 4-6), the radionuclide contents are lower because of decay of short lived fission products. Upon standing, the waste separates into a supernate and an insoluble sludge which contains about 60% of the radionuclides. Consequently, sludge feed to the DWPF (Table 4-9) has elevated levels of spontaneous fission neutron emission as compared to the other waste. Evaporator overheads, precipitate feed to DWPF, and recycle from DWPF to WTF (Table 4-9) contain lower radionuclide contents than the other cases and were omitted from the calculations. The tanks exposed to the higher radiation levels are those receiving fresh canyon waste, tanks 33F, 34F, 13H, 32H, 35H, and 39H and those preparing sludge feed to DWPF, tanks 40H, 42H, and 51H [1]. The indicated F-Area tanks are Type III and the indicated H-Area tanks are Type IIIA. The type service, operating history, and current usage of all waste storage tanks are described in the Safety Analysis Report [1].

DISPLACEMENT DAMAGE ESTIMATES

The waste stored in the tanks contains radionuclides that decay by alpha, beta, or gamma emission or are spontaneous neutron sources [1]. These products of radioactive decay interact with solid materials and may displace atoms from their normal sites thus generating vacancies and interstitials which alter the mechanical properties of the steel [4]. Displacement damage from alpha and beta radiation might aggravate corrosion processes but would not affect the bulk mechanical properties of the tank walls. Damage from the alpha radiation (energies of 4.0 to 5.8 MeV) would be limited to a depth of 5 to 15 μm into the steel surface that faces the waste [4,5,6]. Any displacement damage from beta emissions would be limited to a depth of less than one millimeter and can only be caused by beta's with energies greater than approximately 0.5 MeV that originate within 1-cm of the tank wall [4,5,6]. Estimates of displacement damage have been made for the gamma and neutron emissions from high heat waste. The highest values of radionuclide content were chosen from Tables 4-5 to 4-10 of the SAR. These tables cover the several types service for waste storage tanks in both F- and H-Areas.

Gamma Radiation

Displacement damage for each gamma source was based on the radionuclide content (Curies/gal) as given in the SAR [1]. Most radionuclides emit more than one gamma ray [5]. All gamma rays with intensities greater than 0.1 per 100 decays and energies greater than 0.4 MeV were included. Source strengths, #/cm^3/sec , for each gamma were based on the high value of tabulated radionuclide contents and the Radioactive Decay Data Tables [5]. For gamma energies in the range 0.5 to 2 MeV, typical of those encountered from decay of radionuclides in the waste, displacement damage occurs primarily via the Compton Effect [4,6]. The displacement cross section for gamma rays interacting with an iron target was taken as 0.1 millebarn per electron for energies between 0.4 to 0.85 MeV and was a function of energy for energies greater than 0.85 MeV [7,8]. Values for the attenuation coefficients (μ) for gamma rays assumed transport through water with density 1 gram/cm^3 and were interpolated from Table 3.7 in Lamarsh [6].

The model for calculation of the gamma flux at a point on the tank wall assumed a uniform distribution of internal sources (S) within water as an attenuating medium [6]. Taking the wall as a plane sheet, the total buildup flux ($\o_b$) at the tank wall accumulated from the volume of waste in the tank is given by

$$\o_b = (S/2\mu)\ \Sigma A_n \{ 1- E_2[(1+ \alpha_n)\mu a]\}$$, where

S source intensity, #/cc/sec,

μ attenuation coefficient for water, cm^-1 [6],

A_n,α_n parameters for the Taylor form of the exposure buildup factor for point isotropic sources. n = 1,2 and $A_1 + A_2 = 1$ [6],

E_2 an integral function of $[(1+ \alpha_n)\mu a]$. [9],

a depth of waste measured from tank wall.

As the distance (a) through the waste from the tank wall increases, μa decreases, the function $E_2[(1+ \alpha_n)\mu a]$ becomes smaller so that $\Sigma A_n \{ 1- E_2[(1+ \alpha_n)\mu a]\}$ goes to ΣA_n which is equal to one, and the buildup flux, $\o_b \Rightarrow (S/2\mu)$. The displacement damage accumulated in 100 years for each gamma is given by:

$$\text{dpa} = \o_b \times \sigma(\text{mb/e})(0.001\text{b/mb}) \times 26\text{e/Fe} \times 10^{-24}\ \text{cm}^2/\text{b} \times (100\ \text{years})\ (3.15\times10^{7}\ \text{sec/year}),$$

where σ(mb/e) is the microscopic displacement cross section per electron which is a function of gamma energy [7,8]. This calculation is conservative in that the buildup flux is considered to be at the initial gamma ray energy rather than at the lower energies caused by attenuation while passing through the waste. Two other factors contribute conservatism to the radiation damage estimates. First, continuous replenishment of the radionuclide sources is postulated, overemphasizing the short lived radionuclides (Zr-95, Y-91, Nb-95, Ce-144, and Ru-106). Second, damage calculations were based on the Cesium-137 content of the waste rather than the Barium-137 content which is the principal source of gamma radiation damage. Cs-137 decays by beta emission to form .

The dpa was calculated for a 100 year exposure, Table III, which exceeds the maximum expected service life of any tank. Estimates of dpa may be made for shorter service by taking the ratio of the exposure times. Detailed tables of the calculations are given in Appendix A.

Neutron Radiation

Estimates of displacement damage from neutrons emitted by spontaneous fission of the actinides were based on the radionuclide contents given in Tables 4-5 to 4-10 of the SAR [1]. The estimates account for the fission neutrons that reach the tank walls but not the thermal neutrons. The cross section for displacement damage by thermal neutrons is approximately 12 barns in contrast to ~500 barns for fission neutrons [10].

The model for calculation of the neutron flux at a point on the tank wall assumed a uniform distribution of sources [6]. In the first step of the calculation, the neutron flux (ø) reaching a point on the tank wall from a plane source is given by:

$ø =$ $(SA/2)\,[E_1(\Sigma_r a)]$, where
S number of neutrons per cubic centimeter per second,
Σ_r cross section for removal of fission neutrons from the high energy (~ 1 MeV) group,
E_1 an integral function of $(\Sigma_r a)$ [9]
a distance from the point source to the tank wall.

The source strength, S is given by:

$S =$ (Ci/gal)(3785 cc/gal)((3.7E+10) d/Ci)(% Spon Fission/100) x (neutrons/fission).

