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PROPERTIES OF RADIOACTIVE WASTES AND WASTE CONTAINERS

QUARTERLY PROGRESS REPORT
OCTOBER — DECEMBER 1981

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ABSTRACT

A study correlating the leachability of ^{137}Cs from small-scale to large-scale cement forms was performed. The waste forms consisted of organic ion exchange resins incorporated in Portland I cement, with a waste-to-cement ratio of 0.6 and a water-to-cement ratio of 0.4 (as free water) and boric acid waste (12% solution), incorporated in Portland III cement, with a waste-to-cement ratio of 0.7. ^{137}Cs was added to both waste types prior to solidification. The samples' dimensions varied from 1 in. x 1 in. to 22 in. x 22 in. (diameter x height) in size. Leach data extending over a period of 260 days were obtained. A method based on semi-infinite plane source diffusion model was applied to analyze the leach data. An effective bulk diffusion coefficient was calculated from the leach data for both types of solidified waste. A derived mathematical expression allows prediction of the amount of ^{137}Cs leached from the forms as a function of leaching time and waste form dimensions. A reasonably good agreement between the experimental and calculated data is obtained.

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SUMMARY

A study correlating the leachability of ^{137}Cs from small-scale to large-scale cement forms was performed. The waste forms consisted of organic ion exchange resins incorporated in Portland I cement, with a waste-to-cement ratio of 0.6 and a water-to-cement ratio of 0.4 (as free water) and boric acid waste (12% solution), incorporated in Portland III cement, with a waste-to-cement ratio of 0.7. ^{137}Cs was added to both waste types prior to solidification. The samples' dimensions varied from 1 in. x 1 in. to 22 in. x 22 in. (diameter x height) in size. Leach data extending over a period of 260 days were obtained.

The observed ^{137}Cs leach data for resin/cement and boric acid/cement can be represented by a diffusional mass transport relationship. This semi-empirical relationship has been used to estimate the cumulative fractional releases from forms varying in size from 2 x 2 to 22 x 22 for a given leaching period. The following observations were made from the ^{137}Cs release curves:

- The initial ^{137}Cs release reactions were primarily surface-controlled, the effect being most pronounced in the smallest waste form studied (1 x 1).

- The diffusion-controlled regions of the release curves were linear with $t^{1/2}$ and were represented by a slope = $[2 \times S/V(D_e/\pi)^{1/2}]$. The slope increased linearly with increasing geometric surface-to-volume ratios (S/V) of the waste forms.

- Larger resin/cement forms (6 x 12, 12 x 12, and 22 x 22) disintegrated after 150, 120, and 70 days of leaching, respectively. The larger the form, the earlier the disintegration occurred. This disintegration may be attributed to variations in curing with waste form size.

- The effective bulk diffusion coefficients (D_e) for ^{137}Cs in the two waste form matrices were calculated from the slopes of the linear regions of the ^{137}Cs release curves vs $t^{1/2}$. D_e values were on the order of 10^{-8} cm^2/s, and increased with increasing waste form size for both matrices. The observed increase in D_e with waste form size may be attributed to variations in the degree of curing of the waste forms.

PROPERTIES OF RADIOACTIVE WASTES AND WASTE CONTAINERS
QUARTERLY PROGRESS REPORT, SEPTEMBER-DECEMBER 1981

CORRELATION OF ^{137}Cs LEACHABILITY FROM SMALL-SCALE (LABORATORY) SAMPLES TO LARGE-SCALE WASTE FORMS (P. Hayde, M. Hope, L. Milian, and N. Morcos)

1. Introduction

This report presents experimental data and the conclusions of the study, initiated in FY 1980, on the correlation of ^{137}Cs leachability from small-scale (laboratory) samples to large-scale waste forms. The waste forms evaluated in this study are typical of those that are expected to be generated at nuclear power plants, e.g., organic ion exchange resins and boric acid waste solidified in Portland cements. In an earlier report,(1) we presented ^{137}Cs "scale-up" leach data for ion exchange resin/cement composites.

