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D. J. Bradley

September 1978

Prepared for the U.S. Department of Energy under Contract EY-76-C-06-1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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SUMMARY

As part of continuing Department of Energy (DOE)-sponsored studies in waste management, the Pacific Northwest Laboratory (PNL) has been conducting the High-Level Waste Immobilization Program. The purpose of this program is to develop and demonstrate technology for incorporating nuclear wastes into final waste forms. This report describes the preparation and leach testing of fully radioactive, zinc borosilicate glass, which was prepared from power reactor waste.

Leach testing using the International Atomic Energy Association (IAEA) procedure was performed in deionized water for a period of 1.75 years. Leach rates were determined for activation products, fission products, and actinides. These rates ranged from 4×10^{-5} g of glass/cm^2-day, based on cesium, to 4×10^{-9} g of glass/cm^2-day, based on cerium. Following is the ranking of the release rates of the elements, from highest to lowest:

Cs > Sr > Co > Sb > Mn > Pu > Eu > Rh > Cm > Ce.

A similar leach test, using the same glass composition but with nonradioactive elements, has recently been completed. The leach rates of Cs and Sr for the nonradioactive glass were found to be in close agreement with those in this study.

Slopes calculated from curves of cumulative fractions leached show that radioisotope release begins with a diffusion-type mechanism and changes gradually to a silicate lattice alteration mechanism. Changes in sampling frequency altered the apparent release mechanism when leachant changes were longer than one month. The leach rates were quite constant for samples taken from the top to the bottom of the glass melt, indicating a homogeneous product.

Safety assessment studies and modeling programs use leach rates to predict the amount of radioactive material released should the waste be contacted by aqueous solutions. Further tests, focusing on geologic storage conditions and using fully radioactive wastes, are planned.

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INTRODUCTION

Release rate data for radionuclides from fully radioactive waste forms are needed to evaluate the safety of nuclear waste glass. Presently, contact with water is considered the most important release path; therefore, the release properties of waste glass in water are of primary concern.

This work on high-level waste glasses was begun in 1975, before the change in Administration policy that deferred commercial nuclear reactor fuel reprocessing. However, this work has broad applications for understanding the properties of waste glass. Leach tests must be conducted on actual nuclear waste glass to validate the work on simulated waste glasses. Data is also needed on elements not included in simulated waste glasses. Only by testing the fully radioactive glasses can the full spectrum of radioisotopes be studied.

This report examines the leach testing of fully radioactive high-level waste glass developed at the Pacific Northwest Laboratory (PNL), operated by Battelle Memorial Institute for the Department of Energy (DOE). This glass, having a low sodium and a high fission product content, is called the reference composition glass.

High-level waste was generated by separating out the fission product and actinide (including about 90% of the uranium and plutonium) fractions from power reactor fuel irradiated to 55,000 MWd/MTU. The liquid waste was batch calcined, combined with a glass frit, and melted in a stainless steel crucible to prepare waste glass in approximately 100-g batches. Leach tests were conducted on this fully radioactive reference glass to:

- determine the release rates of radioactive material from the glass,
- compare leach rates to those of nonradioactive waste of the same composition, and
- recommend further studies needed in this area.

CONCLUSIONS

The release rates of 10 radioisotopes from fully radioactive waste glass, in deionized water for a period of 1.75 years, were determined. For cesium and strontium, good agreement exists between the leach rates for simulated and fully radioactive glass of the same composition.

It was shown that the release rate mechanism is dependent on time, sampling frequency, and type of element. For this study, only sampling intervals greater than one month had significant impact on the leach rate. Over the long testing period, two different release mechanisms occurred. This is consistent with previously reported observations.

Special areas needing additional work were identified, as follows:

- the effects of sample size and radiation on leaching
- the release mechanisms of radioactive material from glass
- the release rates of actinides and other elements from actual radioactive waste forms; the release rates of these elements must be measured under conditions of simulated geologic storage.

PREPARATION OF HIGH-LEVEL WASTE

In July 1975, 2764 g of spent irradiated power reactor fuel were reprocessed in the hot cell facilities at PNL. Characteristics of this fuel are listed in Table 1. After dissolution of the fuel and extraction of uranium and plutonium, the liquid waste was boiled down, and then dried at 500°C for 1 hr to yield 380 g of fine granular material, called calcine. A sample of this calcine was then analyzed for isotopic contents. An ORIGEN[1] code computer run was made, which calculated the isotopic inventory in the waste, given the fuel's irradiation and decay history, and the uranium and plutonium separation history.

Table 2 compares (on the basis of curies) the quantitites of isotopes predicted by ORIGEN and measured by the above analysis. The agreement is quite good for all isotopes except ^{106}Ru, ^{125}Sb, and ^{134}Cs. The quantities of these isotopes were all lower than predicted by ORIGEN. For ruthenium and antimony, this difference might have been due to partial losses during the fuel dissolving operation. The reason for the low ^{134}Cs value is not known, since a low value was not reflected in the ^{137}Cs value, where the agreement was excellent. Note that manganese and cobalt, neutron activation products of fuel assemblies and fuel dissolving equipment, were also seen in the calcine and the waste glass, although they were not computed in this ORIGEN run.

TABLE 1. Characteristics of Spent Power Reactor Fuel

Enrichment = 5.81 wt% U^{235}

Theoretical Density = 93.6% of theoretical

Effective Fuel Power Hours = 27,800 hr

Initial Irradiation Date = Dec. 1968

Discharge Date = Oct. 1973

Average Burnup = 54,550 MWd/MTU

Peak Burnup = 60,100 MWd/ MTU

TABLE 2. Comparison Between ORIGEN Value and Actual Abundance of Isotopes[(a)]

Isotope	Measured[(b)] Value, Ci in 380 g Calcine	ORIGEN Value, Ci in 2764 g Fuel	Ratio of Measured Ci to ORIGEN Curies
^{90}Sr	418	359	1.16
^{106}Ru	25.1	268	0.094
^{125}Sb	3.8	15.8	0.24
^{134}Cs	194	525	0.37
^{137}Cs	456	470	0.97
^{144}Ce	418	332	1.26
^{154}Eu	29.6	33.2	0.89
^{155}Eu	16.7	13.3	1.26
$^{239+240}Pu$[(c)]	0.14 (1.65 before reprocessing)	2.3	0.72
^{242}Cm	13.7	14.9	0.92
^{244}Cm	4.9	2.7	1.81

(a) Measured and ORIGEN values are decay-corrected to the same time.
(b) Takes into consideration volatilization losses measured during boil-down of liquid high-level waste.
(c) Analysis of the high-level liquid waste after fuel dissolution yielded 1.65 Ci of $^{239+240}Pu$ present. After separation, only 0.14 Ci remained. Thus, the separation loss for $^{239+240}Pu$ is 8.5%. For uranium, similar analysis shows a 9% separation loss.

A detailed listing of the composition of the spent fuel, as output from an ORIGEN run, is given in Appendix A.

A zinc borosilicate glass frit was blended with waste calcine in a 3:1 weight ratio to make the waste glass. The composition of the product glass, based on frit composition, ORIGEN, and measured values, is given in Table 3.

A cylindrical melting container of 304 L stainless steel, 3.8 cm x 12.7 cm, with a wall thickness of 0.165 cm, was used for the glass-making run. Table 4 gives the details of this glass run and Figure 1 shows the glass melting apparatus.

TABLE 3. Fully Radioactive Waste Glass Composition

Component	Weight, %
SiO_2	27.8
ZnO	21.7
B_2O_3	11.3
UO_2	10.3
Na_2O	4.1
K_2O	4.1
SrO	1.9
ZrO_2	1.6
MoO_3	1.6
MgO	1.5
CaO	1.5
BaO	1.5
Nd_2O_3	1.5
CeO_2	1.0
Cs_2O	0.8
BaO	0.5
La_2O_3	0.45
Pr_2O_3	0.44
PdO	0.43
Tc_2O_7	0.39
Sm_2O_3	0.29
NpO_2	0.22
Y_2O_3	0.19
PuO_2	0.12
RuO_2	0.09
Eu_2O_3	0.06
AmO_2	0.06
Gd_2O_3	0.05
CoO	1.1×10^{-4}
MnO	6.0×10^{-6}
	95.5

(a) The remaining material is made up of chemicals used in the fuel dissolution and uranium/plutonium separation operations.

After 3 hr at melt temperature, the furnace was shut off and the glass was allowed to cool at an average rate of 220°C/hr. The stainless steel canister was then sectioned into disks with a diamond saw. This same procedure, on subsequent glass making runs, provided samples of fully radioactive glass for metallography and electron microscopy. Information on these analyses, along with glass making volatization data, is given in BNWL-2252[2] and BNWL-2625.[3] It was assumed that the preleaching effects of the diamond saw cutting operation would be negligible for a long-term leaching test.

Figure 2 depicts the sectioning of the melting container and Table 5 gives details on the resulting sections. Figure 3 shows three of the four sections used for this leaching study. The upper-middle section, not shown because of a camera exposure problem, appears identical to the bottom-middle section. The top section appears as a donut because the top of the melt is concave due to shrinkage. All sections appear homogeneous, without large cracks or voids. Prior to the start of the leach test, all wafers were washed in acetone to remove surface particles, and dried in air.

TABLE 4. Preparation of High-Level Waste Glass

Wt Calcine + Frit	=	99.34 g
Melt Temperature	=	1050°C
Calcine Waste Loading	=	25%
Time to Reach Melt Temperature	=	110 min
Time at Melt Temperature	=	180 min
Cover Gas Flow Rate	=	0.44 ℓ/min
Date	=	12/21/75

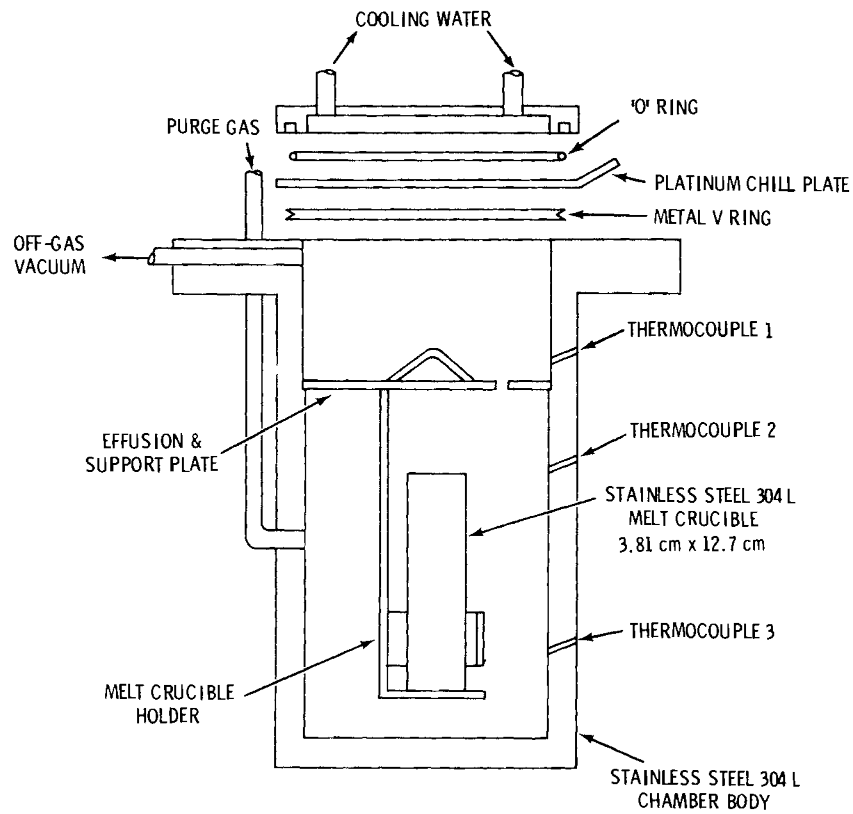


FIGURE 1. High-level Waste Glass Melting Apparatus

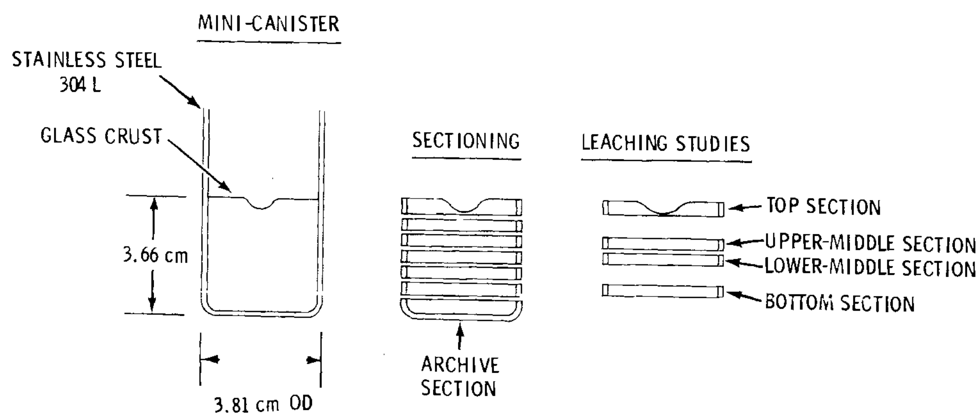
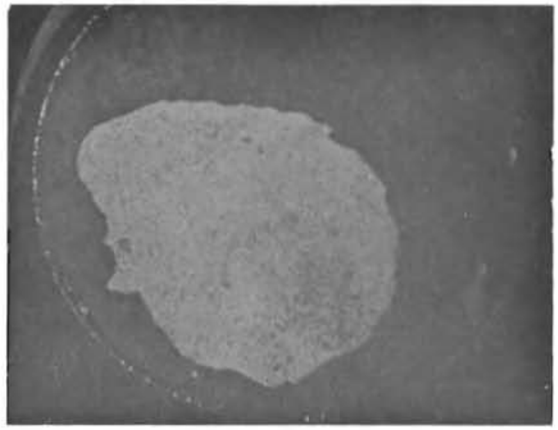


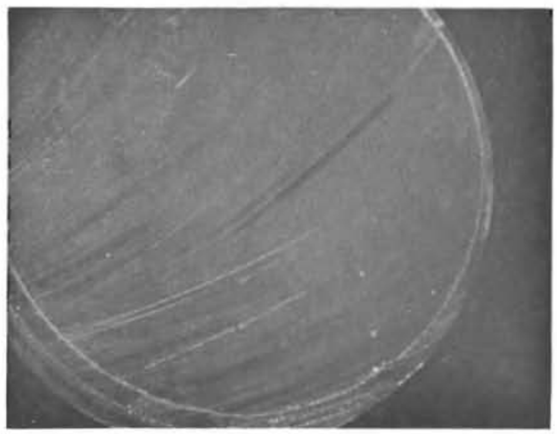
FIGURE 2. Sectioning of High-Level Waste Glass Canister

TABLE 5. Characteristics of High-Level Waste Glass Sections

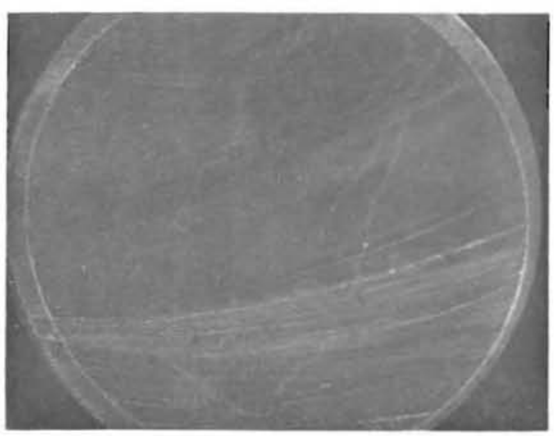
Section	Total Wt, g	Thickness, cm	Stainless Steel Wt, g	Glass Wt, g	Geometric Glass Surface Area, cm^2
Bottom	17.06	0.361	5.03	12.03	19.0
Lower-middle	12.20	0.274	3.82	8.38	19.0
Upper-middle	13.17	0.292	4.07	9.10	19.0
Top	12.64	0.541	7.54	5.10	13.5



TOP SECTION



BOTTOM-
MIDDLE SECTION



BOTTOM SECTION

FIGURE 3. Photographs of High-Level Waste Glass Sections

LEACHING OF HIGH-LEVEL WASTE

The four high-level waste glass sections began leaching in February 1976. The leaching apparatus is depicted in Figure 4. The leachate was deionized water, and its composition after passing through a hot cell piping system is given in Table 6. The ratio of leachate volume (500 mℓ) to sample surface area was 26. The leachate was changed according to the International Atomic Energy Association (IAEA)[4] procedure shown in Table 7. On leachate changing day, a 10 mℓ aliquot was removed from the container and acidified with concentrated nitric acid to a pH of 1. This acid was added to prevent adherence of isotopes on the sample container walls. Analysis of the sample consisted of:

- gamma spectroscopy
- separation of cesium and strontium[5]
- recount by gamma spectroscopy
- beta counting of separated ^{90}Sr
- alpha energy analysis.