The values for the coefficient ,A , and the removal cross section, Σ_r , which depend on the surrounding medium, are 0.12 and 0.103 cm^-1, respectively, for ordinary water [6]. With an internal source of neutrons distributed throughout a volume, the flux at a point on the tank wall is obtained by integrating the previous equation from x=0 to x=a and becomes

$$ø = (SA/2\Sigma_r)\,[\,1- E_2(\Sigma_r a)].$$

Beyond 40 cm neutrons are removed from the fission group [6]. For values of $\Sigma_r a$ (= 0.103 x 40) greater than 4, the function $E_2(\Sigma_r a)$ becomes less than 0.001, and $\phi \Rightarrow SA/2\Sigma_r$, which is the estimated flux of fission neutrons reaching the tank wall. The displacement damage for a 100 year exposure is

dpa = (0.12 S/0.103 x2) x(100years) (3.15E7 sec/year) x
(500 b) (1E-24 cm^2/b)

The dpa estimates are listed in Table III with the estimates from gamma ray damage. Detailed tables of the calculations are given in Appendix B.

RADIATION DAMAGE EFFECTS

The major effects of displacement damage on carbon steels (ferritic steel) are an increase in the temperature that separates low temperature brittle fracture from ductile failure at higher temperatures, a lowering of the energy of ductile failure, and an increase in the strength [11]. The transition from ductile to brittle behavior is indicated by the nil-ductility transition temperature (NDTT). Shift in NDTT has been taken as a representative mechanical property for judging the potential for radiation damage to the carbon steel in the waste storage tanks. The drop-weight test is the method specified in the ASTM Standards and ASME code for measurement of NDTT [12]. In practice, however, the more convenient and common approach for estimating the NDTT is measurement of the temperature dependence of CVN impact energy [11]. NDTT is indexed to the temperature where CVN energy equals 40J (30 ft-lb) or 20J (15 ft-lb) depending upon the yield strength of the steel. The several approaches to estimating NDTT are approximately equal and yield consistent interpretations of radiation damage.

The internationally accepted measure of radiation damage is the number of displacements per atom (dpa). ASTM Standard Practice E 693-79 describes the method for calculating dpa from neutron flux spectra for ferritic steels, thus allowing direct comparison of radiation damage among specimens exposed in different reactors to differing neutron spectra [10]. Unfortunately, dpa calculations are not available for the data cited in the references to this report except for the recent HFIR and ORR data on A212 [12]. Total fluence for neutrons with energies greater than 1 MeV was reported in all cases and these fluences have been converted to dpa to allow NDTT changes caused by gamma ray displacement damage to be estimated by comparison with the measured neutron displacement damage data. A ratio of dpa to fluence (E> 1MeV) of 1.5 x 10^-21 was adopted for this purpose. Conversion ratios for the ORR and HFIR data were 1.39x10^-21 and 1.49x10^-21, respectively [12].

The effects of radiation on NDTT and USE have been measured and reported for several of the common pressure vessel steels [13-18]. Increase in NDTT for ASTM A212, A285, and A537 are shown in Figure 1 for radiation damage levels of 1.0E-5 to 1.0E-2 dpa. The trend line (labelled "Porter") shown in the figure was based on neutron irradiation of more than a dozen steels with neutron fluences (E>1MeV) of approximately 1.0E17 to 1.0E19 (1.5E-4 to 1.5E-2 dpa) [14]. The trend line represents the average change in NDTT based on a statistical analysis of these data. There is a 95% confidence that 75% of the data lie within about 50°F of the trend line [14]. The Porter trend line is a reasonable representation of the average change in NDTT for weld and heat affected zone metal as well as base metal for ASTM 537B steel. Data from ASTM A212 surveillance specimens irradiated in the High Flux Isotope Reactor (HFIR) and data from ASTM A212 specimens irradiated in the Oak Ridge Research Reactor (ORR) in 1987 fall within the scatter band for data collected prior to 1960 and show the the Porter trend line represents the experimental data to as low as 2.0E-5 dpa.

An estimate of the effect of displacement damage on the NDTT of the waste tank steels was based on extrapolation of the trend equation reported by Porter. For a dpa level of 4.0E-7, an increase of ~ 6.4°F (<4°C) was calculated. The expected changes in mechanical properties are, therefore, negligible for the range of damage levels that have been estimated for the storage tanks for high level waste.

CONCLUSION

Because radiation damage is negligible, structural assessment of tanks for storage of high level waste may be based on the nominal or code values of the mechanical properties of the carbon steels from which the tanks were constructed. The calculated displacement damage caused by gamma radiation from high level waste (< 4.0E-7 dpa) is below the lower limit (< 1.0E-5 dpa) of experimental data for effects of radiation on the NDTT of carbon steels. Radiation effects on the other mechanical properties would be negligible also. The maximum increase in the NDTT is expected to be less than 6.4°F (<4°C) for 4.0E-7 dpa based on extrapolation of published correlation between dpa and change in transition temperature. The maximum displacement damage from spontaneous neutron fission is estimated to be less than 4.0E-11 dpa.

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TABLE I

MATERIALS OF CONSTRUCTION AND
NIL-DUCTILITY TRANSITION TEMPERATURES
FOR WASTE TANKS*

TYPE TANK	TANK NUMBER	LOCATION AND CONSTRUCTION DATES	MATERIAL	NDTT, °C
I	1 - 12	F and H 1951-1953	A 285-B	20
II	13 - 16	H 1955-1956	A 285-B	20
III	29-32, 33-34	H 1967-1970:F 1969-1972	A 516-70: as rolled	15
IIIA	35-37, 25-28	H 1974 -1977:F 1975-1978	A 516-70: normalized	- 18
IIIA	38 - 51	H 1976-1981:F 1977-1980	A 537- I: normalized	- 45
IV		F - 1958	A 285-B	20
		H - 1959-1961	A 212-B	20

* NDTT from Ref. 2.