Licensing of near surface low-level radioactive waste disposal sites and waste forms/containers may require the ability to predict the dispersibility of radionuclides from waste forms and waste containers disposed in burial sites. Basic concerns in licensing radioactive waste forms and containers are their dimensional stability and the potential for migration of the radionuclides enclosed therein in a near- and long-term predictable fashion. To assess these concerns, a data base is needed for evaluating the acceptability of solidified low-level radioactive waste packages for disposal. Furthermore, the need to develop test procedures and methodologies exists to enable the prediction and extrapolation of long-term performance of waste forms based on short-term laboratory tests.

Several theoretical and empirical methods based on mass transport and diffusion theory have been developed to predict the leachability of radioisotopes from waste composites.(1-9) A method has been recommended earlier (1970) by the International Atomic Energy Agency (IAEA) for leaching samples and for the analysis and interpretation of leaching data.(10) Recently, a standard leaching method, which has much in common with the earlier IAEA method, was proposed by the American Nuclear Society Standards Committee Working Group (ANS-16.1). This method proposes the accumulation of data over a short-term period (five days) to determine the "Leachability Index," a material parameter. This parameter characterizes the leaching of a radionuclide from the waste form and may be used for performance predictions under actual environmental conditions, if the type of material being tested was characterized through generic studies. A working group (ISO/TC 85/SC 5/WG 5) of the International Standards Organization (ISO) is also currently directing efforts toward the adoption of a uniform standard leach test.

The IAEA method assumes a semi-infinite plane source model of diffusion for radioisotopes from waste composites and relates the amount of substance diffused out of a waste composite to the leaching time, the amount of that substance initially present, and the diffusion rate. The mass transport rate equation describing this diffusion mode can be written as[2,11]:

$$f = \frac{S}{V} \times 2\left(\frac{D\,t}{\pi}\right)^{1/2} \tag{1}$$

where f = fraction of substance diffused out of the composite during time t,

S/V = ratio of the geometric surface of the sample to its volume,

D = effective diffusion coefficient of the substance for the particular composite matrix,

The underlying assumptions dictated by Equation (1) are that the isotope under study is either stable or has a long half-life as compared to the duration of the experiment and that the initial isotope surface concentration of the waste form is zero. Furthermore, the relationship in Equation (1) implies that initially for $t = 0$, the fraction leached (f) is also zero. However, experimental leach data deviate from this prediction for small values of t and a more general relationship is suggested[2,12]:

$$f = \frac{S}{V} \cdot 2\left(\frac{D\,t}{\pi}\right)^{1/2} + \alpha \tag{2}$$

where the term (α) represents non-diffusive contributions from the surface of the waste form.[4,13] Furthermore, a linear relationship of the term (α) with the S/V ratio of the waste form was shown to exist,[13] indicating that it is indeed surface controlled.

Experiments were conducted to determine if the ^{137}Cs leach data on small-scale laboratory samples could be used in predicting the leaching behavior of larger samples. This report presents the experimental data obtained from 1 x 1 (diameter x height in inches), 2 x 2, 2 x 4, 3 x 3, 6 x 6, 6 x 12, 12 x 12, and 22 x 22 forms incorporating organic ion exchange resins or boric acid waste solidified in Portland cements. ^{137}Cs was added to both waste types prior to solidification.

A method is presented to correlate the leach data from small-scale samples to those from large samples. It also allows estimating the cumulative fractional release for a given waste form size in a given leaching time for two simulated waste streams solidified in Portland cement (organic ion exchange resins and boric acid).

2. Experimental

The waste form nominal dimensions (diameter x height in inches) were 1 x 1, 2 x 2, 2 x 4, 3 x 3, 6 x 6, 6 x 12, 12 x 12 and 22 x 22 for the organic ion exchange resins waste stream and 1 x 1, 2 x 2, 2 x 4, 3 x 3 and 6 x 6 for the boric acid waste stream. Cesium-137 was the radioactive tracer used in both formulations. This radiotracer was selected because it is one of the major long-lived radioactive components of reactor waste and one of the least reactive (among these components) with Portland cement.