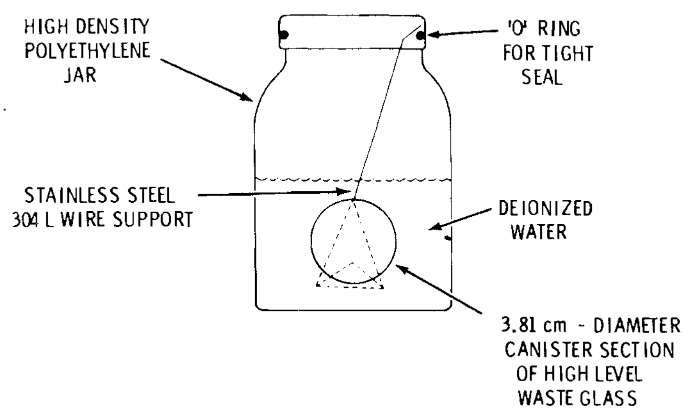


FIGURE 4. Long-Term Leaching Apparatus of IAEA Test

TABLE 6. Analysis of Hot Cell Deionized Water

- pH = 6.1
- Conductivity = 4.8 μmho/cm
- Eh = 497 mV
- Elemental Analysis - Spark Source Mass Spectrographic Analysis

Element	ppm (± factor of 3)
Na	10.0
K	2.0
Al	2.0
S	1.0
Fe	0.3
Ca	0.2
Cl	0.2
F	0.1
Eu	0.1
Be	0.05

Leach rates based on various isotopes were calculated by the equation:[6]

$$Ri = \frac{a_o}{A_o\ S\ t}$$

where Ri = incremental leach rate, g/cm^2-day

a_o = activity of isotope in leachate, sec^{-1}

A_o = specific activity of isotope in sample, sec^{-1}-$gram^{-1}$ (Based on measured activity of the high-level waste calcine; resulting glass assumed to be homogeneous. All activities a_o and A_o were decay corrected to the same time.)

S = geometric surface area of sample, cm^2

t = leaching time, days.

TABLE 7. High-Level Waste Leach Solution Sampling Schedule

Series No.	Leaching Time, Days	Cummulative Leach Time, Days
1	1 Day	1
2	1 Day	2
3	1 Day	3
4	1 Day	4
5	4 Days	8
6	6 Days	14
7	7 Days	21
8	7 Days	28
9	7 Days	35
10	7 Days	42
11	7 Days	49
12	7 Days	56
13	30 Days	86
14	30 Days	116
15	34 Days	150
16	32 Days	182
17	29 Days	211
18	28 Days	239
19	182 Days	421
20	218 Days	639

Cumulative fraction leached was calculated by the equation:[6]

$$\text{Cumulative Fraction} = \frac{\sum a_o}{A_o W}$$

where a_o = activity of isotope in leachate, sec^{-1}

A_o = specific activity of isotope in sample, sec^{-1}-$gram^{-1}$

W = sample weight, grams.

Figures 5 through 7 show plots of leach rate versus time for the top, upper-middle, and bottom sections of high-level waste glass. [Parts (a) and (b) of each figure are for different groups of isotopes.] All isotopes have a higher leach rate at the beginning of the test and rapidly level off within one week.

The leach rates seen here can be compared to those from a similar test on simulated waste glass of the same composition. The leach rates for cesium and strontium from the fully radioactive glass were in very close agreement with the leach rates of cesium and strontium from the simulated glass.[3] Leaching data on other elements from simulated glass are not available at this time. Although both tests were done on bulk glass samples, they differed in configuration. The fully radioactive samples were disks [∿0.3 cm (height) x 3.5 cm (diameter)], and the simulated glass sample was a cylinder [0.73 cm (height) x 0.98 cm (diameter)].

The size of the sample being leached has been found to have a large effect, up to a factor of 100, on the apparent leach rate.[3] In contrast, radiation is believed to have a very small effect on leach rates; this has been shown for the case of alpha radiation.[7] Further studies are needed to show that this is the case for fully radioactive glass.