TABLE II

NOMINAL COMPOSITIONS OF WASTE TANK STEELS*

Material	Carbon	Manganese	Phosphorous	Sulfur	Silicon	Other
A212	0.31	0.90	0.04	0.04	0.15/0.30	Cu - 0.25 max
A285-B	0.22	0.90	0.035	0.04	ns	
A516-70	0.27	0.85/1.20	0.035	0.04	0.13/0.45	Cu - 0.35 max
A537-I	0.24	0.70/1.35	0.035	0.04	0.15/0.50	Ni - 0.25 max Cr - 0.25 max Mo - 0.08

* ASTM STANDARDS/ ASME SECTION II. Maximum values unless a range is given.
ns= not specified

TABLE III
DISPLACEMENT DAMAGE TO TANK WALLS FROM GAMMA AND SPONTANEOUS NEUTRON EMISSIONS
(Displacements per Atom)

	F - AREA		H - AREA	
SERVICE	GAMMA	NEUTRON	GAMMA	NEUTRON
Combined Tanks	1.87 E-08	3.19 E-11	7.16 E-08	1.52 E-14
High Heat Waste	1.70 E-08	9.10 E-16	7.03 E-08	1.78 E-14
High Heat Supernate	4.67 E-09	1.30 E-11	9.07 E-09	3.76 E-16
Evaporator Concentrate	3.73 E-09	4.38 E-17	3.83 E-09	6.07 E-16
Sludge Feed	7.67 E-09	3.24 E-12	7.67 E-09	3.24 E-12
Fresh Canyon Waste	3.30 E-07	2.58 E-13	1.72 E-07	1.25 E-14

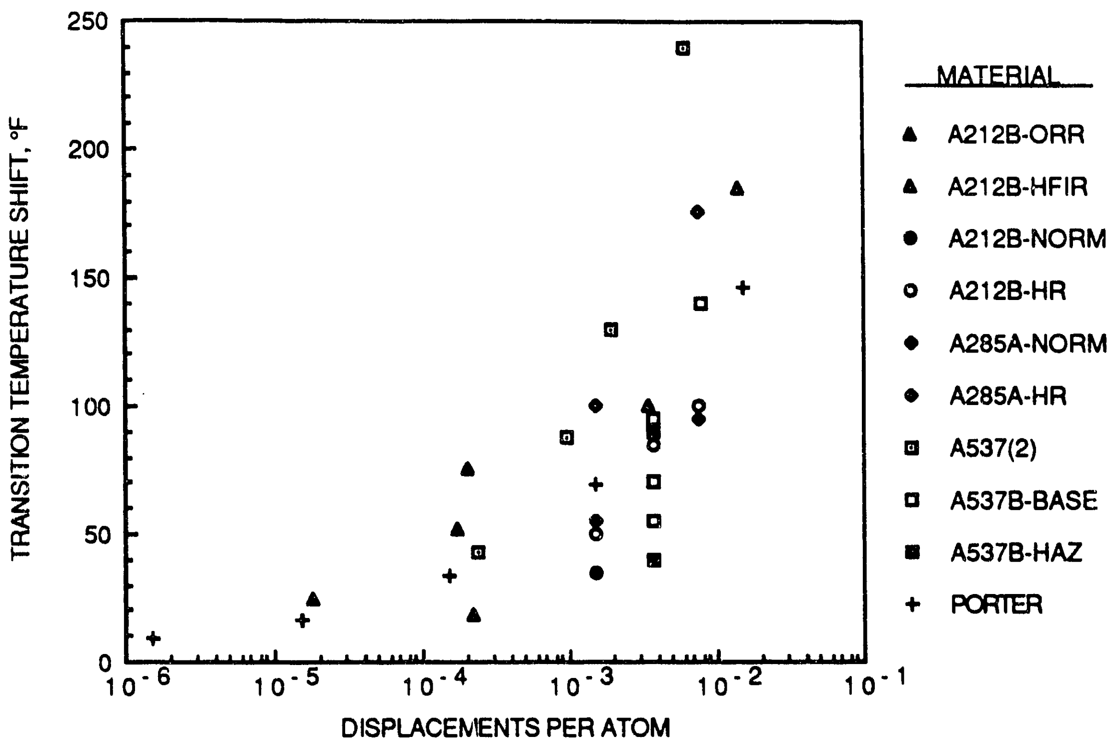

FIGURE 1
SHIFT IN NIL-DUCTILITY TRANSITION TEMPERATURE CAUSED BY NEUTRON RADIATION DAMAGE

APPENDIX A

ESTIMATED DISPLACEMENT DAMAGE FROM GAMMA EMISSIONS

NOTES FOR TABLES IN APPENDIX A

Col 1: Radionuclide data from DPSTSA-200-10, SUP-18.
Col 2: Half-life. DOE/TIC-11026. 1981.
Col 3: Radionuclide activities are the highest values listed in Tables 4-5 through 4-10 of DPSTSA-200-10,SUP-18.
Col 4: Gamma's listed in sequence of increasing energy. Omissions are because of low intensity. DOE/TIC-11026,1981.
Col 5: Number G's per 100 disintegrations. Data from Radioactive Decay Data Tables. DOE/TIC-11026. 1981.
Col 6: G/cc/sec=((Ci/gal*3.7e10 dis/Ci)*((#G/100dis)/100))/3785 cc/gal
Col 7: Gamma energy, Mev. Data from Radioactive Decay Data Tables. DOE/TIC-11026. 1981.
Col 8: Mass attenuation coefficient. Introduction to Nuclear Engineering. J.R.Lamarsh. Table 3.7. Assume water.
Col 9: Displacement cross section for gamma interaction with iron, millibarn/electron. DPST-88-871.
Col 10: DPA = (#/cm^3/sec)/2/μ(cm^2/gm)*1gm/cm^3*mb/e*26e/atom*0.001*(1e-24)*100 years*3.15E7sec/year