The amounts of ^{137}Cs added to the different size waste forms were chosen by scaling the amounts used in earlier leaching experiments involving 2 x 4 waste forms. For this purpose, the relationship $f_1(V/S)_1 = f_2(V/S)_2$, where f_1 and f_2 are the cumulative fractional releases leached from two different size waste forms during the same leaching time and $(V/S)_1$ and $(V/S)_2$ are the geometric volume-to-surface ratios of these two forms, was used. Using the leached fractions from 2 x 4 organic cation exchange resin/Portland II cement composites[14] as f_1, f_2 was calculated for the various sizes using the appropriate $(V/S)_2$ values.

A modified IAEA leaching procedure[4] was followed. The first leaching period was 100 minutes, and thereafter the leachant was changed daily, during the first 42 days, except for weekends, where the leaching periods extended from Friday to Monday. (However, the leachant was changed during the first weekend). After 42 days, the daily leaching period was extended to a week, and later to a month, except for the 12 x 12 and 22 x 22 forms. For these forms, the daily leaching period was not changed.

2.1 Preparation of Simulated Wastes

2.1.1 Organic Cation Exchange Resins

To simulate spent ion exchange resins in this study, organic cation exchange resins (Rohm and Haas IRN-77, H^+ form) were converted to the Na^+ form with 2 molar NaOH solution.[1] The volume of NaOH solution was twice that of the resin. Following complete sorption of Na^+ ions, the NaOH solution was decanted. The resins were then rinsed with deionized water until the pH of the rinse water was comparable to that of the deionized water, indicating that the excess NaOH was rinsed out completely. The resins were stored in deionized water.

2.1.2 Boric Acid Waste

Work was performed earlier in our laboratory on optimized process parameters and the treatment of boric acid waste prior to solidification in Portland III cement.[16,17] This work indicated that adjustment of the boric acid waste pH to a value of 10 to 12 assured proper solidification for a waste-to-binder ratio of 0.7.

A stock solution containing 12 weight percent boric acid was prepared. Its pH was adjusted to approximately 12 by the addition of sodium hydroxide. This solution is hereafter referred to as "simulated waste."

2.2 Waste Form Preparation

2.2.1 Organic Ion Exchange Resin/Cement Composites

Organic cation exchange resin/cement composites were fabricated with a waste-to-cement (w/w) (Portland I) ratio of 0.6 and a water-to-cement (w/w) ratio of 0.4. The simulated waste composition consisted of 33 weight percent IRN-77 Na^+ form cation exchange resin loaded with ^{137}Cs and 67 weight percent deionized water as added free water. This formulation was chosen because preliminary test samples maintained their physical integrity during a prolonged leaching period (4-5 weeks) and because it provided good workability of the mixture during the mixing stage. Earlier process parameter investigations[16] for the solidification of IRN-77 resins in cement had defined boundaries for the components of the waste form (resin, water, and cement) where a freestanding solid product was produced. However, the durability of the solidified product upon immersion in water had not been evaluated. Formulations corresponding to those shown in the area bounded by heavy lines in the table reproduced from Reference 16 were evaluated (see next page). Up to twelve 2-inch-diameter by 4-inch-high forms were made and immersed in deionized water to evaluate their physical integrity (no evidence of crumbling) under leaching conditions. Only two formulations, denoted by the triangle and circle in the table, passed the immersion and workability tests. However, some of the forms with the triangle formulation began to crumble after several days in water, whereas there was no failure of the formulation shown in the circle.

The following procedure was used in preparing the 1 x 1, 2 x 2, 2 x 4, and 3 x 3 forms: appropriate amounts of resins were added to each mold and covered with deionized water to which a measured amount of ^{137}Cs radiotracer was added while stirring. After a 24-hour equilibration period, the water was sampled and assayed for ^{137}Cs content to assure uptake by the resin. The water was then removed by suction through a fritted filter and an amount of deionized water was added commensurate with the formulation for the composite.