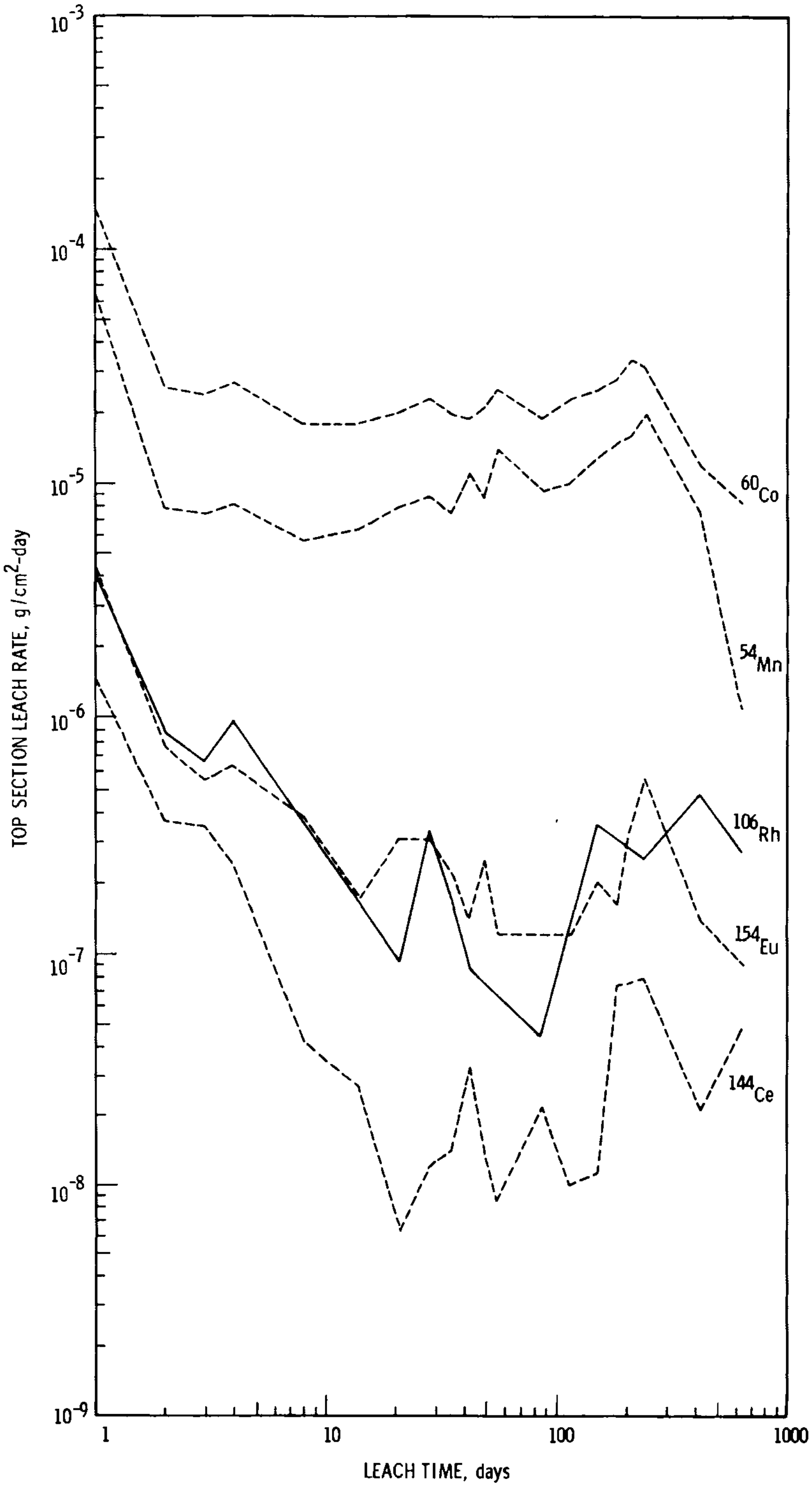


FIGURE 5a. Leach Rate as a Function of Time, Top Section

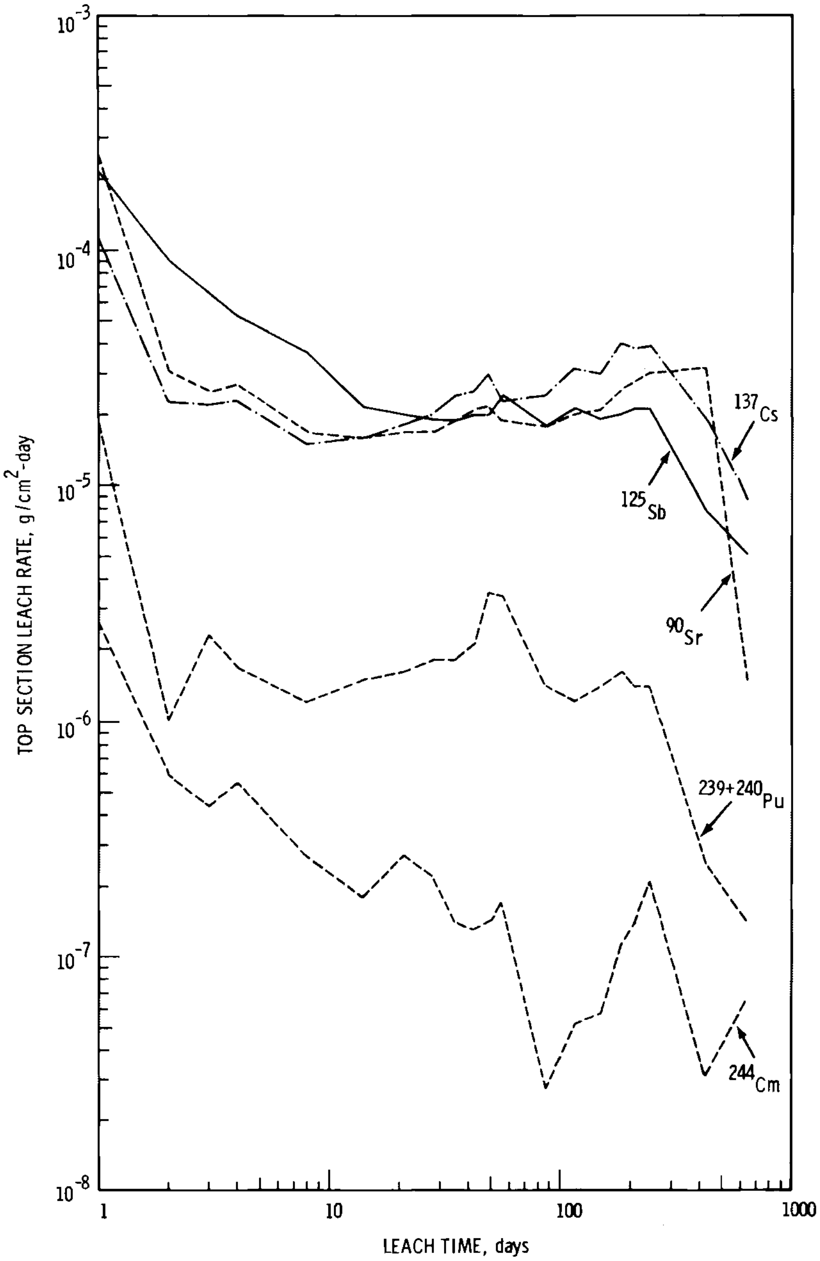


FIGURE 5b. Leach Rate as a Function of Time, Top Section

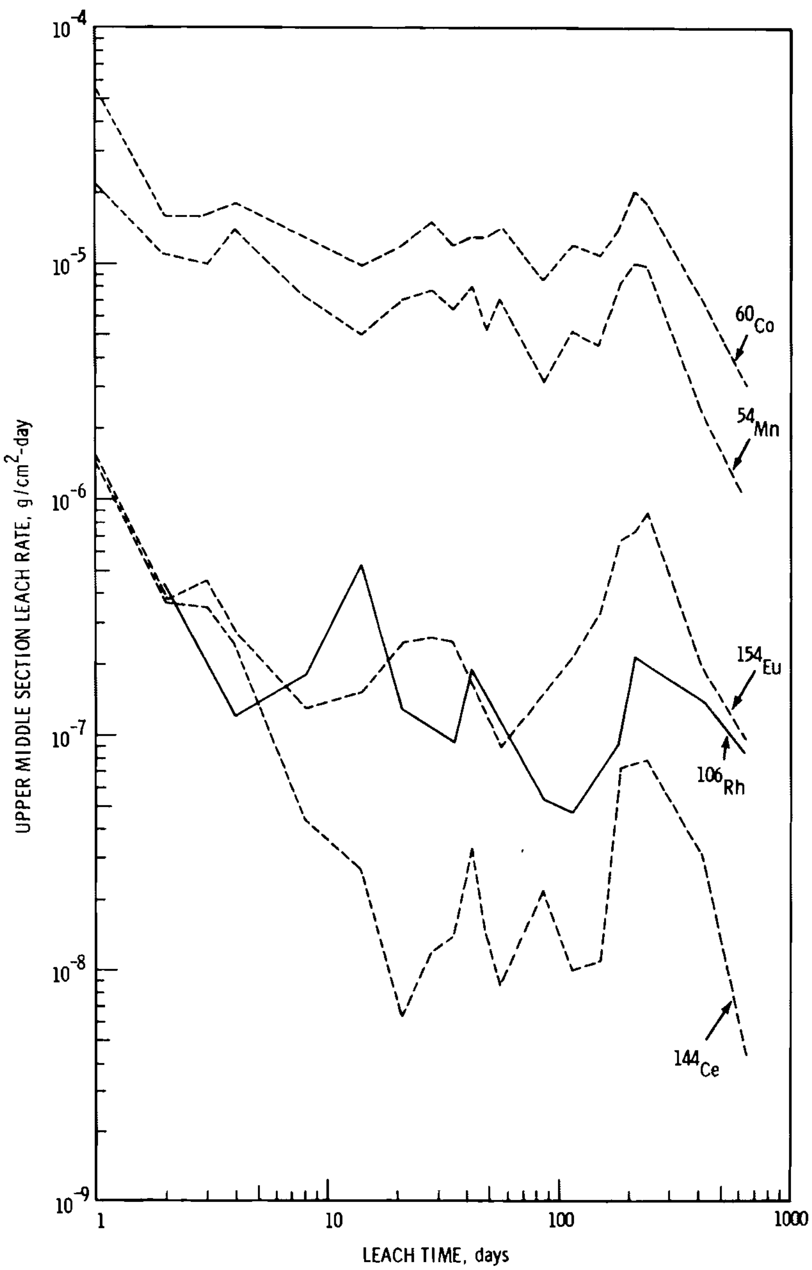


FIGURE 6a. Leach Rate as a Function of Time, Upper-Middle Section

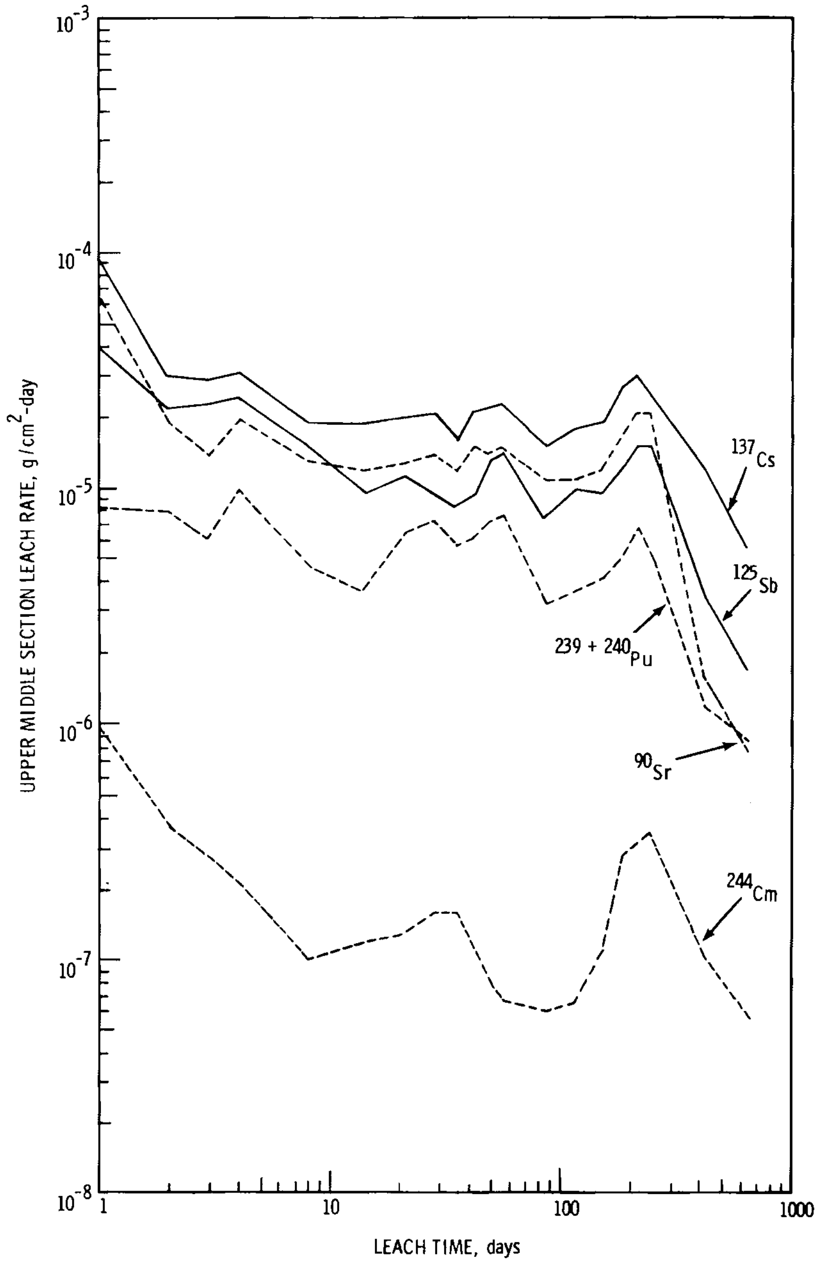


FIGURE 6b. Leach Rate as a Function of Time, Upper-Middle Section

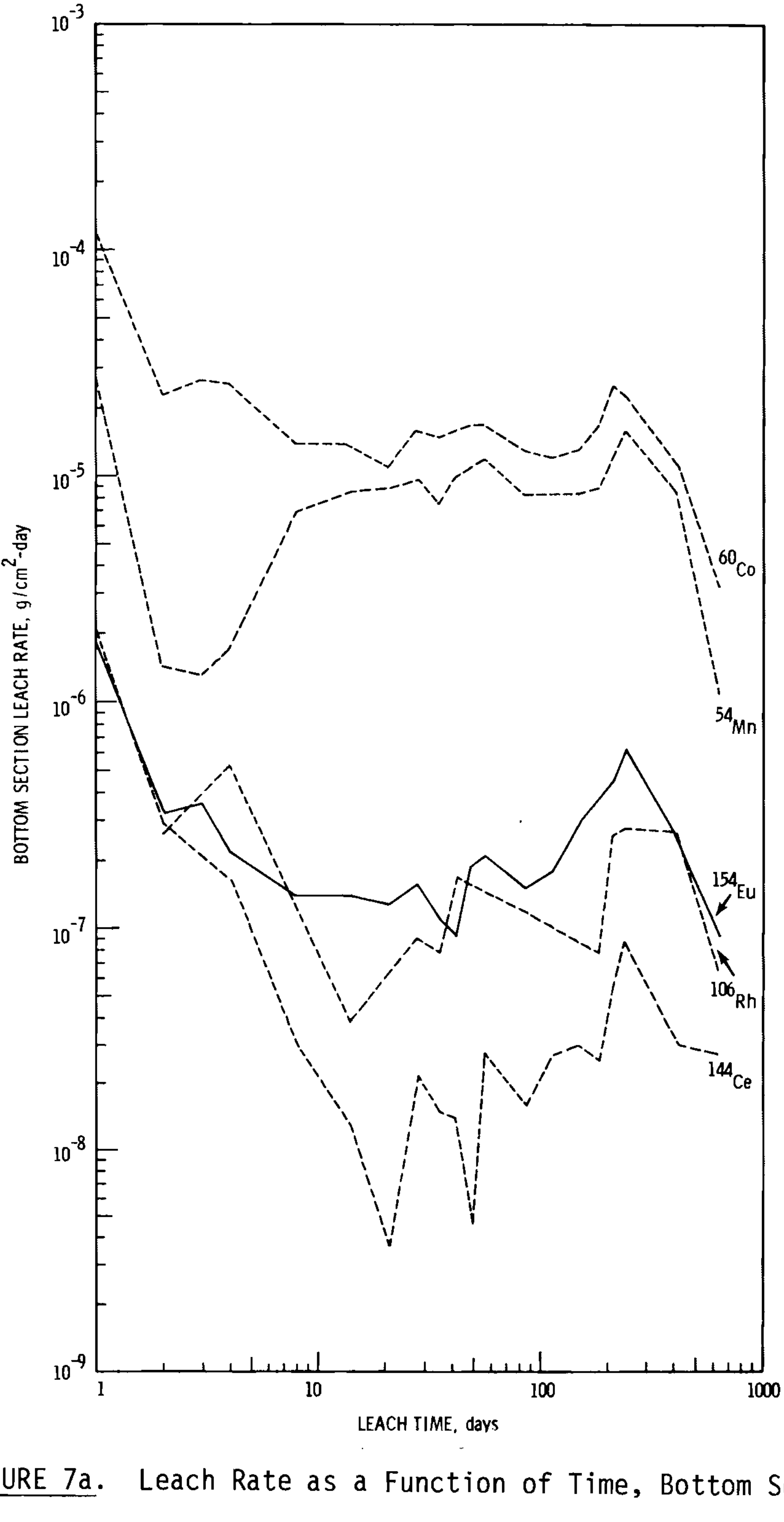


FIGURE 7a. Leach Rate as a Function of Time, Bottom Section

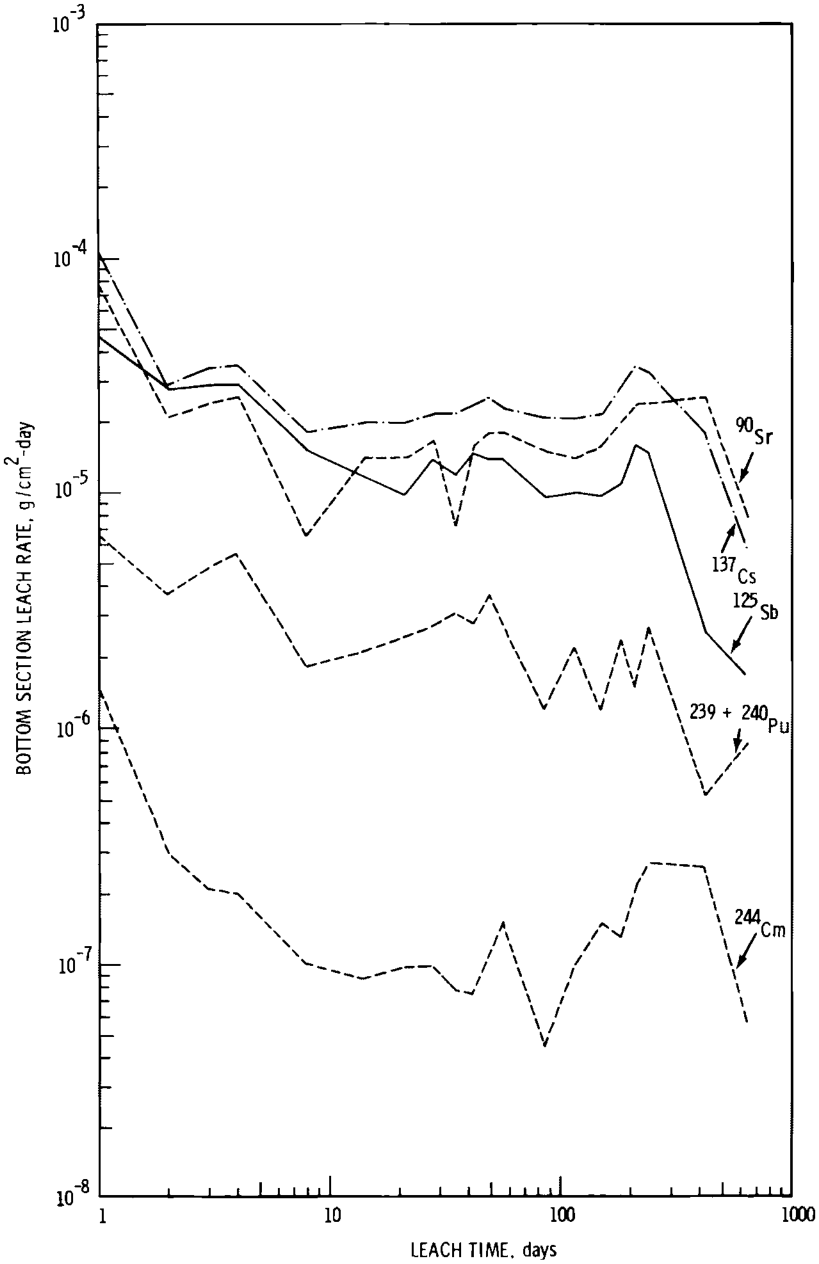


FIGURE 7b. Leach Rate as a Function of Time, Bottom Section

Figures 8 and 9 show the leach rates of ^{54}Mn, ^{137}Cs, ^{154}Eu, and $^{239+240}Pu$ for each section. From these figures, it can be seen that the leach rates vary little from top to bottom of the waste canister. Although these four isotopes represent a wide range in mass and expected volatility, they indicate that there are no significant inhomogeneities in the glass column. This conclusion is supported by recent gamma spectroscopy on the high-level waste glass sections.(3) The widest deviation is seen in $^{239+240}Pu$, which has a higher leach rate in the middle section.

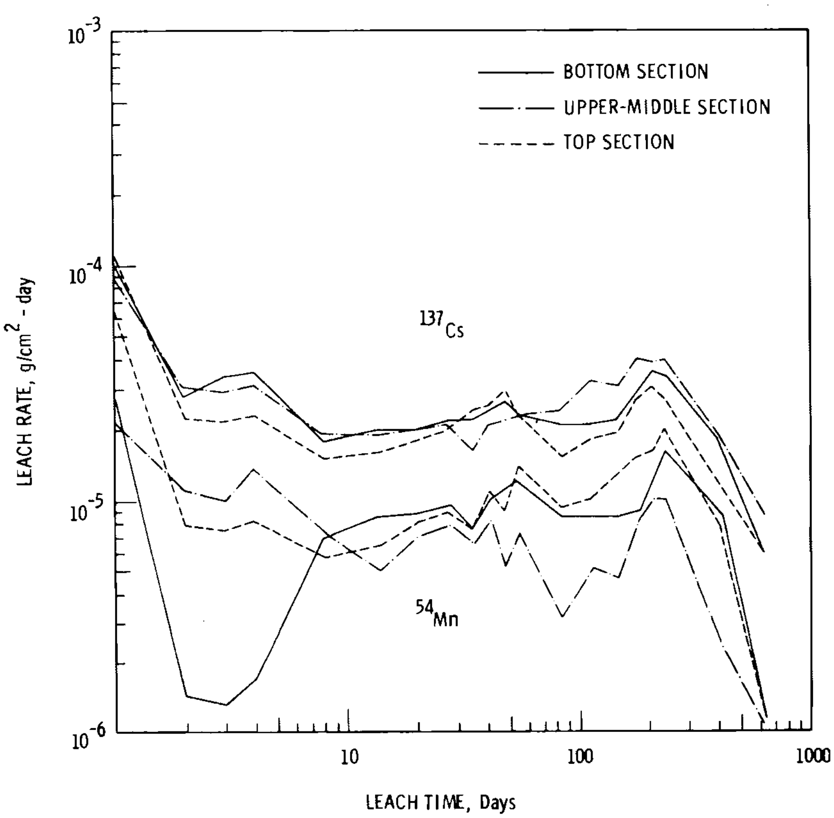


FIGURE 8. Leach Rate as a Function of Time and Section for ^{54}Mn and ^{137}Cs

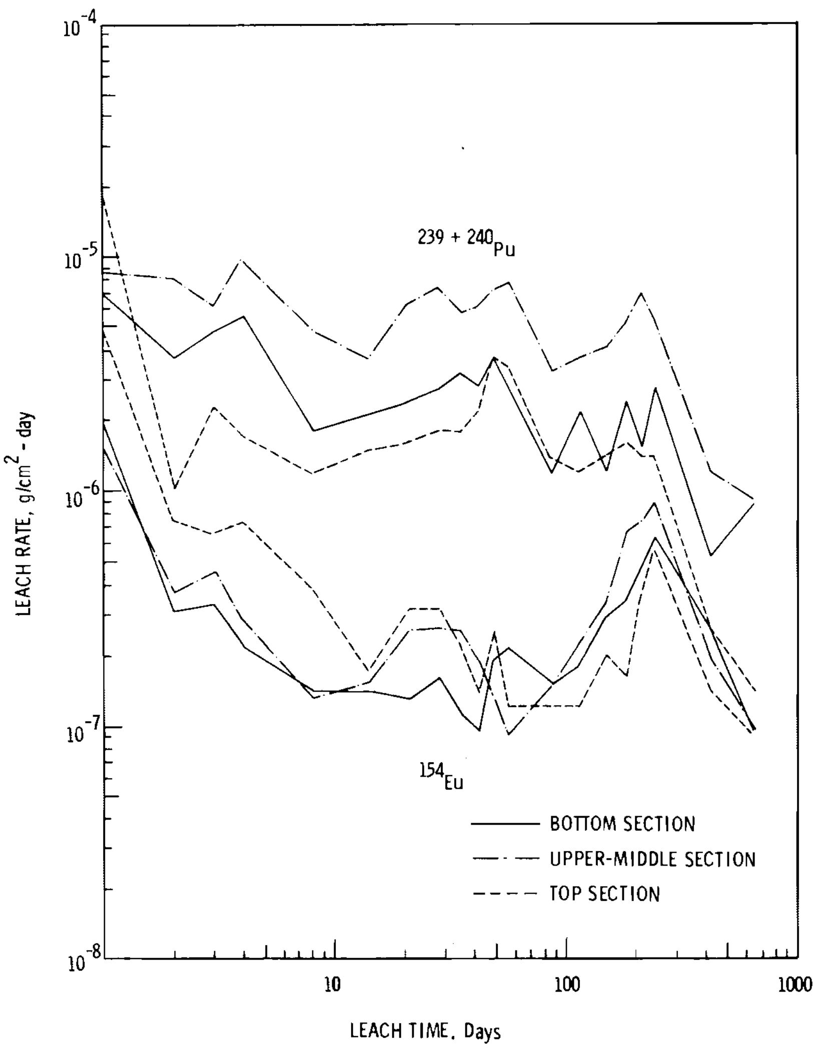


FIGURE 9. Leach Rate as a Function of Time and Section for ^{154}Eu and $^{239+240}Pu$

Curves showing the cumulative fractions leached were also calculated from the data and are shown for the top and bottom sections in Figures 10 and 11, respectively. A complete set of leaching data (including cumulative fractions leached) is given in Appendix B. From the curves of leach rate and cumulative fractions leached (and data in Appendix B) a ranking of the elements can be made with respect to their leachability. This ranking follows (on page 24) in Table 8. Because of the time and cost required for multiple actinide separations, analyses for only Pu and Cm were made.