TABLE A-1
COMBINED TANKS - F-AREA, TABLE 4-5 of SAR

RADIONUCLIDE	HALF-LIFE	ACTIVITY Ci/gal	GAMMA PHOTONS No	GAMMA PHOTONS #/100	GAMMA PHOTONS #/sec/cc	GAMMA PHOTONS Energy,Mev	μ/ρ cm^2/gm	Xtion mb/e	DPA
Ce-144/Pr-144	284.3d	11	4	1.48	1.59E+06	0.696	0.085	0.10	7.67E-11
		11	9	0.30	3.23E+05	1.489	0.057	0.44	1.02E-10
		11	11	0.77	8.28E+05	2.185	0.047	11.50	8.30E-09
Zr-95	64d	2.9	2	43.70	1.24E+07	0.724	0.082	0.10	6.19E-10
		2.9	3	55.30	1.57E+07	0.756	0.080	0.10	8.02E-10
Y-91	58.5d	1.9	1	0.30	5.57E+04	1.205	0.062	0.63	2.32E-11
Nb-95	35d	6.3	3	99.80	6.15E+07	0.765	0.080	0.10	3.15E-09
Ru-106/Rh-106	368d	0.78	7	20.60	1.57E+06	0.512	0.096	0.10	6.70E-11
		0.78	12	0.70	5.34E+04	0.616	0.088	0.10	2.48E-12
		0.78	13	9.80	7.47E+05	0.622	0.088	0.10	3.48E-11
		0.78	21	0.40	3.05E+04	0.874	0.075	0.11	1.83E-12
		0.78	25	1.70	1.30E+05	1.050	0.069	0.30	2.31E-11
		0.78	29	0.40	3.05E+04	1.128	0.066	0.43	8.14E-12
		0.78	50	0.16	1.22E+04	1.562	0.057	3.00	2.64E-11
Cs-137/Ba-137	30.17y	13	1	90.00	1.14E+08	0.661	0.086	0.10	5.45E-09
								TOTAL DPA =	1.87E-08

TABLE A-2
COMBINED TANKS - H-AREA, TABLE 4-5 of SAR

		ACTIVITY	GAMMA PHOTONS				μ/p	Xtion	
RADIONUCLIDE	HALF-LIFE	Ci/gal	No	#/100	#/sec/cc	Energy Mev	cm^2/gm	mb/e	DPA
Ce-144/Pr-144	284.3d	73	4	1.48	1.06E+07	0.696	0.085	0.10	5.09E-10
		73	9	0.30	2.14E+06	1.489	0.057	0.44	6.77E-10
		73	11	0.77	5.49E+06	2.185	0.047	11.50	5.51E-08
Zr-95	64d	5.7	2	43.70	2.43E+07	0.724	0.082	0.10	1.22E-09
		5.7	3	55.30	3.08E+07	0.756	0.080	0.10	1.58E-09
Y-91	58.5d	3.5	1	0.30	1.03E+05	1.205	0.062	0.63	4.27E-11
Nb-95	35d	12	3	99.80	1.17E+08	0.765	0.080	0.10	5.99E-09
Ru-106/Rh-106	368d	5.1	7	20.60	1.03E+07	0.512	0.096	0.10	4.38E-10
		5.1	12	0.70	3.49E+05	0.616	0.088	0.10	1.62E-11
		5.1	13	9.80	4.89E+06	0.622	0.088	0.10	2.27E-10
		5.1	21	0.40	1.99E+05	0.874	0.075	0.11	1.20E-11
		5.1	25	1.70	8.48E+05	1.050	0.069	0.30	1.51E-10
		5.1	29	0.40	1.99E+05	1.128	0.066	0.43	5.32E-11
		5.1	50	0.16	7.98E+04	1.562	0.057	3.00	1.73E-10
Cs-137/Ba-137	30.17y	13	1	90.00	1.14E+08	0.661	0.086	0.10	5.45E-09
								TOTAL DPA =	7.16E-08

TABLE A-3

HIGH HEAT WASTE RECEIVER TANKS - F-AREA, TABLE 4-6 of SAR

		ACTIVITY	GAMMA PHOTONS				µ/p	Xtion	
RADIONUCLIDE	HALF-LIFE	Ci/gal	No	#/100	#/sec/cc	Energy,Mev	cm^2/gm	mb/e	DPA
Ce-144/Pr-144	284.3d	11	4	1.48	1.59E+06	0.696	0.085	0.10	7.67E-11
		11	9	0.3	3.23E+05	1.489	0.057	0.44	1.02E-10
		11	11	0.77	8.28E+05	2.185	0.047	11.50	8.30E-09
Zr-95	64d	2.9	2	43.7	1.24E+07	0.724	0.082	0.10	6.19E-10
		2.9	3	55.3	1.57E+07	0.756	0.080	0.10	8.02E-10
Y-91	58.5d	1.9	1	0.3	5.57E+04	1.205	0.062	0.63	2.32E-11
Nb-95	35d	6.3	3	99.8	6.15E+07	0.765	0.080	0.10	3.15E-09
Ru-106/Rh-106	368d	7.8	7	20.6	1.57E+07	0.512	0.096	0.10	6.70E-10
		7.8	12	0.7	5.34E+05	0.616	0.088	0.10	2.48E-11
		7.8	13	9.8	7.47E+06	0.622	0.088	0.10	3.48E-10
		7.8	21	0.4	3.05E+05	0.874	0.075	0.11	1.83E-11
		7.8	25	1.7	1.30E+06	1.05	0.069	0.30	2.31E-10
		7.8	29	0.4	3.05E+05	1.128	0.066	0.43	8.14E-11
		7.8	50	0.16	1.22E+05	1.562	0.057	3.00	2.64E-10
Cs-137/Ba-137	30.17y	5.4	1	90	4.75E+07	0.661	0.086	0.10	2.26E-09
								TOTAL DPA =	1.70E-08

TABLE A-4

HIGH HEAT WASTE RECEIVER TANKS - H-AREA, TABLE 4-6 of SAR

RADIONUCLIDE	HALF-LIFE	ACTIVITY Ci/gal	GAMMA PHOTONS No	#/100	#/sec/cc	Energy,Mev	μ/p cm^2/gm	Xtion mb/e	DPA
Ce-144/Pr-144	284.3d	73	4	1.48	1.06E+07	0.696	0.085	0.10	5.09E-10
		73	9	0.3	2.14E+06	1.489	0.057	0.44	6.77E-10
		73	11	0.77	5.49E+06	2.185	0.047	11.50	5.51E-08
Zr-95	64d	5.7	2	[illegible]	2.43E+07	0.724	0.082	0.10	1.22E-09
		5.7	3	55.3	3.08E+07	0.756	0.080	0.10	1.58E-09
Y-91	58.5d	3.5	1	0.3	1.03E+05	1.205	0.062	0.63	4.27E-11
Nb-95	35d	12	3	99.8	1.17E+08	0.765	0.080	0.10	5.99E-09
Ru-106/Rh-106	368d	5.1	7	20.6	1.03E+07	0.512	0.096	0.10	4.38E-10
		5.1	12	0.7	3.49E+05	0.616	0.088	0.10	1.62E-11
		5.1	13	9.8	4.89E+06	0.622	0.088	0.10	2.27E-10
		5.1	21	0.4	1.99E+05	0.874	0.075	0.11	1.20E-11
		5.1	25	1.7	8.48E+05	1.05	0.069	0.30	1.51E-10
		5.1	29	0.4	1.99E+05	1.128	0.066	0.43	5.32E-11
		5.1	50	0.16	7.98E+04	1.562	0.057	3.00	1.73E-10
Cs-137/Ba-137	30.17y	9.8	1	90	8.62E+07	0.661	0.086	0.10	4.11E-09
								TOTAL DPA =	7.02E-08