The larger samples (6 x 6, 6 x 12, 12 x 12, and 22 x 22) were prepared in a slightly different manner. The amount of water added to the resins prior to the addition of ^{137}Cs was the amount needed for solidification and therefore was not decanted after equilibration and ^{137}Cs assay. The amount of ^{137}Cs remaining in the aqueous phase (after sorption) for all samples was less than 0.1% of the initially added activity, indicating that greater than 99.9% of the ^{137}Cs was sorbed onto the resins.

The mixtures of cement, water, and resins in individual molds were hand stirred with polyethylene rods (for samples up to 3 x 3) or mechanically stirred with a stainless steel mixer attached to a motor for the larger forms. Specimens were stirred for five minutes and capped to prevent water evaporation during the 28-29-day curing period. Earlier work has shown that ion exchange resin/cement composites, cured in air or left open to air after curing, disintegrated after immersion in water.

Table Showing Formulation of
Ion Exchange Resin Test Samples (Manaktala and Weiss[16])
(all weights are given in grams)

Water/Cement ↓ \ Waste/Cement →	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
0.3	15.7[a]	41.2	61.1	77.0	90.0	100.8	110.0	117.9
	47.1	41.2	36.7	33.0	30.0	27.5	25.4	23.6
	157.1	137.6	122.2	110.0	100.0	91.7	84.6	78.6
0.4	0.0	27.5	48.9	66.0	80.0	91.7	101.5	110.0
	62.8	55.0	48.9	44.0	40.0	36.7	33.9	31.4
	157.2	137.5	122.2	110.0	100.0	91.7	84.6	78.6
0.5		13.8	36.7	55.0	70.0	82.5	93.1	102.1
		68.7	61.1	55.0	50.0	45.8	42.3	39.3
		137.5	122.2	110.0	100.0	91.7	84.6	78.6
0.6		0.0	24.4	44.0	60.0	73.3	84.6	94.3
		82.5	73.3	66.0	60.0	55.0	50.8	47.1
		137.5	122.2	110.0	100.0	91.7	84.6	78.6
0.7			12.2	33.0	50.0	64.2	76.2	86.4
			85.6	77.0	70.0	64.2	59.2	55.0
			122.2	110.0	100.0	91.7	84.6	78.6
0.8			0.0	22.0	40.0	55.0	67.7	78.6
			97.8	88.0	80.0	73.3	67.7	62.8
			122.2	110.0	100.0	91.7	84.6	78.6
0.9				110.0	30.0	45.8	59.2	70.7
				99.0	90.0	82.5	76.2	70.7
				110.0	100.0	91.7	84.6	78.6
1.0				0.0	20.0	36.6	50.8	62.8
				110.0	100.0	91.7	84.6	78.6
				110.0	100.0	91.7	84.6	78.6

[a]Each entry is composed of three parts, viz., resin (15.7), water (47.1), and cement (157.1).

Table 1 summarizes the waste composite sizes made, together with their contents, volume-to-surface ratios, and leachant volumes. Each sample size was prepared in triplicate with the exception of 22 x 22.

Table 1

Composite Dimensions, Components, and Leachant Volumes For Waste Forms Incorporating IRN-77 Resins