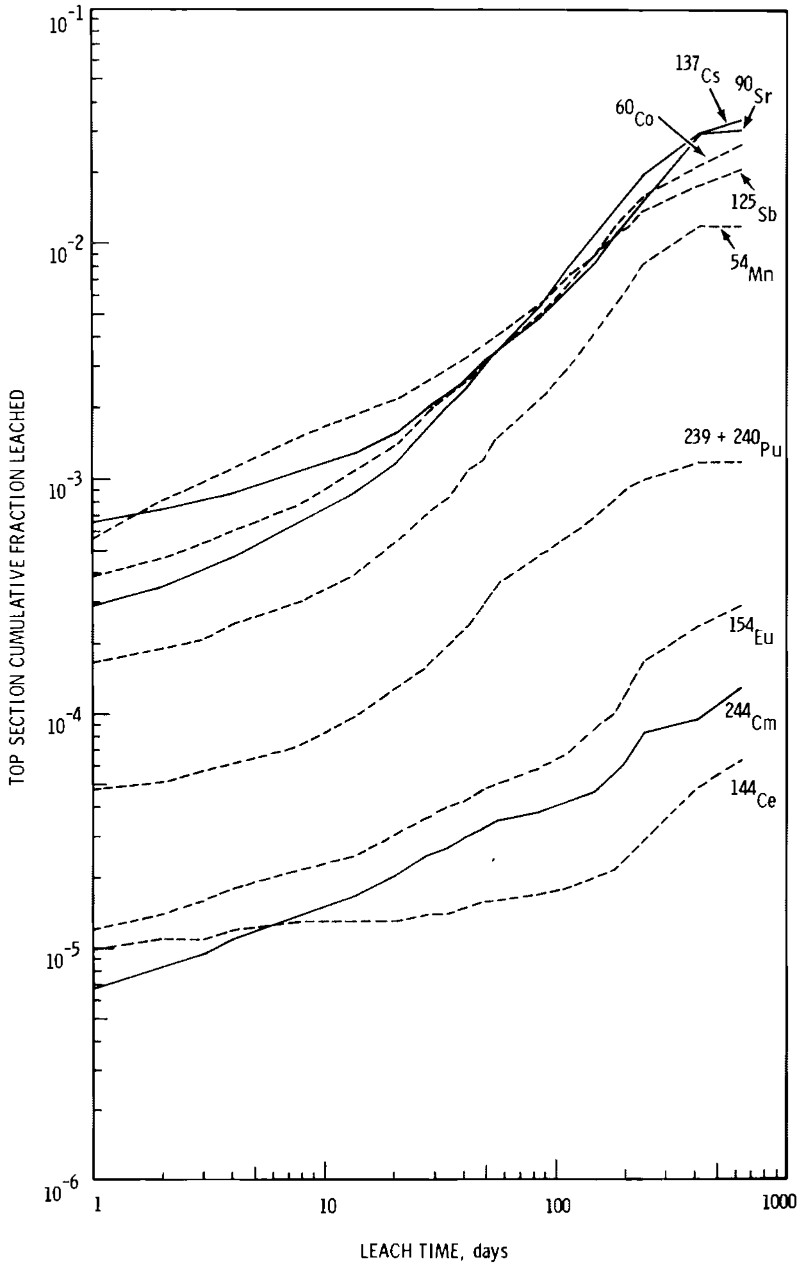


FIGURE 10. Cumulative Fractions Leached as a Function of Time, Top Section

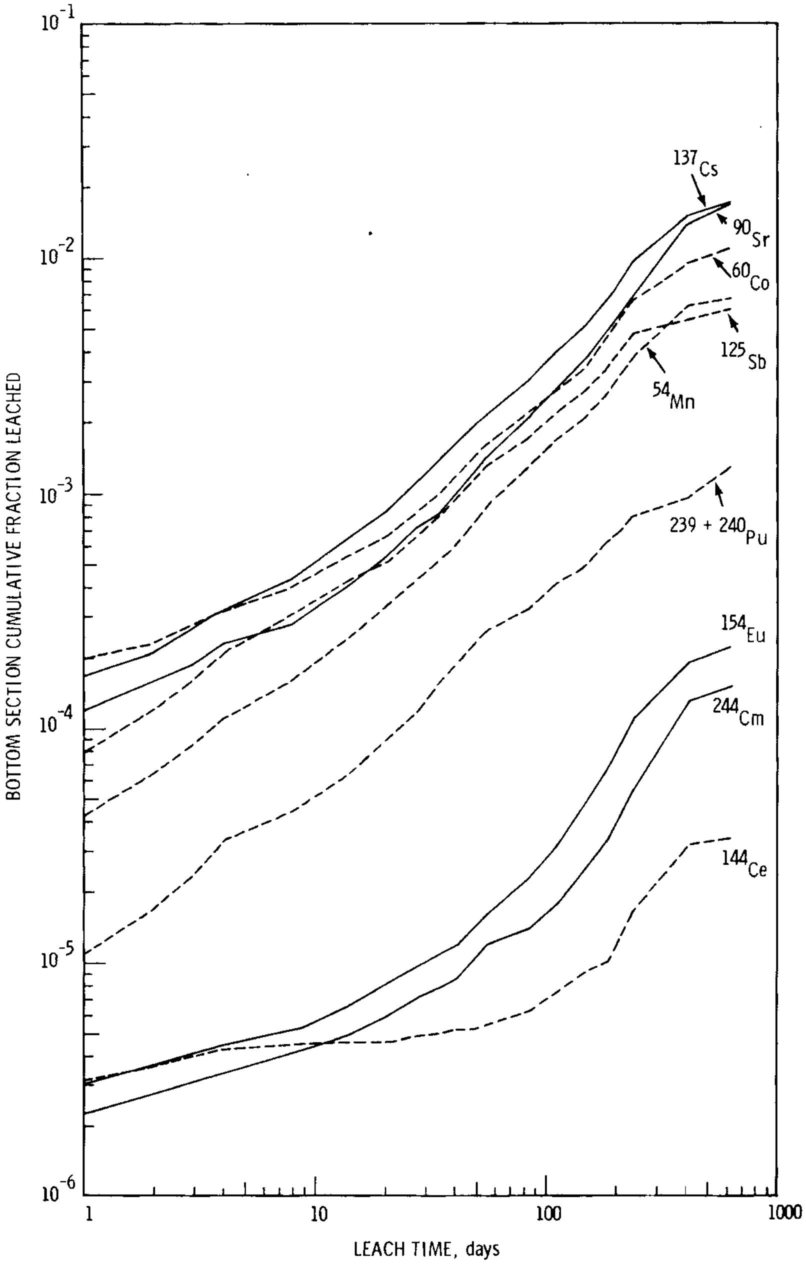


FIGURE 11. Cumulative Fractions Leached as a Function of Time, Bottom Section

TABLE 8. Element Release Fractions After 639 Days

Element	Fraction Released at 639 Days[a]	Source
Cs	2.8×10^{-2}	Fission product
Sr	2.0×10^{-2}	Fission product
Co	1.6×10^{-2}	Activation product
Sb	1.1×10^{-2}	Fission product
Mn	7.7×10^{-3}	Activation product
Pu	2.3×10^{-3}	Actinide
Eu	2.6×10^{-4}	Fission product
Cm	1.9×10^{-4}	Actinide
Ce	4.8×10^{-5}	Fission product

(a) Averaged over the four glass sections

Changes in the leach rate curves due to sampling frequency are reflected both in the graphs of leach rate (Figures 5-7) and in the graphs of cumulative fractions leached (Figures 10 and 11). The plots of cumulative fractions leached show that several mechanisms have controlled release behavior. Fractional release can be expressed using Fick's Law as:[6]

$$F_r = bT^m$$

or:

$$\log F_r = m \log T + \log b = m \log T + B$$

where F_r = Isotope fraction released
T = Time
B = Intercept
m = Slope of the line.

The slope is indicative of the type of leaching mechanism. A slope of 0.5 indicates a diffusion controlled release; a slope of 1.0 indicates a silicate lattice alteration mechanism, commonly referred to as corrosion.[6,8,9] The diffusion release mechanism is characterized by surface adsorption, ion exchange, and migration. Chemical attack or alteration of the silicate lattice is characterized by hydroxyl attack on silicon or hydrogen attack on bridging oxygens.[10]

To illustrate the effect of sampling frequency, slopes were calculated from sections of the graphs of cumulative fractions leached for the initial leaching period (1 to 10 days), periods of constant sampling frequency (10 to 56 days and 100 to 240 days), and periods following a change in sampling frequency. These are tabulated in Table 9. The change from daily to weekly sampling seems to have had very little effect on the slope and, for this reason, was included in the first 10 days of the leaching period. Extensive leaching time on a monthly frequency shows a definite shift to a lattice alteration mechanism for all elements except plutonium, which appears to remain stable at a point between the two mechanisms. This behavior is most likely to be a combination of diffusion and corrosion release as discussed by Douglas[9] and Diebold.[10] The change from weekly to monthly sampling times appears to have had little effect, except possibly for extending the time needed to approach a slope of 1. The effect of the change in sampling frequency from monthly to semi-annually is dramatic. The apparent mechanism shifted from lattice alteration to diffusion release; this shift illustrates the important role of dissolved species in lowering the leach rate. These results are consistent with the work of El-Shamy[11] and Paul.[12]

From the curves of cumulative fraction release, the general trend over the total testing time shows two different slopes for each element. All of the elements have a slope less than 0.50 at the beginning of the leach test, indicating a type of diffusion controlled release. After a period of time this slope gradually approaches a value of 1, indicating a combination of release mechanisms. This result is consistent with discussion of release mechanisms in the literature.[6,8,10] This leaching study is being continued to observe the longer term leaching behavior. Table 10 summarizes these results by element for the top and bottom sections of high-level waste glass.

TABLE 9. Slopes Calculated from Curves of Cumulative Fractions Leached

Isotope	Time = 1-10 days Bottom	Time = 1-10 days Top	Time = 10-56 days Bottom	Time = 10-56 days Top	Time = 56-100 days Bottom	Time = 56-100 days Top	Time = 100-240 days Bottom	Time = 100-240 days Top	Time = 240-639 days Bottom	Time = 240-639 days Top
^{54}Mn	0.65	0.30	0.90	0.87	0.92	0.94	1.00	1.25	0.59	0.38
^{60}Co	0.35	0.38	0.68	0.81	0.76	0.89	1.03	1.06	0.64	0.53
^{90}Sr	0.43	0.25	0.87	0.64	0.97	0.81	1.13	1.06	0.93	0.74
^{125}Sb	0.63	0.48	0.77	0.55	0.73	.78	0.97	0.84	0.24	0.44
^{137}Cs	0.48	0.43	0.84	0.92	0.89	1.11	1.06	1.19	0.60	0.56
^{144}Ce	0.15	0.11	0.11	0.13	0.43	0.16	0.94	0.56	0.71	0.80
^{154}Eu	0.26	0.28	0.61	0.45	0.91	0.43	1.50	1.03	0.71	0.56
^{239}Pu	0.66	0.24	0.94	0.84	0.64	0.66	0.84	0.72	0.51	0.19
^{244}Cm	0.29	0.35	0.65	0.48	0.51	0.25	1.38	0.81	1.02	0.47
Ave.	0.43	0.31	0.71	0.63	0.75	0.67	1.09	0.95	0.66	0.52
Ave.	0.37		0.67		0.71		1.02		0.59	

TABLE 10. Slopes of Initial and Long-Term Release Mechanisms

Elements	Initial Slope/ Time Period, Days	Long-Term Slope/ Time Period, Days
Mn	0.31/1-8	0.84/8-639
Co	0.33/1-8	0.81/8-639
Sr	0.24/1-8	0.76/8-639
Sb	0.47/1-30	0.67/30-639
Cs	0.40/1-8	0.91/8-639
Ce	0.12/1-100	0.70/100-639
Eu	0.31/1-20	0.66/20-639
Pu	0.21/1-8	0.64/8-639
Cm	0.39/1-150	0.72/150-639

The scope of this work was not intended to study and analyze leaching mechanisms beyond this point, but the data do show that the mechanism is dependent on time, sampling frequency, and type of element. Also, over the long testing period, two different mechanisms account for the release of material. More work is needed to increase our understanding of these high-level waste glass - solution interactions.

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APPENDIX A

ISOTOPIC COMPOSITION OF SPENT REACTOR FUEL AS CALCULATED BY AN ORIGEN CODE COMPUTER RUN

APPENDIX A

ISOTOPIC COMPOSITION OF SPENT REACTOR FUEL AS CALCULATED BY AN ORIGEN[2] CODE COMPUTER RUN[a]

Isotope	Grams[b]	Isotope	Grams[b]
^{74}Ge	1.36E-04[c]	^{95}Mo	1.99E+00
^{75}As	2.19E-04	^{96}Zr	2.20E+00
^{76}Ge	7.55E-04	^{96}Mo	1.53E-01
^{77}Se	2.39E-03	^{97}Mo	2.18E+00
^{78}Se	6.54E-03	^{98}Mo	2.21E+00
^{79}Se	1.53E-02	^{99}Tc	2.14E+00
^{80}Se	2.68E-02	^{100}Mo	2.51E+00
^{81}Br	4.00E-02	^{100}Ru	1.92E-01
^{82}Se	8.84E-02	^{101}Ru	1.97E+00
^{85}Rb	2.73E-01	^{102}Ru	1.96E+00
^{86}Sr	4.45E-04	^{103}Rh	8.01E-01
^{87}Rb	6.63E-01	^{104}Ru	1.29E+00
^{88}Sr	9.67E-01	^{104}Pd	7.64E-01
^{89}Y	1.30E+00	^{105}Pd	6.98E-01
^{90}Sr	1.43E+00	^{106}Ru	8.64E-02
^{90}Y	3.70E-04	^{106}Pd	8.83E-01
^{90}Zr	1.60E-01	^{107}Pd	4.95E-01
^{91}Zr	1.67E+00	^{108}Pd	3.27E-01
^{92}Zr	1.81E+00	^{109}Ag	1.14E-01
^{93}Zr	1.97E+00	^{110}Pd	7.14E-02
^{94}Zr	2.13E+00	^{110m}Ag	3.04E-04
^{95}Zr	1.59E-04	^{110}Cd	1.05E-01
^{95}Nb	1.84E-04	^{111}Cd	3.78E-02

(a) Noble gases are not included. Only isotopes present in quantities greater than 10^{-4} g are given.
(b) Based on one fuel rod of 1564 g.
(c) 1.36E-04 = 1.36×10^{-4}.