TABLE A-5
HIGH HEAT SUPERNATE - F-AREA, TABLE 4-7 OF SAR

RADIONUCLIDE	HALF-LIFE	ACTIVITY Ci/gal	GAMMA PHOTONS No	GAMMA PHOTONS #/100	GAMMA PHOTONS #/sec/cc	GAMMA PHOTONS Energy,Mev	μ/p cm^2/gm	Xtion mb/e	DPA
Ce-144/Pr-144	284.3d	0.75	4	1.48	1.09E+05	0.696	0.085	0.10	5.23E-12
		0.75	9	0.30	2.20E+04	1.489	0.057	0.44	6.95E-12
		0.75	11	0.77	5.65E+04	2.185	0.047	11.50	5.66E-10
Zr-95	64d	0.76	2	43.70	3.25E+06	0.724	0.082	0.10	1.62E-10
		0.76	3	55.30	4.11E+06	0.756	0.080	0.10	2.10E-10
Y-91	58.5d	0.0503	1	0.30	1.48E+03	1.205	0.062	0.63	6.14E-13
Nb-95	35d	1.7	3	99.80	1.66E+07	0.765	0.080	0.10	8.49E-10
Ru-106/Rh-106	368d	0.21	7	20.60	4.23E+05	0.512	0.096	0.10	1.80E-11
		0.21	12	0.70	1.44E+04	0.616	0.088	0.10	6.69E-13
		0.21	13	9.80	2.01E+05	0.622	0.088	0.10	9.36E-12
		0.21	21	0.40	8.21E+03	0.874	0.075	0.11	4.93E-13
		0.21	25	1.70	3.49E+04	1.050	0.069	0.30	6.21E-12
		0.21	29	0.40	8.21E+03	1.128	0.066	0.43	2.19E-12
		0.21	50	0.16	3.28E+03	1.562	0.057	3.00	7.12E-12
Cs-137/Ba-137	30.17y	6.7	1	90.00	5.89E+07	0.661	0.086	0.10	2.81E-09
								TOTAL DPA =	4.65E-09

TABLE A-6
HIGH HEAT SUPERNATE - H-AREA, TABLE 4-7

RADIONUCLIDE	HALF-LIFE	ACTIVITY Ci/gal	GAMMA PHOTONS No	#/100	#/sec/cc	Energy,Mev	µ/p cm^2/gm	Xtion mb/e	DPA
Ce-144/Pr-144	284.3d	3.8	4	1.48	5.50E+05	0.696	0.085	0.10	2.65E-11
		3.8	9	0.30	1.11E+05	1.489	0.057	0.44	3.52E-11
		3.8	11	0.77	2.86E+05	2.185	0.047	11.50	2.87E-09
Zr-95	64d	1.2	2	43.70	5.13E+06	0.724	0.082	0.10	2.56E-10
		1.2	3	55.30	6.49E+06	0.756	0.080	0.10	3.32E-10
Y-91	58.5d	0.073	1	0.30	2.14E+03	1.205	0.062	0.63	8.91E-13
Nb-95	35d	2.6	3	99.80	2.54E+07	0.765	0.080	0.10	1.30E-09
Ru-106/Rh-106	368d	1.1	7	20.60	2.22E+06	0.512	0.096	0.10	9.45E-11
		1.1	12	0.70	7.53E+04	0.616	0.088	0.10	3.50E-12
		1.1	13	9.80	1.05E+06	0.622	0.088	0.10	4.90E-11
		1.1	21	0.40	4.30E+04	0.874	0.075	0.11	2.58E-12
		1.1	25	1.70	1.83E+05	1.050	0.069	0.30	3.25E-11
		1.1	29	0.40	4.30E+04	1.128	0.066	0.43	1.15E-11
		1.1	50	0.16	1.72E+04	1.562	0.057	3.00	3.73E-11
Cs-137/Ba-137	30.17y	9.6	1	90.00	8.45E+07	0.661	0.086	0.10	4.02E-09
								TOTAL DPA =	9.07E-09

TABLE A-7

EVAPORATOR COMCENTRATE - F-AREA, TABLE 4-8 OF SAR

RADIONUCLIDE	HALF-LIFE	ACTIVITY Ci/gal	GAMMA PHOTONS No	GAMMA PHOTONS #/100	GAMMA PHOTONS #/sec/cc	GAMMA PHOTONS Energy,Mev	μ/p cm^2/gm	Xtion mb/e	DPA
Ce-144/Pr-144	284.3d	1.70E-04	4	1.48	2.46E+01	0.696	0.085	0.10	1.18E-15
		1.70E-04	9	0.30	4.99E+00	1.489	0.057	0.44	1.58E-15
		1.70E-04	11	0.77	1.28E+01	2.185	0.047	11.50	1.28E-13
Zr-95	64d	0.00E+00	2	43.70	0.00E+00	0.724	0.082	0.10	0.00E+00
		0.00E+00	3	55.30	0.00E+00	0.756	0.080	0.10	0.00E+00
Y-91	58.5d	0.00E+00	1	0.30	0.00E+00	1.205	0.062	0.63	0.00E+00
Nb-95	35d	0.00E+00	3	99.80	0.00E+00	0.765	0.080	0.10	0.00E+00
Ru-106/Rh-106	368d	2.90E-04	7	20.60	5.84E+02	0.512	0.096	0.10	2.49E-14
		2.90E-04	12	0.70	1.98E+01	0.616	0.088	0.10	9.23E-16
		2.90E-04	13	9.80	2.78E+02	0.622	0.088	0.10	1.29E-14
		2.90E-04	21	0.40	1.13E+01	0.874	0.075	0.11	6.81E-16
		2.90E-04	25	1.70	4.82E+01	1.050	0.069	0.30	8.58E-15
		2.90E-04	29	0.40	1.13E+01	1.128	0.066	0.43	3.03E-15
		2.90E-04	50	0.16	4.54E+00	1.562	0.057	3.00	9.83E-15
Cs-137/Ba-137	30.17y	8.90E+00	1	90.00	7.83E+07	0.661	0.086	0.10	3.73E-09
								TOTAL DPA =	3.73E-09