Sample	Composite				Components (g)			^{137}Cs Added to Composite (μCi)	Volume of Leachant (mL)
	Diameter (in.)	Height (in.)	V/S (cm)	Weight (g)	Cement Portland I	Waste IRN-77[a]	Waste H_2O		
1 x 1	0.93	0.94	0.396	20	12.5	2.5	5.0	1	265
	0.93	0.94	0.396	b	12.5	2.5	5.0	1	265
	0.93	0.94	0.396	b	12.5	2.5	5.0	1	265
2 x 2	1.83	1.89	0.784	150	93.8	18.8	37.5	10	1,050
	1.83	1.89	0.784	150	93.8	18.8	37.5	10	1,050
	1.83	1.89	0.784	150	93.8	18.8	37.5	10	1,050
2 x 4	1.85	3.62	0.936	290	181.3	36.3	72.5	10	1,700
	1.85	3.62	0.936	290	181.3	36.3	72.5	10	1,700
	1.85	3.62	0.936	290	181.3	36.3	72.5	10	1,700
3 x 3	3.00	3.34	1.32	734	460	92.0	184	10	2,950
	3.00	3.34	1.32	735	460	92.0	184	10	2,950
	3.00	3.34	1.32	735	460	92.0	184	10	2,950
6 x 6	6.06	5.79	2.53	b	3,250	650	1,300	500	11,000
	6.06	5.73	2.52	b	3,250	650	1,300	500	11,000
	6.06	5.71	2.51	b	3,250	650	1,300	500	11,000
6 x 12	6.00	11.6	3.03	9,620	6,139	1,228	2,456	1,000	18,200
	6.00	12.5	3.07	9,250	6,139	1,228	2,456	1,000	18,200
	6.00	11.1	3.00	9,430	6,139	1,228	2,456	1,000	18,200
12 x 12	12.5	11.5	5.14	40,000	24,900	4,990	9,980	10,000	44,000
	12.3	11.5	5.09	40,100	24,900	4,990	9,980	10,000	44,000
	12.3	11.5	5.09	39,800	24,900	4,990	9,980	10,000	44,000
22 x 22	21.5	21.5	9.10	228,340	143,700	28,740	51,480	20,000	136,200

[a]Rohm and Haas Amberlite organic cation exchange resin.
[b]Not weighed.

2.2.2 Boric Acid/Cement Composites

The simulated boric acid waste described above was heated to 170°F prior to solidification in Portland III cement so as to simulate actual solidification conditions at power reactor sites. The ratio of waste-to-cement was 0.7 and the nominal dimensions (in inches) of the solidified samples were 1 x 1, 2 x 2, 2 x 4, 3 x 3, and 6 x 6. The ^{137}Cs radiotracer was added to the simulated waste prior to solidification. The amount of the radiotracer incorporated in each waste form was determined using the procedure described earlier in this report.

The compositions of simulated boric acid waste forms are summarized in Table 2. All samples were made in triplicate (except for the 3 x 3 size samples which were made in duplicate) and cured for 31 days in sealed polyethylene containers.

Table 2

Composite Dimensions, Components, and Leachant Volumes for Waste Forms Incorporating Boric Acid

Sample	Composite				Components (g)				^{137}Cs Added to Composite	Volume of Leachant
					Cement	Waste				
	Diameter (in.)	Height (in.)	V/S (cm)	Weight[a] (g)	Portland III	H_3BO_3	NaOH	H_2O	(μCi)	(mL)
1 x 1	0.97	0.94	0.408	19.8	11.8	0.9	0.9	6.5	1	275
	0.97	0.93	0.405	19.8	11.8	0.9	0.9	6.5	1	275
	0.97	0.91	0.402	19.5	11.8	0.9	0.9	6.5	1	275
2 x 2	1.83	1.89	0.783	149	88.2	6.6	6.7	48.4	20	1,050
	1.83	1.89	0.783	150	88.2	6.6	6.7	48.4	20	1,050
	1.83	1.89	0.783	150	88.2	6.6	6.7	48.4	20	1,050
2 x 4	1.86	3.62	0.939	288	170.6	12.8	13.0	93.6	20	1,700
	1.86	3.62	0.939	288	170.6	12.8	13.0	93.6	20	1,700
	1.86	3.58	0.937	289	170.6	12.8	13.0	93.6	20	1,700
3 x 3	3.06	3.27	1.32	697	412	30.8	31.5	22.6	20	2,950
	3.06	3.27	1.32	698	412	30.8	31.5	22.6	20	2,950
6 x 6	5.91	6.02	2.52	b	2,941	220	225	1614	1,000	11,000
	5.91	5.98	2.51	b	2,941	220	225	1614	1,000	11,000
	5.91	6.10	2.53	b	2,941	220	225	1614	1,000	11,000

[a]Weight of waste form after removal from mold.
[b]Not weighed.

2.3 Waste Form Leaching

The composites were leached in deionized water using a modified IAEA leaching procedure[15] described earlier. The leaching volume was determined by the relationship: V = 10 cm x S, where V is the leachant volume and S is the geometric surface of the composite being leached.