Isotope	Grams[a]	Isotope	Grams[a]
^{112}Cd	2.07E-02[b]	^{134}Ba	5.50E-01
^{113m}Cd	1.24E-04	^{135}Cs	1.04E+00
^{113}Cd	3.87E-04	^{135}Ba	2.15E-04
^{114}Cd	2.94E-02	^{135}Ba	2.15E-04
^{115}In	2.19E-03	^{136}Ba	9.14E-02
^{115}Sn	4.56E-04	^{137}Cs	3.02E+00
^{116}Cd	8.82E-03	^{137}Ba	2.96E-01
^{116}Sn	7.15E-03	^{138}Ba	3.14E+00
^{117}Sn	9.15E-03	^{139}La	3.32E+00
^{118}Sn	9.38E-03	^{140}Ce	3.40E+00
^{119}Sn	9.72E-03	^{141}Pr	3.16E+00
^{120}Sn	1.02E-02	^{142}Ce	3.10E+00
^{121}Sb	1.05E-02	^{142}Nd	7.43E-02
^{122}Sn	1.21E-02	^{143}Nd	1.95E+00
^{122}Te	9.77E-04	^{144}Ce	1.36E-01
^{123}Sb	1.27E-02	^{144}Nd	3.63E+00
^{124}Sn	1.78E-02	^{145}Nd	1.79E+00
^{124}Te	4.99E-04	^{146}Nd	1.91E+00
^{125}Sb	1.07E-02	^{147}Pm	1.35E-01
^{125m}Te	2.61E-04	^{147}Sm	2.32E-01
^{125}Te	1.46E-02	^{148}Nd	9.66E-01
^{126}Sn	4.43E-02	^{148}Sm	5.48E-01
^{126}Te	1.63E-04	^{149}Sm	1.38E-02
^{127}I	9.22E-02	^{150}Nd	4.44E-01
^{128}Te	3.18E-01	^{150}Sm	9.51E-01
^{129m}Te	1.22E-08	^{151}Sm	9.92E-02
^{129}I	5.64E-01	^{151}Eu	1.47E-03
^{130}Te	1.08E+00	^{152}Sm	2.08E-01
^{133}Cs	2.42E+00	^{152}Eu	1.50E-04
^{134}Cs	3.11E-01	^{152}Gd	5.50E-04

(a) Based on one fuel rod of 1564 g.
(b) 2.07E-02 = 2.07×10^{-2}

Isotope	Grams[a]
^{153}Eu	3.27E-01[b]
^{154}Sm	8.59E-02
^{154}Eu	1.31E-01
^{154}Gd	1.73E-02
^{155}Eu	8.46E-03
^{155}Gd	7.80E-03
^{156}Gd	2.99E-01
^{158}Gd	3.18E-02
^{159}Tb	3.67E-03
^{160}Gd	2.02E-03
^{160}Dy	1.04E-03
^{161}Dy	5.03E-04
^{162}Dy	3.88E-04
^{163}Dy	4.60E-04
^{164}Dy	1.61E-04
^{165}Ho	2.82E-04
Subtotal = 7.15×10^{1} g	

Isotope	Grams[a]
^{234}U	1.71E-03
^{235}U	7.94E-02
^{236}U	6.52E-02
^{238}U	7.13E+00
^{237}Np	1.63E+00
^{238}Pu	3.45E-03
^{239}Pu	4.22E-02
^{240}Pu	1.82E-02
^{241}Pu	8.92E-03
^{242}Pu	4.03E-03
^{241}Am	2.03E-01
^{242m}Am	2.37E-03
^{243}Am	2.72E-01
^{242}Cm	1.96E-03
^{243}Cm	2.34E-04
^{244}Cm	1.07E-01
^{245}Cm	8.75E-03
^{246}Cm	1.29E-03
Subtotal = 9.59×10^{0} g	
Total = 8.11×10^{1} g	

(a) Based on one fuel rod of 1564 g.
(b) 3.27E-01 = 3.27×10^{-1}

APPENDIX B

LEACHING DATA

APPENDIX B

^{54}Mn-Bottom Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	2.7×10^{-5}	4.3×10^{-5}
2	1.4×10^{-6}	6.5×10^{-5}
3	1.3×10^{-6}	8.6×10^{-5}
4	1.7×10^{-6}	1.1×10^{-4}
5	6.9×10^{-6}	1.6×10^{-4}
6	8.5×10^{-6}	2.4×10^{-4}
7	8.9×10^{-6}	3.4×10^{-4}
8	9.6×10^{-6}	4.4×10^{-4}
9	7.5×10^{-6}	5.2×10^{-4}
10	1.0×10^{-5}	6.3×10^{-4}
11	1.1×10^{-5}	7.5×10^{-4}
12	1.2×10^{-5}	8.8×10^{-4}
13	8.3×10^{-6}	1.3×10^{-3}
14	8.3×10^{-6}	1.7×10^{-3}
15	8.4×10^{-6}	2.1×10^{-3}
16	9.0×10^{-6}	2.6×10^{-3}
17	1.2×10^{-5}	3.1×10^{-3}
18	1.6×10^{-5}	3.8×10^{-3}
19	8.2×10^{-6}	6.3×10^{-3}
20	1.1×10^{-6}	6.7×10^{-3}

^{54}Mn-Lower-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	3.0×10^{-5}	6.8×10^{-5}
2	1.2×10^{-5}	9.5×10^{-5}
3	7.4×10^{-6}	1.1×10^{-4}
4	1.2×10^{-5}	1.4×10^{-4}
5	5.6×10^{-6}	1.9×10^{-4}
6	7.1×10^{-6}	2.9×10^{-4}
7	5.9×10^{-6}	3.8×10^{-4}
8	6.8×10^{-6}	4.9×10^{-4}
9	5.0×10^{-6}	5.7×10^{-4}
10	7.0×10^{-6}	6.8×10^{-4}
* 11	6.2×10^{-6}	7.8×10^{-4}
12	1.6×10^{-5}	1.0×10^{-3}
13	6.4×10^{-6}	1.5×10^{-3}
14	5.2×10^{-6}	1.8×10^{-3}
15	6.8×10^{-6}	2.3×10^{-3}
16	9.7×10^{-6}	3.1×10^{-3}
17	1.2×10^{-5}	3.9×10^{-3}
18	1.5×10^{-5}	4.8×10^{-3}
19	3.0×10^{-6}	6.1×10^{-3}
20	1.7×10^{-6}	7.0×10^{-3}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{54}Mn-Upper-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	2.2×10^{-5}	4.6×10^{-5}
2	1.1×10^{-5}	6.8×10^{-5}
3	1.0×10^{-5}	8.9×10^{-5}
4	1.4×10^{-5}	1.2×10^{-4}
5	7.2×10^{-6}	1.8×10^{-4}
6	5.0×10^{-6}	2.4×10^{-4}
7	7.0×10^{-6}	3.4×10^{-4}
8	7.8×10^{-6}	4.6×10^{-4}
9	6.4×10^{-6}	5.5×10^{-4}
10	8.0×10^{-6}	6.7×10^{-4}
11	5.2×10^{-6}	7.5×10^{-4}
12	7.0×10^{-6}	8.5×10^{-4}
13	3.1×10^{-6}	1.0×10^{-3}
14	5.1×10^{-6}	1.4×10^{-3}
15	4.5×10^{-6}	1.7×10^{-3}
16	8.2×10^{-6}	2.2×10^{-3}
17	1.0×10^{-5}	2.9×10^{-3}
18	9.8×10^{-6}	3.4×10^{-3}
19	2.3×10^{-6}	4.3×10^{-3}
20	1.0×10^{-6}	5.1×10^{-3}

^{54}Mn-Top Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	6.5×10^{-5}	1.7×10^{-4}
2	7.9×10^{-6}	1.9×10^{-4}
3	7.5×10^{-6}	2.1×10^{-4}
4	8.1×10^{-6}	2.4×10^{-4}
5	5.7×10^{-6}	3.0×10^{-4}
6	6.4×10^{-6}	4.0×10^{-4}
7	8.0×10^{-6}	5.5×10^{-4}
8	8.8×10^{-6}	7.1×10^{-4}
9	7.5×10^{-6}	8.5×10^{-4}
10	1.1×10^{-5}	1.1×10^{-3}
* 11	8.8×10^{-6}	1.2×10^{-3}
12	1.4×10^{-5}	1.5×10^{-3}
13	9.3×10^{-6}	2.2×10^{-3}
14	1.0×10^{-5}	3.0×10^{-3}
15	1.3×10^{-5}	4.2×10^{-3}
16	1.5×10^{-5}	5.5×10^{-3}
17	1.6×10^{-5}	6.7×10^{-3}
18	2.0×10^{-5}	8.2×10^{-3}
19	7.6×10^{-6}	1.2×10^{-2}
20	1.1×10^{-6}	1.2×10^{-2}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{60}Co-Bottom Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	1.2×10^{-4}	2.0×10^{-4}
2	2.3×10^{-5}	2.3×10^{-4}
3	2.7×10^{-5}	2.8×10^{-4}
4	2.6×10^{-5}	3.2×10^{-4}
5	1.4×10^{-5}	4.0×10^{-4}
6	1.4×10^{-5}	5.4×10^{-4}
7	1.1×10^{-5}	6.6×10^{-4}
8	1.6×10^{-5}	8.4×10^{-4}
9	1.5×10^{-5}	1.0×10^{-3}
10	1.6×10^{-5}	1.2×10^{-3}
11	1.7×10^{-5}	1.4×10^{-3}
12	1.7×10^{-5}	1.6×10^{-3}
13	1.3×10^{-5}	2.2×10^{-3}
14	1.2×10^{-5}	2.7×10^{-3}
15	1.3×10^{-5}	3.4×10^{-3}
16	1.7×10^{-5}	4.3×10^{-3}
17	2.5×10^{-5}	5.4×10^{-3}
18	2.3×10^{-5}	6.5×10^{-3}
19	1.1×10^{-5}	9.5×10^{-3}
20	3.2×10^{-6}	1.1×10^{-2}

^{60}Co-Lower-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	7.2×10^{-5}	1.6×10^{-4}
2	1.3×10^{-5}	1.9×10^{-4}
3	1.5×10^{-5}	2.3×10^{-4}
4	1.7×10^{-5}	2.7×10^{-4}
5	1.3×10^{-5}	3.8×10^{-4}
6	1.2×10^{-5}	5.5×10^{-4}
7	9.9×10^{-6}	7.0×10^{-4}
8	1.4×10^{-5}	9.2×10^{-4}
9	1.3×10^{-5}	1.1×10^{-3}
10	9.8×10^{-6}	1.3×10^{-3}
* 11	1.2×10^{-5}	1.5×10^{-3}
12	1.9×10^{-5}	1.8×10^{-3}
13	1.2×10^{-5}	2.6×10^{-3}
14	1.2×10^{-5}	3.4×10^{-3}
15	1.1×10^{-5}	4.3×10^{-3}
16	1.6×10^{-5}	5.4×10^{-3}
17	2.2×10^{-5}	6.8×10^{-3}
18	2.2×10^{-5}	8.2×10^{-3}
19	7.9×10^{-6}	1.1×10^{-2}
20	3.7×10^{-6}	1.3×10^{-2}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{60}Co-Upper-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	5.6×10^{-5}	1.2×10^{-4}
2	1.6×10^{-5}	1.5×10^{-4}
3	1.6×10^{-5}	1.8×10^{-4}
4	1.8×10^{-5}	2.2×10^{-4}
5	1.3×10^{-5}	3.3×10^{-4}
6	9.8×10^{-6}	4.5×10^{-4}
7	1.2×10^{-5}	6.2×10^{-4}
8	1.5×10^{-5}	8.4×10^{-4}
9	1.2×10^{-5}	1.0×10^{-3}
10	1.3×10^{-5}	1.2×10^{-3}
11	1.3×10^{-5}	1.4×10^{-3}
12	1.4×10^{-5}	1.6×10^{-3}
13	8.5×10^{-6}	2.1×10^{-3}
14	1.2×10^{-5}	2.9×10^{-3}
15	1.1×10^{-5}	3.6×10^{-3}
16	1.4×10^{-5}	4.6×10^{-3}
17	2.0×10^{-5}	5.8×10^{-3}
18	1.8×10^{-5}	6.8×10^{-3}
19	6.9×10^{-6}	9.4×10^{-3}
20	3.1×10^{-6}	1.1×10^{-2}

^{60}Co-Top Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	1.5×10^{-4}	3.9×10^{-4}
2	2.6×10^{-5}	4.6×10^{-4}
3	2.4×10^{-5}	5.3×10^{-4}
4	2.7×10^{-5}	6.0×10^{-4}
5	1.8×10^{-5}	7.9×10^{-4}
6	1.8×10^{-5}	1.1×10^{-3}
7	2.0×10^{-5}	1.4×10^{-3}
8	2.3×10^{-5}	1.9×10^{-3}
9	2.0×10^{-5}	2.3×10^{-3}
10	1.9×10^{-5}	2.6×10^{-3}
* 11	2.1×10^{-5}	3.0×10^{-3}
12	2.5×10^{-5}	3.5×10^{-3}
13	1.9×10^{-5}	5.0×10^{-3}
14	2.3×10^{-5}	6.8×10^{-3}
15	2.5×10^{-5}	9.1×10^{-3}
16	2.8×10^{-5}	1.2×10^{-2}
17	3.4×10^{-5}	1.4×10^{-2}
18	3.2×10^{-5}	1.6×10^{-2}
19	1.2×10^{-5}	2.2×10^{-2}
20	8.3×10^{-6}	2.7×10^{-2}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

	^{90}Sr-Bottom Section	
Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	7.8×10^{-5}	1.2×10^{-4}
2	2.1×10^{-5}	1.6×10^{-4}
3	2.4×10^{-5}	1.9×10^{-4}
4	2.6×10^{-5}	2.3×10^{-4}
5	6.5×10^{-6}	2.8×10^{-4}
6	1.4×10^{-5}	4.0×10^{-4}
7	1.4×10^{-5}	5.5×10^{-4}
8	1.7×10^{-5}	7.4×10^{-4}
9	7.3×10^{-6}	8.2×10^{-4}
10	1.6×10^{-5}	1.0×10^{-3}
11	1.8×10^{-5}	1.2×10^{-3}
12	1.8×10^{-5}	1.4×10^{-3}
13	1.5×10^{-5}	2.1×10^{-3}
14	1.4×10^{-5}	2.8×10^{-3}
15	1.6×10^{-5}	3.6×10^{-3}
16	2.0×10^{-5}	4.6×10^{-3}
17	2.4×10^{-5}	5.7×10^{-3}
18	2.4×10^{-5}	6.8×10^{-3}
19	2.6×10^{-5}	1.4×10^{-2}
20	7.9×10^{-6}	1.7×10^{-2}

^{90}Sr-Lower-Middle Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	6.2×10^{-5}	1.4×10^{-4}
2	1.4×10^{-5}	1.7×10^{-4}
3	1.8×10^{-5}	2.1×10^{-4}
4	1.9×10^{-5}	2.6×10^{-4}
5	1.3×10^{-5}	3.8×10^{-4}
6	1.3×10^{-5}	5.5×10^{-4}
7	1.2×10^{-5}	7.4×10^{-4}
8	1.5×10^{-5}	9.8×10^{-4}
9	1.3×10^{-5}	1.2×10^{-3}
10	1.6×10^{-5}	1.4×10^{-3}
* 11	1.4×10^{-5}	1.7×10^{-3}
12	2.7×10^{-5}	2.1×10^{-3}
13	1.2×10^{-5}	2.9×10^{-3}
14	1.5×10^{-5}	3.9×10^{-3}
15	1.5×10^{-5}	5.1×10^{-3}
16	2.0×10^{-5}	6.5×10^{-3}
17	2.4×10^{-5}	8.1×10^{-3}
18	2.6×10^{-5}	9.8×10^{-3}
19	1.9×10^{-5}	1.8×10^{-2}
20	9.7×10^{-7}	1.8×10^{-2}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{90}Sr-Upper-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	6.7×10^{-5}	1.4×10^{-4}
2	1.9×10^{-5}	1.8×10^{-4}
3	1.4×10^{-5}	2.1×10^{-4}
4	2.0×10^{-5}	2.5×10^{-4}
5	1.3×10^{-5}	3.6×10^{-4}
6	1.2×10^{-5}	5.1×10^{-4}
7	1.3×10^{-5}	6.9×10^{-4}
8	1.4×10^{-5}	9.0×10^{-4}
9	1.2×10^{-5}	1.1×10^{-3}
10	1.5×10^{-5}	1.3×10^{-3}
11	1.4×10^{-5}	1.5×10^{-3}
12	1.5×10^{-5}	1.7×10^{-3}
13	1.1×10^{-5}	2.4×10^{-3}
14	1.1×10^{-5}	3.1×10^{-3}
15	1.2×10^{-5}	4.0×10^{-3}
16	1.7×10^{-5}	5.1×10^{-3}
17	2.1×10^{-5}	6.4×10^{-3}
18	2.1×10^{-5}	7.6×10^{-3}
19	1.6×10^{-5}	1.4×10^{-2}
20	7.5×10^{-7}	1.4×10^{-2}

^{90}Sr-Top Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	2.5×10^{-4}	6.6×10^{-4}
2	3.1×10^{-5}	7.5×10^{-4}
3	2.5×10^{-5}	8.1×10^{-4}
4	2.7×10^{-5}	8.8×10^{-4}
5	1.7×10^{-5}	1.1×10^{-3}
6	1.6×10^{-5}	1.3×10^{-3}
7	1.7×10^{-5}	1.6×10^{-3}
8	1.7×10^{-5}	2.0×10^{-3}
9	1.9×10^{-5}	2.3×10^{-3}
10	2.1×10^{-5}	2.7×10^{-3}
* 11	2.2×10^{-5}	3.1×10^{-3}
12	1.9×10^{-5}	3.5×10^{-3}
13	1.8×10^{-5}	4.9×10^{-3}
14	2.0×10^{-5}	6.5×10^{-3}
15	2.1×10^{-5}	8.4×10^{-3}
16	2.6×10^{-5}	1.1×10^{-2}
17	2.8×10^{-5}	1.3×10^{-2}
18	3.0×10^{-5}	1.5×10^{-2}
19	3.2×10^{-5}	3.0×10^{-2}
20	1.5×10^{-6}	3.1×10^{-2}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{106}Rh-Bottom Section[(a)]

Series #	Leach Rate[(b)] g/cm^2-day
1	
2	2.6×10^{-7}
3	
4	5.3×10^{-7}
5	
6	3.9×10^{-8}
7	
8	9.2×10^{-8}
9	7.8×10^{-8}
10	1.7×10^{-7}
11	
12	
13	1.2×10^{-7}
14	
15	
16	7.7×10^{-8}
17	2.6×10^{-7}
18	2.8×10^{-7}
19	2.7×10^{-7}
20	6.3×10^{-8}

(a) ^{106}Rh is the daughter product of ^{106}Ru.
(b) Blanks indicate that no data were obtained for that series.