TABLE A-8
EVAPORATOR CONCENTRATE - H-AREA, TABLE 4-8 OF SAR

		ACTIVITY	GAMMA PHOTONS				μ/p	Xtion	
RADIONUCLIDE	HALF-LIFE	Ci/gal	No	#/100	#/sec/cc	Energy,Mev	cm^2/gm	mb/e	DPA
Ce-144/Pr-144	284.3d	6.30E-03	4	1.48	9.11E+02	0.696	0.085	0.10	4.39E-14
		6.30E-03	9	0.30	1.85E+02	1.489	0.057	0.44	5.84E-14
		6.30E-03	11	0.77	4.74E+02	2.185	0.047	11.50	4.75E-12
Zr-95	64d	0.00E+00	2	43.70	0.00E+00	0.724	0.082	0.10	0.00E+00
		0.00E+00	3	55.30	0.00E+00	0.756	0.080	0.10	0.00E+00
Y-91	58.5d	0.00E+00	1	0.30	0.00E+00	1.205	0.062	0.63	0.00E+00
Nb-95	35d	0.00E+00	3	99.80	0.00E+00	0.765	0.080	0.10	0.00E+00
Ru-106/Rh-106	368d	5.40E-03	7	20.60	1.09E+04	0.512	0.096	0.10	4.64E-13
		5.40E-03	12	0.70	3.70E+02	0.616	0.088	0.10	1.72E-14
		5.40E-03	13	9.80	5.17E+03	0.622	0.088	0.10	2.41E-13
		5.40E-03	21	0.40	2.11E+02	0.874	0.075	0.11	1.27E-14
		5.40E-03	25	1.70	8.97E+02	1.050	0.069	0.30	1.60E-13
		5.40E-03	29	0.40	2.11E+02	1.128	0.066	0.43	5.63E-14
		5.40E-03	50	0.16	8.45E+01	1.562	0.057	3.00	1.83E-13
Cs-137/Ba-137	30.17y	9.10E+00	1	90.00	8.01E+07	0.661	0.086	0.10	3.81E-09
								TOTAL DPA =	3.82E-09

TABLE A-9
SLUDGE FEED TO DWPF

RADIONUCLIDE	HALF-LIFE	ACTIVITY Ci/gal	GAMMA PHOTONS No	#/100	#/sec/cc	Energy Mev	μ/ρ cm^2/gm	Xtion mb/e	DPA
Ce-144/Pr-144	284.3d	8.70E+00	4	1.48	1.26E+06	0.696	0.085	0.10	6.06E-11
		8.70E+00	9	0.30	2.55E+05	1.489	0.057	0.44	8.07E-11
		8.70E+00	11	0.77	6.55E+05	2.185	0.047	11.50	6.56E-09
Zr-95	64d	8.90E-06	2	43.70	3.80E+01	0.724	0.082	0.10	1.90E-15
		8.90E-06	3	55.30	4.81E+01	0.756	0.080	0.10	2.46E-15
Y-91	58.5d	6.60E-07	1	0.30	1.94E-02	1.205	0.062	0.63	8.05E-18
Nb-95	35d	1.90E-05	3	99.80	1.85E+02	0.765	0.080	0.10	9.49E-15
Ru-106/Rh-106	368d	2.00E+00	7	20.60	4.03E+06	0.512	0.096	0.10	1.72E-10
		2.00E+00	12	0.70	1.37E+05	0.616	0.088	0.10	6.37E-12
		2.00E+00	13	9.80	1.92E+06	0.622	0.088	0.10	8.92E-11
		2.00E+00	21	0.40	7.82E+04	0.874	0.075	0.11	4.70E-12
		2.00E+00	25	1.70	3.32E+05	1.05	0.069	0.30	5.92E-11
		2.00E+00	29	0.40	7.82E+04	1.128	0.066	0.43	2.09E-11
		2.00E+00	50	0.16	3.13E+04	1.562	0.057	3.00	6.78E-11
Cs-137/Ba-137	30.17y	1.30E+00	1	90.00	1.14E+07	0.661	0.086	0.10	5.45E-10
								TOTAL DPA =	7.67E-09

TABLE A-10
FRESH CANYON WASTE - F-AREA, TABLE 4-10 OF SAR

RADIONUCLIDE	HALF-LIFE	ACTIVITY Ci/gal	GAMMA PHOTONS No	#/100	#/sec/cc	Energy,Mev	µ/p cm^2/gm	Xtion mb/e	DPA
Ce-144/Pr-144	284.3d	170	4	1.48	2.46E+07	0.696	0.085	0.10	1.18E-09
		170	9	0.30	4.99E+06	1.489	0.057	0.44	1.58E-09
		170	11	0.77	1.28E+07	2.185	0.047	11.50	1.28E-07
Zr-95	64d	140	2	43.70	5.98E+08	0.724	0.082	0.10	2.99E-08
		140	3	55.30	7.57E+08	0.756	0.080	0.10	3.87E-08
Y-91	58.5d	100	1	0.30	2.93E+06	1.205	0.062	0.63	1.22E-09
Nb-95	35d	250	3	99.80	2.44E+09	0.765	0.080	0.10	1.25E-07
Ru-106/Rh-106	368d	9	7	20.60	1.81E+07	0.512	0.096	0.10	7.73E-10
		9	12	0.70	6.16E+05	0.616	0.088	0.10	2.87E-11
		9	13	9.80	8.62E+06	0.622	0.088	0.10	4.01E-10
		9	21	0.40	3.52E+05	0.874	0.075	0.11	2.11E-11
		9	25	1.70	1.50E+06	1.050	0.069	0.30	2.66E-10
		9	29	0.40	3.52E+05	1.128	0.066	0.43	9.39E-11
		9	50	0.16	1.41E+05	1.562	0.057	3.00	3.05E-10
Cs-137/Ba-137	30.17y	7	1	90.00	6.16E+07	0.661	0.086	0.10	2.93E-09
								TOTAL DPA =	3.30E-07