Leaching was carried out in two sets of containers. The samples were placed in a fresh leachant and the leachate from the previous period was acidified with HNO_3 (volume of conc. acid 1% volume of leachate). Ten-milliliter aliquots of this acidified leachate were withdrawn in a plastic test tube and assayed for ^{137}Cs content using a 3 in. x 3 in. NaI well crystal. The remaining liquid was removed, the container was washed, and fresh leachant was added to it for the next leaching period. The leachant was allowed to equilibrate to room temperature overnight before transferring the waste form from the other container.

All samples were counted until a minimum of 1,000 counts were accumulated in the "window" set around the ^{137}Cs photopeak (661.6 keV). Data reduction was performed using a computer program developed at BNL.[18] Incremental fractional and cumulative fractional releases were calculated. Cumulative fractional release data are presented as a function of time.

3. Results and Discussion

3.1 Leaching Data

The calculated incremental and cumulative fractional releases from each waste form are given in Appendix A for the organic ion exchange resin/cement composites (Tables A.1-A.8) and for the boric acid/cement composites (Tables A.9-A.13). The errors quoted represent only the statistical errors associated with the counting.

The solution for the mass transport diffusion model (Eq. 2) considered infers that CFR is a linear function of $t^{1/2}$. Therefore, the CFR data were plotted vs $t^{1/2}$. These plots are shown in Figures 1-16 for the organic ion exchange resins/cement composites, and Figures 17-26 for the boric acid/cement composites. Each pair of figures shown on a page represents the leach data of three replicate samples, and where applicable, the average cumulative fractional release of the intact replicates, except for the 3 x 3 and 22 x 22 samples. Some of the resin/cement composites physically deteriorated during the course of the experiment. Two of the 1 x 1, one of the 6 x 6 and the larger waste forms (6 x 12, 12 x 12, and 22 x 22) disintegrated at various times during the experiment. Leach data obtained from these forms were considered only while the forms remained intact. Further details are given in CFR plots displayed in Figures 1-16. The average cumulative fractional release curves were normalized for V/S variation in the waste forms. The vertical error bars represent variation in leach data of replicate samples.

Continued on Page 22

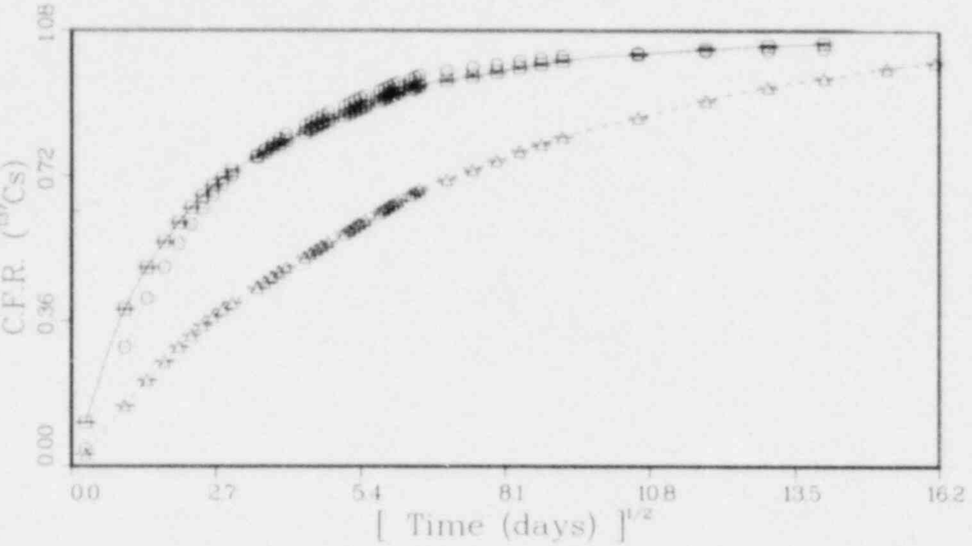

Figure 1 ^{137}Cs cumulative fractional release vs $(time)^{1/2}$ from 1-inch-diameter x 1-inch-high resin waste composites (w/c = 0.6). The two forms denoted by □ and • partially disintegrated during the first three weeks of leaching.