^{106}Rh-Lower-Middle Section[a]

Series #	Leach Rate[b] g/cm^2-day	Cumulative Fraction Leached
1	1.6×10^{-7}	2.5×10^{-7}
2	3.6×10^{-7}	8.2×10^{-7}
* 3	2.6×10^{-7}	1.2×10^{-6}
4	2.7×10^{-7}	1.7×10^{-6}
5		
6		
7		
8	1.9×10^{-7}	
9	2.9×10^{-8}	
10	4.4×10^{-8}	
11		
12		
13	6.0×10^{-8}	
14	2.7×10^{-8}	
15	1.5×10^{-7}	
16		
17		
18		
19	2.0×10^{-7}	
20	1.3×10^{-7}	

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

(a) ^{106}Rh is the daughter product of ^{106}Ru.

(b) Blanks indicate that no data were obtained for that series.

^{106}Rh-Upper-Middle Section[a]

Series #	Leach Rate[b] g/cm^2-day
1	
2	4.4×10^{-7}
3	
4	1.2×10^{-7}
5	1.8×10^{-7}
6	5.3×10^{-7}
7	1.3×10^{-7}
8	
9	9.4×10^{-8}
10	1.9×10^{-7}
11	
12	
13	5.5×10^{-8}
14	4.7×10^{-8}
15	
16	9.2×10^{-8}
17	2.2×10^{-7}
18	
19	1.4×10^{-7}
20	8.4×10^{-8}

(a) ^{106}Rh is the daughter product of ^{106}Ru.
(b) Blanks indicate that no data were obtained for that series.

^{106}Rh-Top Section[a]

Series #	Leach Rate[b] g/cm²-day	Cumulative Fraction Leached
1	4.3×10^{-6}	1.1×10^{-5}
2	8.8×10^{-7}	1.4×10^{-5}
3	6.6×10^{-7}	1.6×10^{-5}
4	9.8×10^{-7}	1.8×10^{-5}
5		
6		
7	9.1×10^{-8}	
8	3.3×10^{-7}	
9	1.7×10^{-7}	
10	8.6×10^{-8}	
11		
12		
13	4.4×10^{-8}	
14		
15	3.6×10^{-7}	
16		
17		
18	2.5×10^{-7}	
19	4.8×10^{-7}	
20	2.7×10^{-7}	

(a) ^{106}Rh is the daughter product of ^{106}Ru.
(b) Blanks indicate that no data were obtained for that series.

^{125}Sb-Bottom Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	4.7×10^{-5}	7.4×10^{-5}
2	2.8×10^{-5}	1.2×10^{-4}
3	2.9×10^{-5}	1.6×10^{-4}
4	2.9×10^{-5}	2.1×10^{-4}
5	1.5×10^{-5}	3.0×10^{-4}
6	1.2×10^{-5}	4.2×10^{-4}
7	9.9×10^{-6}	5.2×10^{-4}
8	1.4×10^{-5}	6.7×10^{-4}
9	1.2×10^{-5}	8.0×10^{-4}
10	1.5×10^{-5}	9.7×10^{-4}
11	1.4×10^{-5}	1.1×10^{-3}
12	1.4×10^{-5}	1.3×10^{-3}
13	9.6×10^{-6}	1.7×10^{-3}
14	1.0×10^{-5}	2.2×10^{-3}
15	9.7×10^{-6}	2.7×10^{-3}
16	1.1×10^{-5}	3.3×10^{-3}
17	1.6×10^{-5}	4.0×10^{-3}
18	1.5×10^{-5}	4.7×10^{-3}
19	2.6×10^{-6}	5.5×10^{-3}
20	1.7×10^{-6}	6.0×10^{-3}

^{125}Sb-Lower-Middle Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	4.1×10^{-5}	9.3×10^{-5}
2	2.1×10^{-5}	1.4×10^{-4}
3	2.4×10^{-5}	2.0×10^{-4}
4	2.3×10^{-5}	2.5×10^{-4}
5	1.4×10^{-5}	3.7×10^{-4}
6	1.1×10^{-5}	5.3×10^{-4}
7	1.1×10^{-5}	6.9×10^{-4}
8	1.2×10^{-5}	8.8×10^{-4}
9	1.2×10^{-5}	1.1×10^{-3}
10	1.2×10^{-5}	1.3×10^{-3}
* 11	1.2×10^{-5}	1.4×10^{-3}
12	2.1×10^{-5}	1.8×10^{-3}
13	1.0×10^{-5}	2.5×10^{-3}
14	1.2×10^{-5}	3.2×10^{-3}
15	1.0×10^{-5}	4.0×10^{-3}
16	1.2×10^{-5}	4.9×10^{-3}
17	1.8×10^{-5}	6.1×10^{-3}
18	1.9×10^{-5}	7.3×10^{-3}
19	3.4×10^{-6}	8.7×10^{-3}
20	2.0×10^{-6}	9.7×10^{-3}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{125}Sb-Upper-Middle Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	4.0×10^{-3}	8.4×10^{-5}
2	2.2×10^{-3}	1.3×10^{-4}
3	2.3×10^{-3}	1.8×10^{-4}
4	2.4×10^{-3}	2.3×10^{-4}
5	1.5×10^{-3}	3.5×10^{-4}
6	9.8×10^{-6}	4.7×10^{-4}
7	1.1×10^{-5}	6.3×10^{-4}
8	1.4×10^{-5}	8.3×10^{-4}
9	8.2×10^{-6}	9.5×10^{-4}
10	9.2×10^{-6}	1.1×10^{-3}
11	1.3×10^{-5}	1.3×10^{-3}
12	1.4×10^{-5}	1.6×10^{-3}
13	7.5×10^{-6}	2.0×10^{-3}
14	1.0×10^{-5}	2.7×10^{-3}
15	9.5×10^{-6}	3.3×10^{-3}
16	1.2×10^{-5}	4.2×10^{-3}
17	1.5×10^{-5}	5.1×10^{-3}
18	1.5×10^{-5}	5.9×10^{-3}
19	3.5×10^{-6}	7.3×10^{-3}
20	1.7×10^{-6}	8.0×10^{-3}

^{125}Sb-Top Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	2.2×10^{-4}	5.7×10^{-4}
2	9.1×10^{-5}	8.1×10^{-4}
3	6.7×10^{-5}	9.9×10^{-4}
4	5.2×10^{-5}	1.1×10^{-3}
5	3.7×10^{-5}	1.5×10^{-3}
6	2.2×10^{-5}	1.9×10^{-3}
7	2.0×10^{-5}	2.2×10^{-3}
8	1.9×10^{-5}	2.6×10^{-3}
9	1.9×10^{-5}	3.0×10^{-3}
10	2.0×10^{-5}	3.3×10^{-3}
* 11	2.0×10^{-5}	3.7×10^{-3}
12	2.4×10^{-5}	4.1×10^{-3}
13	1.8×10^{-5}	5.6×10^{-3}
14	2.1×10^{-5}	7.3×10^{-3}
15	1.9×10^{-5}	9.0×10^{-3}
16	2.0×10^{-5}	1.1×10^{-2}
17	2.1×10^{-5}	1.2×10^{-2}
18	2.1×10^{-5}	1.4×10^{-2}
19	7.9×10^{-6}	1.8×10^{-2}
20	5.1×10^{-6}	2.1×10^{-2}

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* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{134}Cs-Bottom Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	1.0×10^{-4}	1.6×10^{-4}
2	2.8×10^{-5}	2.1×10^{-4}
3	3.3×10^{-5}	2.6×10^{-4}
4	3.4×10^{-5}	3.1×10^{-4}
5	1.8×10^{-5}	4.3×10^{-4}
6	2.0×10^{-5}	6.2×10^{-4}
7	1.9×10^{-5}	8.3×10^{-4}
8	2.3×10^{-5}	1.1×10^{-3}
9	2.2×10^{-5}	1.3×10^{-3}
10	2.3×10^{-5}	1.6×10^{-3}
11	2.6×10^{-5}	1.9×10^{-3}
*12	2.3×10^{-5}	2.1×10^{-3}
13	2.2×10^{-5}	3.1×10^{-3}
14	2.1×10^{-5}	4.1×10^{-3}
15	2.2×10^{-5}	5.3×10^{-3}
16	3.0×10^{-5}	6.8×10^{-3}
17	5.6×10^{-5}	9.3×10^{-3}
18	5.3×10^{-5}	1.2×10^{-2}
19	2.7×10^{-5}	1.9×10^{-2}
20	8.3×10^{-6}	2.2×10^{-2}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{134}Cs-Lower-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	8.6×10^{-5}	2.0×10^{-4}
2	2.1×10^{-5}	2.4×10^{-4}
3	2.6×10^{-5}	3.0×10^{-4}
4	2.8×10^{-5}	3.7×10^{-4}
5	1.9×10^{-5}	5.4×10^{-4}
6	1.9×10^{-5}	7.9×10^{-4}
7	1.8×10^{-5}	1.1×10^{-3}
8	2.2×10^{-5}	1.4×10^{-3}
9	2.1×10^{-5}	1.8×10^{-3}
10	2.2×10^{-5}	2.1×10^{-3}
*11	2.1×10^{-5}	2.4×10^{-3}
*12	2.1×10^{-5}	2.8×10^{-3}
13	1.9×10^{-5}	4.1×10^{-3}
14	2.4×10^{-5}	5.7×10^{-3}
15	2.4×10^{-5}	7.5×10^{-3}
16	3.3×10^{-5}	9.9×10^{-3}
17	5.8×10^{-5}	1.4×10^{-2}
18	5.8×10^{-5}	1.7×10^{-2}
19	2.2×10^{-5}	2.6×10^{-2}
20	1.0×10^{-5}	3.1×10^{-2}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{134}Cs-Upper-Middle Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	9.3×10^{-5}	1.9×10^{-4}
2	2.9×10^{-5}	2.5×10^{-4}
3	2.8×10^{-5}	3.1×10^{-4}
4	2.9×10^{-5}	3.7×10^{-4}
5	1.8×10^{-5}	5.3×10^{-4}
6	1.8×10^{-5}	7.5×10^{-4}
7	1.9×10^{-5}	1.0×10^{-3}
8	2.1×10^{-5}	1.3×10^{-3}
9	1.5×10^{-5}	1.6×10^{-3}
10	2.1×10^{-5}	1.9×10^{-3}
11	2.2×10^{-5}	2.2×10^{-3}
12	2.3×10^{-5}	2.5×10^{-3}
13	1.5×10^{-5}	3.5×10^{-3}
14	1.8×10^{-5}	4.6×10^{-3}
15	2.0×10^{-5}	6.0×10^{-3}
16	2.8×10^{-5}	7.9×10^{-3}
17	5.0×10^{-5}	1.1×10^{-2}
18	4.4×10^{-5}	1.3×10^{-2}
19	2.0×10^{-5}	2.1×10^{-2}
20	1.4×10^{-5}	2.7×10^{-2}

^{134}Cs-Top Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	1.1×10^{-4}	2.0×10^{-4}
2	2.2×10^{-5}	2.4×10^{-4}
3	2.1×10^{-5}	4.0×10^{-4}
4	2.3×10^{-5}	4.6×10^{-4}
5	1.5×10^{-5}	6.2×10^{-4}
6	1.5×10^{-5}	8.6×10^{-4}
7	1.8×10^{-5}	1.2×10^{-3}
8	2.0×10^{-5}	1.6×10^{-3}
9	2.3×10^{-5}	2.0×10^{-3}
10	2.4×10^{-5}	2.4×10^{-3}
11	2.8×10^{-5}	3.0×10^{-3}
*12	2.3×10^{-5}	3.4×10^{-3}
13	2.5×10^{-5}	5.4×10^{-3}
14	3.1×10^{-5}	7.8×10^{-3}
15	3.1×10^{-5}	1.1×10^{-2}
16	4.0×10^{-5}	1.4×10^{-2}
17	6.0×10^{-5}	1.9×10^{-2}
18	6.4×10^{-5}	2.3×10^{-2}
19	3.0×10^{-5}	3.8×10^{-2}
20	2.0×10^{-5}	4.9×10^{-2}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{137}Cs-Bottom Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	1.1×10^{-4}	1.7×10^{-4}
2	2.8×10^{-5}	2.1×10^{-4}
3	3.4×10^{-5}	2.7×10^{-4}
4	3.5×10^{-5}	3.2×10^{-4}
5	1.8×10^{-5}	4.3×10^{-4}
6	2.0×10^{-5}	6.5×10^{-4}
7	2.0×10^{-5}	8.5×10^{-4}
8	2.2×10^{-5}	1.1×10^{-3}
9	2.2×10^{-5}	1.4×10^{-3}
10	2.4×10^{-5}	1.6×10^{-3}
11	2.6×10^{-5}	1.9×10^{-3}
*12	2.3×10^{-5}	2.1×10^{-3}
13	2.1×10^{-5}	3.0×10^{-3}
14	2.1×10^{-5}	4.0×10^{-3}
15	2.2×10^{-5}	5.0×10^{-3}
16	2.9×10^{-5}	6.5×10^{-3}
17	3.5×10^{-5}	8.0×10^{-3}
18	3.3×10^{-5}	9.5×10^{-3}
19	1.8×10^{-5}	1.5×10^{-2}
20	5.7×10^{-6}	1.7×10^{-2}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{137}Cs-Lower-Middle Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	8.6×10^{-5}	2.0×10^{-4}
2	2.2×10^{-5}	2.5×10^{-4}
3	2.7×10^{-5}	3.1×10^{-4}
4	2.9×10^{-5}	3.7×10^{-4}
5	1.9×10^{-5}	5.5×10^{-4}
6	1.9×10^{-5}	8.0×10^{-4}
7	1.9×10^{-5}	1.1×10^{-3}
8	2.2×10^{-5}	1.5×10^{-3}
9	2.1×10^{-5}	1.8×10^{-3}
10	2.2×10^{-5}	2.2×10^{-3}
*11	2.1×10^{-5}	2.5×10^{-3}
*12	2.1×10^{-5}	2.8×10^{-3}
13	1.9×10^{-5}	4.1×10^{-3}
14	2.3×10^{-5}	5.5×10^{-3}
15	2.3×10^{-5}	7.5×10^{-3}
16	3.3×10^{-5}	1.0×10^{-2}
17	3.6×10^{-5}	1.2×10^{-2}
18	3.6×10^{-5}	1.5×10^{-2}
19	1.5×10^{-5}	2.1×10^{-2}
20	7.2×10^{-6}	2.4×10^{-2}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{137}Cs-Upper-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	9.1×10^{-5}	1.9×10^{-4}
2	2.0×10^{-5}	2.6×10^{-4}
3	2.9×10^{-5}	3.2×10^{-4}
4	3.1×10^{-5}	3.8×10^{-4}
5	1.9×10^{-5}	5.5×10^{-4}
6	1.9×10^{-5}	7.5×10^{-4}
7	2.0×10^{-5}	1.1×10^{-3}
8	2.1×10^{-5}	1.4×10^{-3}
9	1.6×10^{-5}	1.6×10^{-3}
10	2.1×10^{-5}	1.9×10^{-3}
11	2.2×10^{-5}	2.2×10^{-3}
12	2.3×10^{-5}	2.6×10^{-3}
13	1.5×10^{-5}	3.5×10^{-3}
14	1.8×10^{-5}	4.6×10^{-3}
15	1.9×10^{-5}	6.0×10^{-3}
16	2.7×10^{-5}	8.0×10^{-3}
17	3.0×10^{-5}	9.5×10^{-3}
18	2.6×10^{-5}	1.1×10^{-2}
19	1.2×10^{-5}	1.6×10^{-2}
20	5.7×10^{-6}	1.8×10^{-2}