TABLE A-11
FRESH CANYON WASTE - H-AREA, TABLE 4-10 OF SAR

RADIONUCLIDE	HALF-LIFE	ACTIVITY Ci/gal	GAMMA PHOTONS No	GAMMA PHOTONS #/100	GAMMA PHOTONS #/sec/cc	GAMMA PHOTONS Energy Mev	μ/p cm^2/gm	Xtion mb/e	DPA
Ce-144/Pr-144	284.3d	110	4	1.48	1.59E+07	0.696	0.085	0.10	7.67E-10
		110	9	0.30	3.23E+06	1.489	0.057	0.44	1.02E-09
		110	11	0.77	8.28E+06	2.185	0.047	11.50	8.30E-08
Zr-95	64d	57	2	43.70	2.43E+08	0.724	0.082	0.10	1.22E-08
		57	3	55.30	3.08E+08	0.756	0.080	0.10	1.58E-08
Y-91	58.5d	40	1	0.30	1.17E+06	1.205	0.062	0.63	4.88E-10
Nb-95	35d	110	3	99.80	1.07E+09	0.765	0.080	0.10	5.49E-08
Ru-106/Rh-106	368d	6	7	20.60	1.21E+07	0.512	0.096	0.10	5.15E-10
		6	12	0.70	4.11E+05	0.616	0.088	0.10	1.91E-11
		6	13	9.80	5.75E+06	0.622	0.088	0.10	2.67E-10
		6	21	0.40	2.35E+05	0.874	0.075	0.11	1.41E-11
		6	25	1.70	9.97E+05	1.050	0.069	0.30	1.78E-10
		6	29	0.40	2.35E+05	1.128	0.066	0.43	6.26E-11
		6	50	0.16	9.38E+04	1.562	0.057	3.00	2.03E-10
Cs-137/Ba-137	30.17y	6	1	90.00	5.28E+07	0.661	0.086	0.10	2.51E-09
								TOTAL DPA =	1.72E-07

APPENDIX B

ESTIMATED DISPLACEMENT DAMAGE FROM SPONTANEOUS NEUTRON EMISSIONS

NOTES FOR APPENDIX B

Col 1: Data from DPSTSA-200-10, SUP-18 and DP-1476, Table 3.
Col 2: Highest activities listed in Tables 4-5 through 4-10 of DPSTA-200-10, SUP-18
Col 3: Data from DOE/TIC-11026
Col 4: Neutron yield per fission
Displacement damage = (Ci/gal)/(3785cc/gal)*3.7E10d/Ci*(%Spont Fission/100)/2
*(neutrons/fission)/(removal cross section=0.12/0.103)
*(100 years)(3.15E7 sec/year)(500 barns)(1E-24 cm^2)
Assume all neutrons with 1 MeV energy and 500 barn displacement cross section
* Pu-242 activity taken from DP-1476, Table 3.

TABLE B-1
COMBINED TANKS - F AREA, TABLE 4-5 OF SAR

Radionuclide	Activity Ci/gal	% Spontaneous Fission	Number Neutrons	Displacement Damage, DPA
Uranium-235	6.10E-07	4.20E-08	2.3	5.28E-21
Uranium-238	2.90E-05	5.40E-05	2.3	3.23E-16
Plutonium-238	2.30E-03	1.84E-07	2.3	8.73E-17
Plutonium-239	7.70E-03	4.40E-10	2.2	6.68E-19
Plutonium-240	2.10E-03	4.95E-06	2.2	2.05E-15
Plutonium-242*	6.00E-08	5.50E-04	2.2	6.51E-18
Americium-241	1.20E-03	3.77E-10	2.4	9.74E-20
Curium-244	9.40E-01	1.35E-04	2.8	3.19E-11
			TOTAL DPA =	3.19E-11

TABLE B-2
COMBINED TANKS - H AREA, TABLE 4-5 OF SAR

Radionuclide	Activity Ci/gal	% Spontaneous Fission	Number Neutrons	Displacement Damage, DPA
Uranium-235	3.70E-07	4.20E-08	2.3	3.21E-21
Uranium-238	3.90E-06	5.40E-05	2.3	4.34E-17
Plutonium-238	4.00E-01	1.84E-07	2.3	1.52E-14
Plutonium-239	2.90E-03	4.40E-10	2.2	2.52E-19
Plutonium-240	0.00E+00	4.95E-06	2.2	0.00E+00
Plutonium-242*	6.00E-08	5.50E-04	2.2	6.51E-18
Americium-241	1.20E-03	3.77E-10	2.4	9.74E-20
Curium-244	9.60E-04	1.35E-04	2.8	3.25E-14
			TOTAL DPA =	1.52E-14

TABLE B-3
HIGH HEAT WASTE RECEIVER TANKS - F AREA, TABLE 4-6 OF SAR

Radionuclide	Activity Ci/gal	% Spontaneous Fission	Number Neutrons	Displacement Damage, DPA
Uranium-235	8.00E-08	4.20E-08	2.3	6.93E-22
Uranium-238	4.80E-06	5.40E-05	2.3	5.35E-17
Plutonium-238	3.10E-05	1.84E-07	2.3	1.18E-18
Plutonium-239	6.00E-03	4.40E-10	2.2	5.21E-19
Plutonium-240	1.40E-04	4.95E-06	2.2	1.37E-16
Plutonium-242*	6.00E-08	5.50E-04	2.2	6.51E-18
Americium-241	6.50E-04	3.77E-10	2.4	5.27E-20
Curium-244	2.10E-05	1.35E-04	2.8	7.12E-16
			TOTAL DPA =	9.10E-16

TABLE B-4
HIGH HEAT WASTE RECEIVER TANKS - H AREA, TABLE 4-6 OF SAR

Radionuclide	Activity Ci/gal	% Spontaneous Fission	Number Neutrons	Displacement Damage, DPA
Uranium-235	3.50E-08	4.20E-08	2.3	3.03E-22
Uranium-238	2.90E-08	5.40E-05	2.3	3.23E-19
Plutonium-238	4.70E-01	1.84E-07	2.3	1.78E-14
Plutonium-239	3.30E-03	4.40E-10	2.2	2.86E-19
Plutonium-240	0.00E+00	4.95E-06	2.2	0.00E+00
Plutonium-242*	6.00E-08	5.50E-04	2.2	6.51E-18
Americium-241	6.50E-04	3.77E-10	2.4	5.27E-20
Curium-244	2.10E-05	1.35E-04	2.8	7.12E-16
			TOTAL DPA =	1.78E-14