^{137}Cs-Top Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	1.1×10^{-4}	2.9×10^{-4}
2	2.3×10^{-5}	3.5×10^{-4}
3	2.2×10^{-5}	4.1×10^{-4}
4	2.3×10^{-5}	4.7×10^{-4}
5	1.5×10^{-5}	6.5×10^{-4}
6	1.6×10^{-5}	9.0×10^{-4}
7	1.8×10^{-5}	1.2×10^{-3}
8	2.0×10^{-5}	1.6×10^{-3}
9	2.4×10^{-5}	2.1×10^{-3}
10	2.5×10^{-5}	2.5×10^{-3}
11	2.9×10^{-5}	3.0×10^{-3}
*12	2.3×10^{-5}	3.5×10^{-3}
13	2.4×10^{-5}	5.5×10^{-3}
14	3.1×10^{-5}	8.0×10^{-3}
15	3.0×10^{-5}	1.1×10^{-2}
16	4.0×10^{-5}	1.4×10^{-2}
17	3.8×10^{-5}	1.7×10^{-2}
18	3.9×10^{-5}	2.0×10^{-2}
19	1.9×10^{-5}	2.9×10^{-2}
20	8.5×10^{-6}	3.4×10^{-2}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{144}Ce-Bottom Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	2.0×10^{-6}	3.2×10^{-6}
2	3.0×10^{-7}	3.6×10^{-6}
3	2.1×10^{-7}	4.0×10^{-6}
4	1.7×10^{-7}	4.3×10^{-6}
5	3.3×10^{-8}	4.5×10^{-6}
6	1.3×10^{-8}	4.6×10^{-6}
7	3.7×10^{-9}	4.6×10^{-6}
8	2.2×10^{-8}	4.9×10^{-6}
9	1.5×10^{-8}	5.0×10^{-6}
10	1.4×10^{-8}	5.2×10^{-6}
11	4.6×10^{-9}	5.2×10^{-6}
12	2.8×10^{-8}	5.5×10^{-6}
13	1.6×10^{-8}	6.3×10^{-6}
14	2.7×10^{-8}	7.6×10^{-6}
15	3.0×10^{-8}	9.2×10^{-6}
16	2.5×10^{-8}	1.0×10^{-5}
17	5.3×10^{-8}	1.3×10^{-5}
18	8.7×10^{-8}	1.7×10^{-5}
19	5.4×10^{-8}	3.2×10^{-5}
20	3.6×10^{-9}	3.4×10^{-5}

^{144}Ce-Lower-Middle Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	1.2×10^{-6}	2.8×10^{-6}
2	1.6×10^{-7}	3.1×10^{-6}
3	1.0×10^{-7}	3.4×10^{-6}
4	1.1×10^{-7}	3.6×10^{-6}
5	3.6×10^{-8}	3.9×10^{-6}
6	2.3×10^{-8}	4.2×10^{-6}
7	1.2×10^{-8}	4.4×10^{-6}
8	1.8×10^{-8}	4.7×10^{-6}
9	1.4×10^{-8}	4.9×10^{-6}
10	4.4×10^{-8}	5.6×10^{-6}
* 11	2.2×10^{-8}	6.0×10^{-6}
12	4.4×10^{-8}	6.7×10^{-6}
13	1.0×10^{-8}	7.4×10^{-6}
14	1.3×10^{-8}	8.3×10^{-6}
15	1.6×10^{-8}	9.5×10^{-6}
16	8.2×10^{-8}	1.5×10^{-5}
17	9.9×10^{-8}	2.2×10^{-5}
18	1.6×10^{-7}	3.2×10^{-5}
19	3.0×10^{-8}	4.4×10^{-5}
20	2.7×10^{-8}	5.7×10^{-5}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{144}Ce-Upper-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	1.5×10^{-6}	3.0×10^{-6}
2	3.7×10^{-7}	3.8×10^{-6}
3	3.5×10^{-7}	4.5×10^{-6}
4	2.4×10^{-7}	5.0×10^{-6}
5	4.2×10^{-8}	5.4×10^{-6}
6	2.7×10^{-8}	5.7×10^{-6}
7	6.2×10^{-9}	5.8×10^{-6}
8	1.2×10^{-8}	6.0×10^{-6}
9	1.4×10^{-8}	6.2×10^{-6}
10	3.3×10^{-8}	6.7×10^{-6}
11	1.4×10^{-8}	6.9×10^{-6}
12	8.5×10^{-9}	7.0×10^{-6}
13	2.2×10^{-8}	8.4×10^{-6}
14	1.0×10^{-8}	9.0×10^{-6}
15	1.1×10^{-8}	9.8×10^{-6}
16	7.3×10^{-8}	1.5×10^{-5}
17	7.5×10^{-8}	1.9×10^{-5}
18	7.9×10^{-8}	2.4×10^{-5}
19	3.1×10^{-8}	3.5×10^{-5}
20	4.3×10^{-9}	3.7×10^{-5}

^{144}Ce-Top Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	3.8×10^{-6}	1.0×10^{-5}
2	2.9×10^{-7}	1.1×10^{-5}
3	2.0×10^{-7}	1.1×10^{-5}
4	2.6×10^{-7}	1.2×10^{-5}
5	5.1×10^{-8}	1.3×10^{-5}
6	2.2×10^{-8}	1.3×10^{-5}
7	2.1×10^{-8}	1.3×10^{-5}
8	3.4×10^{-8}	1.4×10^{-5}
9	1.6×10^{-8}	1.4×10^{-5}
10	4.5×10^{-8}	1.5×10^{-5}
* 11	2.9×10^{-8}	1.6×10^{-5}
* 12	2.9×10^{-8}	1.6×10^{-5}
* 13	2.9×10^{-8}	1.7×10^{-5}
14	2.1×10^{-8}	1.8×10^{-5}
* 15	2.1×10^{-8}	2.0×10^{-5}
16	2.7×10^{-8}	2.2×10^{-5}
17	3.8×10^{-8}	2.5×10^{-5}
18	5.7×10^{-8}	2.9×10^{-5}
19	2.1×10^{-8}	4.0×10^{-5}
20	4.3×10^{-8}	6.4×10^{-5}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{154}Eu-Bottom Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	1.9×10^{-6}	3.1×10^{-6}
2	3.1×10^{-7}	3.6×10^{-6}
3	3.3×10^{-7}	4.1×10^{-6}
4	2.2×10^{-7}	4.4×10^{-6}
5	1.4×10^{-7}	5.3×10^{-6}
6	1.4×10^{-7}	6.6×10^{-6}
7	1.3×10^{-7}	8.1×10^{-6}
8	1.6×10^{-7}	9.9×10^{-6}
9	1.1×10^{-7}	1.1×10^{-5}
10	9.2×10^{-8}	1.2×10^{-5}
11	1.9×10^{-7}	1.4×10^{-5}
12	2.1×10^{-7}	1.6 x 10-5
13	1.5×10^{-7}	2.3×10^{-5}
14	1.8×10^{-7}	3.2×10^{-5}
15	2.9×10^{-7}	4.8×10^{-5}
16	3.4×10^{-7}	6.5×10^{-5}
17	4.5×10^{-7}	8.5×10^{-5}
18	6.2×10^{-7}	1.1×10^{-4}
19	2.5×10^{-7}	1.9×10^{-4}
20	9.4×10^{-8}	2.2×10^{-4}

^{154}Eu-Lower-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	1.2×10^{-6}	2.8×10^{-6}
2	2.7×10^{-7}	3.4×10^{-6}
3	3.1×10^{-7}	4.1×10^{-6}
4	1.9×10^{-7}	4.6×10^{-6}
5	1.5×10^{-7}	5.9×10^{-6}
6	1.3×10^{-7}	8.2×10^{-6}
7	1.6×10^{-7}	1.1×10^{-5}
8	9.2×10^{-8}	1.2×10^{-5}
9	1.1×10^{-7}	1.4×10^{-5}
10	9.0×10^{-8}	1.5×10^{-5}
11	1.1×10^{-7}	1.7×10^{-5}
12	4.3×10^{-7}	2.4×10^{-5}
13	1.9×10^{-7}	3.7×10^{-5}
14	3.9×10^{-7}	6.3×10^{-5}
15	3.8×10^{-7}	9.3×10^{-5}
16	6.5×10^{-7}	1.4×10^{-4}
17	9.8×10^{-7}	2.0×10^{-4}
18	1.3×10^{-6}	2.9×10^{-4}
19	2.2×10^{-7}	3.8×10^{-4}
20	1.4×10^{-7}	4.5×10^{-4}

^{154}Eu-Upper-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	1.5×10^{-6}	3.2×10^{-6}
2	3.7×10^{-7}	4.0×10^{-6}
3	4.5×10^{-7}	4.9×10^{-6}
4	2.8×10^{-7}	5.5×10^{-6}
5	1.3×10^{-7}	6.6×10^{-6}
6	1.5×10^{-7}	8.4×10^{-6}
7	2.5×10^{-7}	1.2×10^{-5}
8	2.6×10^{-7}	1.6×10^{-5}
9	2.5×10^{-7}	1.9×10^{-5}
10	1.7×10^{-7}	2.2×10^{-5}
11	1.3×10^{-7}	2.4×10^{-5}
12	9.0×10^{-8}	2.5×10^{-5}
13	1.5×10^{-7}	3.4×10^{-5}
14	2.2×10^{-7}	4.8×10^{-5}
15	3.3×10^{-7}	7.1×10^{-5}
16	6.7×10^{-7}	1.2×10^{-4}
17	7.4×10^{-7}	1.6×10^{-4}
18	8.9×10^{-7}	2.1×10^{-4}
19	1.9×10^{-7}	2.9×10^{-4}
20	9.8×10^{-8}	3.3×10^{-4}

^{154}Eu-Top Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	4.7×10^{-6}	1.2×10^{-5}
2	7.6×10^{-7}	1.4×10^{-5}
3	6.6×10^{-7}	1.6×10^{-5}
4	7.3×10^{-7}	1.8×10^{-5}
5	3.8×10^{-7}	2.2×10^{-5}
6	1.7×10^{-7}	2.5×10^{-5}
7	3.1×10^{-7}	3.1×10^{-5}
8	3.3×10^{-7}	3.6×10^{-5}
9	2.2×10^{-7}	4.0×10^{-5}
10	1.4×10^{-7}	4.3×10^{-5}
11	2.5×10^{-7}	4.8×10^{-5}
12	1.2×10^{-7}	5.0×10^{-5}
13	1.2×10^{-7}	5.9×10^{-5}
14	1.2×10^{-7}	6.9×10^{-5}
15	2.0×10^{-7}	8.7×10^{-5}
16	1.6×10^{-7}	1.0×10^{-4}
17	3.5×10^{-7}	1.3×10^{-4}
18	5.7×10^{-7}	1.7×10^{-4}
19	1.4×10^{-7}	2.4×10^{-4}
20	9.0×10^{-8}	2.9×10^{-4}

^{155}Eu-Bottom Section

Series #	Leach Rate[(a)] g/cm²-day	Cumulative Fraction Leached
1	1.8×10^{-6}	2.9×10^{-6}
2	2.5×10^{-7}	3.3×10^{-6}
3	4.2×10^{-7}	3.9×10^{-6}
4	1.7×10^{-7}	4.2×10^{-6}
5	1.6×10^{-7}	5.2×10^{-6}
6	2.2×10^{-7}	7.3×10^{-6}
7	1.1×10^{-7}	8.5×10^{-6}
8	1.6×10^{-7}	1.0×10^{-5}
9	8.2×10^{-8}	1.1×10^{-5}
10	2.4×10^{-7}	1.4×10^{-5}
11	1.5×10^{-7}	1.5×10^{-5}
12	2.5×10^{-7}	1.8×10^{-5}
13	1.3×10^{-7}	2.4×10^{-5}
14	2.6×10^{-7}	3.7×10^{-5}
15	3.0×10^{-7}	5.3×10^{-5}
16	3.2×10^{-7}	6.9×10^{-5}
17	4.7×10^{-7}	9.0×10^{-5}
18	7.0×10^{-7}	1.2×10^{-4}
19		
20		

(a) Blanks indicate that no data were obtained for that series.

^{155}Eu-Lower-Middle Section

Series #	Leach Rate[(a)] g/cm²-day	Cumulative Fraction Leached
1	9.2×10^{-7}	2.2×10^{-6}
2	2.5×10^{-7}	2.8×10^{-6}
3	1.7×10^{-7}	3.2×10^{-6}
4	1.7×10^{-7}	3.6×10^{-6}
5	1.5×10^{-7}	5.0×10^{-6}
6	2.0×10^{-7}	7.9×10^{-6}
7	1.2×10^{-7}	9.8×10^{-6}
8	6.2×10^{-8}	1.1×10^{-5}
9	9.4×10^{-8}	1.2×10^{-5}
10	8.1×10^{-8}	1.4×10^{-5}
* 11	8.9×10^{-8}	1.5×10^{-5}
12	3.8×10^{-7}	2.1×10^{-5}
13	2.2×10^{-7}	3.7×10^{-5}
14	2.7×10^{-7}	5.6×10^{-5}
15	3.1×10^{-7}	8.1×10^{-5}
16	5.7×10^{-7}	1.2×10^{-4}
17	9.9×10^{-7}	1.9×10^{-4}
18	1.2×10^{-6}	2.7×10^{-4}
19		
20		

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

(a) Blanks indicate that no data were obtained for that series.

^{155}Eu-Upper-Middle Section

Series #	Leach Rate[a] g/cm²-day	Cumulative Fraction Leached
1	6.7×10^{-7}	1.5×10^{-6}
2	3.5×10^{-7}	2.2×10^{-6}
3	4.0×10^{-7}	3.1×10^{-6}
4	4.8×10^{-7}	4.1×10^{-6}
5	9.3×10^{-8}	4.9×10^{-6}
6	1.1×10^{-7}	6.3×10^{-6}
7	1.6×10^{-7}	8.8×10^{-6}
8	1.6×10^{-7}	1.1×10^{-5}
9	2.3×10^{-7}	1.5×10^{-5}
10	1.8×10^{-7}	1.7×10^{-5}
11	1.9×10^{-8}	2.0×10^{-5}
12	1.1×10^{-7}	2.2×10^{-5}
13	1.6×10^{-7}	3.3×10^{-5}
14	2.5×10^{-7}	4.9×10^{-5}
15	3.3×10^{-7}	7.3×10^{-5}
16	6.0×10^{-7}	1.1×10^{-4}
17	7.9×10^{-7}	1.6×10^{-4}
18	9.0×10^{-7}	2.2×10^{-4}
19		
20		

(a) Blanks indicate that no data were obtained for that series.

^{155}Eu-Top Section

Series #	Leach Rate[a] g/cm^2-day	Cumulative Fraction Leached
1	6.1×10^{-6}	1.7×10^{-5}
2	5.2×10^{-7}	1.8×10^{-5}
3	6.2×10^{-7}	2.0×10^{-5}
4	6.6×10^{-7}	2.2×10^{-5}
5	3.6×10^{-7}	2.6×10^{-5}
6	2.2×10^{-7}	2.9×10^{-5}
7	3.3×10^{-7}	3.6×10^{-5}
8	2.6×10^{-7}	4.1×10^{-5}
9	3.3×10^{-7}	4.7×10^{-5}
10	7.9×10^{-8}	4.9×10^{-5}
* 11	2.5×10^{-7}	5.3×10^{-5}
12	2.7×10^{-7}	5.9×10^{-5}
13	5.6×10^{-8}	6.3×10^{-5}
14	5.1×10^{-8}	6.7×10^{-5}
15	4.4×10^{-8}	7.1×10^{-5}
16	2.9×10^{-7}	9.7×10^{-5}
17	3.2×10^{-7}	1.2×10^{-4}
18	6.4×10^{-7}	1.7×10^{-4}
19		
20		

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

(a) Blanks indicate that no data were obtained for that series.

$^{239+240}$Pu-Bottom Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	6.8×10^{-6}	1.1×10^{-5}
2	3.7×10^{-6}	1.7×10^{-5}
3	4.8×10^{-6}	2.4×10^{-5}
4	5.6×10^{-6}	3.3×10^{-5}
5	1.8×10^{-6}	4.4×10^{-5}
6	2.1×10^{-6}	6.4×10^{-5}
7	2.4×10^{-6}	9.0×10^{-5}
8	2.7×10^{-6}	1.2×10^{-4}
9	3.1×10^{-6}	1.6×10^{-4}
10	2.8×10^{-6}	1.9×10^{-4}
11	3.7×10^{-6}	2.3×10^{-4}
12	2.8×10^{-6}	2.6×10^{-4}
13	1.2×10^{-6}	3.2×10^{-4}
14	2.2×10^{-6}	4.2×10^{-4}
15	1.2×10^{-6}	4.9×10^{-4}
16	2.4×10^{-6}	6.1×10^{-4}
17	1.5×10^{-6}	6.8×10^{-4}
18	2.7×10^{-6}	8.0×10^{-4}
19	5.2×10^{-7}	9.5×10^{-4}
20	8.8×10^{-7}	1.3×10^{-3}

$^{239+240}Pu$-Lower-Middle Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	1.0×10^{-5}	2.3×10^{-5}
2	6.0×10^{-6}	3.7×10^{-5}
3	8.2×10^{-6}	5.6×10^{-5}
4	8.2×10^{-6}	7.4×10^{-5}
5	3.8×10^{-6}	1.1×10^{-4}
6	5.3×10^{-6}	1.8×10^{-4}
7	4.2×10^{-6}	2.5×10^{-4}
8	7.4×10^{-6}	3.7×10^{-4}
9	6.6×10^{-6}	4.7×10^{-4}
10	6.6×10^{-6}	5.8×10^{-4}
* 11	6.2×10^{-6}	6.8×10^{-4}
12	1.1×10^{-5}	8.5×10^{-4}
13	3.4×10^{-6}	1.1×10^{-3}
14	4.1×10^{-6}	1.4×10^{-3}
15	3.2×10^{-6}	1.6×10^{-3}
16	3.2×10^{-6}	1.8×10^{-3}
17	4.3×10^{-6}	2.1×10^{-3}
18	4.5×10^{-6}	2.4×10^{-3}
19	1.5×10^{-6}	3.0×10^{-3}
20	3.5×10^{-7}	3.2×10^{-3}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

$^{239+240}$Pu-Upper-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	8.4×10^{-6}	1.7×10^{-5}
2	8.1×10^{-6}	3.4×10^{-5}
3	6.1×10^{-6}	4.7×10^{-5}
4	9.7×10^{-6}	6.7×10^{-5}
5	4.8×10^{-6}	1.1×10^{-4}
6	3.7×10^{-6}	1.5×10^{-4}
7	6.4×10^{-7}	2.5×10^{-4}
8	7.4×10^{-6}	3.6×10^{-4}
9	5.7×10^{-6}	4.4×10^{-4}
10	6.1×10^{-6}	5.3×10^{-4}
11	7.2×10^{-6}	6.3×10^{-4}
12	7.8×10^{-6}	7.5×10^{-4}
13	3.2×10^{-6}	9.5×10^{-4}
14	3.7×10^{-6}	1.2×10^{-3}
15	4.1×10^{-6}	1.5×10^{-3}
16	5.2×10^{-6}	1.8×10^{-3}
17	6.7×10^{-6}	2.2×10^{-3}
18	5.4×10^{-6}	2.5×10^{-3}
19	1.2×10^{-6}	3.0×10^{-3}
20	9.0×10^{-7}	3.4×10^{-3}

$^{239+240}$Pu-Top Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	1.8×10^{-5}	4.8×10^{-5}
2	1.0×10^{-6}	5.1×10^{-5}
3	2.3×10^{-6}	5.7×10^{-5}
4	1.7×10^{-6}	6.1×10^{-5}
5	1.2×10^{-6}	7.4×10^{-5}
6	1.5×10^{-6}	9.8×10^{-5}
7	1.6×10^{-6}	1.3×10^{-4}
8	1.8×10^{-6}	1.6×10^{-4}
9	1.8×10^{-6}	2.0×10^{-4}
10	2.2×10^{-6}	2.4×10^{-4}
11	3.5×10^{-6}	3.0×10^{-4}
12	3.4×10^{-6}	3.6×10^{-4}
13	1.4×10^{-6}	4.7×10^{-4}
14	1.2×10^{-6}	5.7×10^{-4}
15	1.4×10^{-6}	7.0×10^{-4}
16	1.6×10^{-6}	8.4×10^{-4}
17	1.4×10^{-6}	9.4×10^{-4}
18	1.4×10^{-6}	1.0×10^{-3}
19	2.5×10^{-7}	1.2×10^{-3}
20	1.4×10^{-7}	1.2×10^{-3}

^{242}Cm-Bottom Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	1.5×10^{-6}	2.4×10^{-6}
2	2.9×10^{-7}	2.8×10^{-6}
3	2.4×10^{-7}	3.2×10^{-6}
4	2.5×10^{-7}	3.6×10^{-6}
5	9.6×10^{-8}	4.2×10^{-6}
6	1.1×10^{-7}	5.3×10^{-6}
7	1.1×10^{-7}	6.5×10^{-6}
8	8.7×10^{-8}	7.5×10^{-6}
9	8.1×10^{-8}	8.4×10^{-6}
10	6.0×10^{-8}	9.0×10^{-6}
11	9.9×10^{-8}	1.0×10^{-5}
12	1.4×10^{-7}	1.2×10^{-5}
13	4.0×10^{-8}	1.4×10^{-5}
14	1.1×10^{-7}	1.9×10^{-5}
15	1.4×10^{-7}	2.6×10^{-5}
16	1.4×10^{-7}	3.3×10^{-5}
17	2.2×10^{-7}	4.3×10^{-5}
18	2.7×10^{-7}	5.5×10^{-5}
19	3.3×10^{-7}	1.5×10^{-4}
20	6.2×10^{-8}	1.7×10^{-4}

^{242}Cm-Lower-Middle Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	8.5×10^{-7}	1.9×10^{-6}
2	1.5×10^{-7}	2.3×10^{-6}
3	1.2×10^{-7}	2.5×10^{-6}
4	1.0×10^{-7}	2.8×10^{-6}
5	7.6×10^{-8}	3.5×10^{-6}
6	1.1×10^{-7}	4.9×10^{-6}
7	7.6×10^{-8}	6.1×10^{-6}
8	7.4×10^{-8}	7.3×10^{-6}
9	8.3×10^{-8}	8.6×10^{-6}
10	8.1×10^{-8}	9.9×10^{-6}
* 11	7.9×10^{-8}	1.1×10^{-5}
12	2.5×10^{-7}	1.5×10^{-5}
13	5.9×10^{-8}	1.9×10^{-5}
14	1.3×10^{-7}	2.8×10^{-5}
15	1.5×10^{-7}	4.0×10^{-5}
16	2.3×10^{-7}	5.7×10^{-5}
17	3.9×10^{-7}	8.2×10^{-5}
18	6.8×10^{-7}	1.3×10^{-4}
19	1.4×10^{-7}	1.8×10^{-4}
20	1.7×10^{-7}	2.6×10^{-4}

* Denotes that an analysis is not available for this series. The number is an average of the above series with the same leach time.

^{242}Cm-Upper-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	9.8×10^{-7}	2.0×10^{-6}
2	4.1×10^{-7}	2.9×10^{-6}
3	3.3×10^{-7}	3.6×10^{-6}
4	2.7×10^{-7}	4.2×10^{-6}
5	6.6×10^{-8}	4.7×10^{-6}
6	1.1×10^{-7}	6.1×10^{-6}
7	1.4×10^{-7}	8.2×10^{-6}
8	1.7×10^{-7}	1.1×10^{-5}
9	1.5×10^{-7}	1.3×10^{-5}
10	1.2×10^{-7}	1.5×10^{-5}
11	7.2×10^{-8}	1.6×10^{-5}
12	7.6×10^{-8}	1.7×10^{-5}
13	6.5×10^{-8}	2.1×10^{-5}
14	5.9×10^{-8}	2.5×10^{-5}
15	1.4×10^{-7}	3.4×10^{-5}
16	2.7×10^{-7}	5.2×10^{-5}
17	3.2×10^{-7}	7.2×10^{-5}
18	3.5×10^{-7}	9.2×10^{-5}
19	1.8×10^{-7}	1.8×10^{-4}
20	6.7×10^{-8}	2.1×10^{-4}

^{242}Cm-Top Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	2.4×10^{-6}	6.3×10^{-6}
2	6.9×10^{-7}	8.1×10^{-6}
3	4.0×10^{-7}	9.2×10^{-6}
4	4.9×10^{-7}	1.1×10^{-5}
5	2.8×10^{-7}	1.3×10^{-5}
6	1.7×10^{-7}	1.6×10^{-5}
7	2.1×10^{-7}	2.0×10^{-5}
8	2.7×10^{-7}	2.5×10^{-5}
9	8.0×10^{-8}	2.7×10^{-5}
10	1.3×10^{-7}	2.9×10^{-5}
11	1.4×10^{-7}	3.1×10^{-5}
12	1.7×10^{-7}	3.5×10^{-5}
13	2.4×10^{-8}	3.7×10^{-5}
14	5.6×10^{-8}	4.1×10^{-5}
15	$5.9 \times 1p^{-8}$	4.6×10^{-5}
16	1.1×10^{-7}	5.5×10^{-5}
17	1.7×10^{-7}	6.9×10^{-5}
18	2.4×10^{-7}	8.6×10^{-5}
19	9.8×10^{-8}	1.3×10^{-4}
20	6.6×10^{-8}	1.9×10^{-4}

^{244}Cm-Bottom Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	1.5×10^{-6}	2.3×10^{-6}
2	3.0×10^{-7}	2.8×10^{-6}
3	2.1×10^{-7}	3.1×10^{-6}
4	2.0×10^{-7}	3.4×10^{-6}
5	1.0×10^{-7}	4.1×10^{-6}
6	8.7×10^{-8}	4.9×10^{-6}
7	9.6×10^{-8}	6.0×10^{-6}
8	9.8×10^{-8}	7.1×10^{-6}
9	7.7×10^{-8}	7.9×10^{-6}
10	7.5×10^{-8}	8.7×10^{-6}
11	1.1×10^{-7}	1.0×10^{-5}
12	1.5×10^{-7}	1.2×10^{-5}
13	4.4×10^{-8}	1.4×10^{-5}
14	1.0×10^{-7}	1.8×10^{-5}
15	1.5×10^{-7}	2.6×10^{-5}
16	1.3×10^{-7}	3.3×10^{-5}
17	2.2×10^{-7}	4.3×10^{-5}
18	2.7×10^{-7}	5.5×10^{-5}
19	2.6×10^{-7}	1.3×10^{-4}
20	5.5×10^{-8}	1.5×10^{-4}

^{244}Cm-Lower-Middle Section

Series #	Leach Rate g/cm^2-day	Cumulative Fraction Leached
1	8.7×10^{-7}	2.0×10^{-6}
2	1.6×10^{-7}	2.3×10^{-6}
3	1.5×10^{-7}	2.7×10^{-6}
4	9.1×10^{-8}	2.9×10^{-6}
5	8.6×10^{-8}	3.7×10^{-6}
6	1.1×10^{-7}	5.2×10^{-6}
7	7.9×10^{-8}	6.4×10^{-6}
8	8.1×10^{-8}	7.7×10^{-6}
9	7.9×10^{-8}	9.0×10^{-6}
10	8.8×10^{-8}	1.0×10^{-5}
11	8.2×10^{-8}	1.2×10^{-5}
12	2.7×10^{-7}	1.6×10^{-5}
13	6.7×10^{-8}	2.1×10^{-5}
14	1.1×10^{-7}	2.8×10^{-5}
15	1.6×10^{-7}	4.1×10^{-5}
16	2.5×10^{-7}	5.9×10^{-5}
17	3.8×10^{-7}	8.4×10^{-5}
18	5.9×10^{-7}	1.2×10^{-4}
19	1.5×10^{-7}	1.8×10^{4}
20	1.3×10^{-7}	2.5×10^{-4}

^{244}Cm-Upper-Middle Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	9.9×10^{-7}	2.1×10^{-6}
2	3.7×10^{-7}	2.8×10^{-6}
3	2.8×10^{-7}	3.4×10^{-6}
4	2.2×10^{-7}	3.9×10^{-6}
5	1.0×10^{-7}	4.7×10^{-6}
6	1.2×10^{-7}	6.2×10^{-6}
7	1.3×10^{-7}	8.2×10^{-6}
8	1.6×10^{-7}	1.1×10^{-5}
9	1.6×10^{-7}	1.3×10^{-5}
10	1.1×10^{-7}	1.4×10^{-5}
11	8.1×10^{-8}	1.6×10^{-5}
12	6.8×10^{-8}	1.7×10^{-5}
13	6.2×10^{-8}	2.1×10^{-5}
14	6.6×10^{-8}	2.5×10^{-5}
15	1.1×10^{-7}	3.3×10^{-5}
16	2.8×10^{-7}	5.1×10^{-5}
17	3.1×10^{-7}	7.0×10^{-5}
18	3.5×10^{-7}	9.0×10^{-5}
19	1.0×10^{-7}	1.3×10^{-4}
20	5.7×10^{-8}	1.5×10^{-4}

^{244}Cm-Top Section

Series #	Leach Rate g/cm²-day	Cumulative Fraction Leached
1	2.6×10^{-6}	6.8×10^{-6}
2	5.9×10^{-7}	8.4×10^{-6}
3	4.4×10^{-7}	9.5×10^{-6}
4	5.5×10^{-7}	1.1×10^{-5}
5	2.7×10^{-7}	1.4×10^{-5}
6	1.8×10^{-7}	1.7×10^{-5}
7	2.7×10^{-7}	2.1×10^{-5}
8	2.2×10^{-7}	2.5×10^{-5}
9	1.4×10^{-7}	2.7×10^{-5}
10	1.3×10^{-7}	3.0×10^{-5}
11	1.4×10^{-7}	3.2×10^{-5}
12	1.7×10^{-7}	3.5×10^{-5}
13	2.7×10^{-8}	3.8×10^{-5}
14	5.0×10^{-8}	4.2×10^{-5}
15	5.7×10^{-8}	4.7×10^{-5}
16	1.1×10^{-7}	5.6×10^{-5}
17	1.4×10^{-7}	6.7×10^{-5}
18	2.1×10^{-7}	8.2×10^{-5}
19	3.0×10^{-8}	9.6×10^{-5}
20	6.7×10^{-8}	1.3×10^{-4}

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