TABLE B-5

HIGH HEAT SUPERNATE - F AREA, TABLE 4-7 OF SAR

Radionuclide	Activity Ci/gal	% Spontaneous Fission	Number Neutrons	Displacement Damage, DPA
Uranium-235	2.20E-09	4.20E-08	2.3	1.91E-23
Uranium-238	1.30E-07	5.40E-05	2.3	1.45E-18
Plutonium-238	8.10E-07	1.84E-07	2.3	3.07E-20
Plutonium-239	1.60E-05	4.40E-10	2.2	1.39E-21
Plutonium-240	3.60E-06	4.95E-06	2.2	3.52E-18
Plutonium-242*	6.00E-08	5.50E-04	2.2	6.51E-18
Americium-241	1.60E+05	3.77E-10	2.4	1.30E-11
Curium-244	5.10E-07	1.35E-04	2.8	1.73E-17
			TOTAL DPA =	1.30E-11

TABLE B-6

HIGH HEAT SUPERNATE - H AREA, TABLE 4-7 OF SAR

Radionuclide	Activity Ci/gal	% Spontaneous Fission	Number Neutrons	Displacement Damage, DPA
Uranium-235	7.30E-10	4.20E-08	2.3	6.32E-24
Uranium-238	5.90E-10	5.40E-05	2.3	6.57E-21
Plutonium-238	9.90E-03	1.84E-07	2.3	3.76E-16
Plutonium-239	6.80E-05	4.40E-10	2.2	5.90E-21
Plutonium-240	0.00E+00	4.95E-06	2.2	0.00E+00
Plutonium-242*	6.00E-08	5.50E-04	2.2	6.51E-18
Americium-241	1.60E-05	3.77E-10	2.4	1.30E-21
Curium-244	5.10E-07	1.35E-04	2.8	1.73E-17
			TOTAL DPA =	3.76E-16

TABLE B-7
EVAPORATOR CONCENTRATE - F AREA, TABLE 4-8 OF SAR

Radionuclide	Activity Ci/gal	% Spontaneous Fission	Number Neutrons	Displacement Damage, DPA
Uranium-235	4.00E-09	4.20E-08	2.3	3.47E-23
Uranium-238	1.30E-07	5.40E-05	2.3	1.45E-18
Plutonium-238	9.70E-07	1.84E-07	2.3	3.68E-20
Plutonium-239	2.00E-05	4.40E-10	2.2	1.74E-21
Plutonium-240	4.70E-06	4.95E-06	2.2	4.59E-18
Plutonium-242*	6.00E-08	5.50E-04	2.2	6.51E-18
Americium-241	2.90E-05	3.77E-10	2.4	2.35E-21
Curium-244	9.20E-07	1.35E-04	2.8	3.12E-17
			TOTAL DPA =	4.38E-17

TABLE B-8
EVAPORATOR CONCENTRATE - H AREA, TABLE 4-8 OF SAR

Radionuclide	Activity Ci/gal	% Spontaneous Fission	Number Neutrons	Displacement Damage, DPA
Uranium-235	1.30E-09	4.20E-08	2.3	1.13E-23
Uranium-238	1.10E-09	5.40E-05	2.3	1.23E-20
Plutonium-238	1.60E-02	1.84E-07	2.3	6.07E-16
Plutonium-239	1.10E-04	4.40E-10	2.2	9.55E-21
Plutonium-240	0.00E+00	4.95E-06	2.2	0.00E+00
Plutonium-242*	6.00E-08	5.50E-04	2.2	6.51E-18
Americium-241	2.90E-05	3.77E-10	2.4	2.35E-21
Curium-244	9.20E-07	1.35E-04	2.8	3.12E-17
			TOTAL DPA =	6.07E-16

TABLE B-9
SLUDGE FEED TO DWPF, TABLE 4-9 OF SAR

Radionuclide	Activity Ci/gal	% Spontaneous Fission	Number Neutrons	Displacement Damage, DPA
Uranium-235	1.40E-07	4.20E-08	2.3	1.21E-21
Uranium-238	9.10E-06	5.40E-05	2.3	1.01E-16
Plutonium-238	1.30E+00	1.84E-07	2.3	4.93E-14
Plutonium-239	1.10E-02	4.40E-10	2.2	9.55E-19
Plutonium-240	7.60E-03	4.95E-06	2.2	7.42E-15
Plutonium-242*	6.00E-08	5.50E-04	2.2	6.51E-18
Americium-241	9.50E-03	3.77E-10	2.4	7.71E-19
Curium-244	9.40E-02	1.35E-04	2.8	3.19E-12
			TOTAL DPA =	3.24E-12

TABLE B-10
FRESH CANYON WASTE - F AREA, TABLE 4-10 OF SAR

Radionuclide	Activity Ci/gal	% Spontaneous Fission	Number Neutrons	Displacement Damage, DPA
Uranium-235	7.20E-08	4.20E-08	2.3	6.24E-22
Uranium-238	3.50E-06	5.40E-05	2.3	3.90E-17
Plutonium-238	2.20E-05	1.84E-07	2.3	8.35E-19
Plutonium-239	7.60E-04	4.40E-10	2.2	6.60E-20
Plutonium-240	0.00E+00	4.95E-06	2.2	0.00E+00
Plutonium-242*	6.00E-08	5.50E-04	2.2	6.51E-18
Americium-241	3.80E-03	3.77E-10	2.4	3.08E-19
Curium-244	7.60E-03	1.35E-04	2.8	2.58E-13
			TOTAL DPA =	2.58E-13

TABLE B-11
FRESH CANYON WASTE - H AREA, TABLE 4-10 OF SAR

Radionuclide	Activity Ci/gal	% Spontaneous Fission	Number Neutrons	Displacement Damage, DPA
Uranium-235	2.60E-08	4.20E-08	2.3	2.25E-22
Uranium-238	1.80E-08	5.40E-05	2.3	2.01E-19
Plutonium-238	3.30E-01	1.84E-07	2.3	1.25E-14
Plutonium-239	7.60E-04	4.40E-10	2.2	6.60E-20
Plutonium-240	0.00E+00	4.95E-06	2.2	0.00E+00
Plutonium-242*	6.00E-08	5.50E-04	2.2	6.51E-18
Americium-241	1.10E-03	3.77E-10	2.4	8.93E-20
Curium-244	1.90E-06	1.35E-04	2.8	6.44E-17
			TOTAL DPA =	1.25E-14

END

DATE FILMED

5/05/93