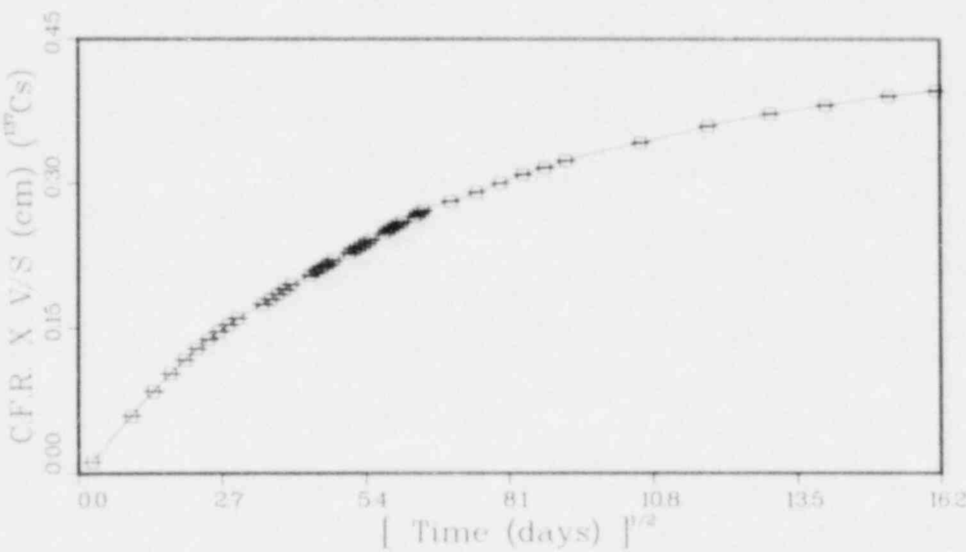

Figure 2 Volume/surface area normalized CFR of ^{137}Cs vs $(time)^{1/2}$ from the intact 1-inch-diameter x 1-inch-high resin waste composite as denoted by Δ in Figure 1 (w/c = 0.6; V/S = 0.396 cm for the three samples).

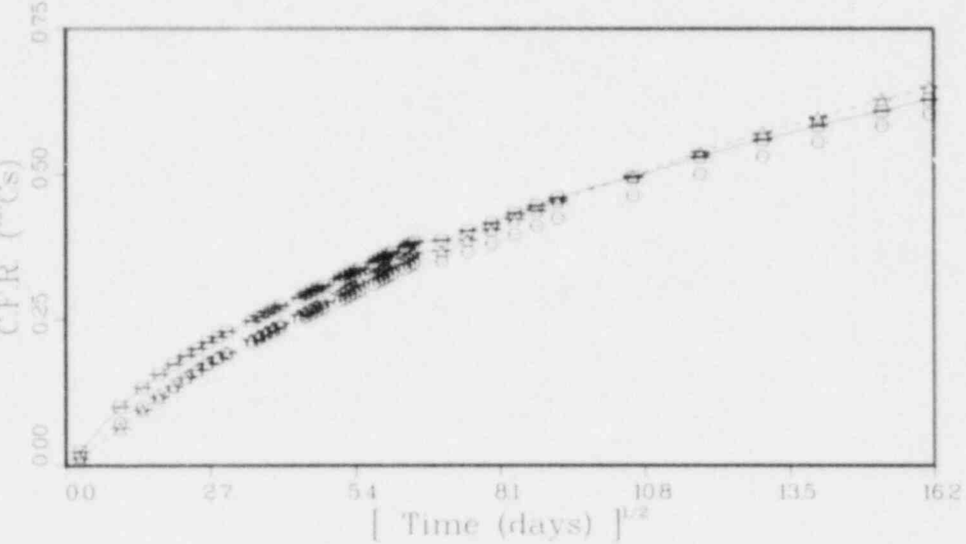

Figure 3 ^{137}Cs cumulative fractional release vs (time)$^{1/2}$ from 2-inch-diameter x 2-inch-high resin waste composites (w/c = 0.6).

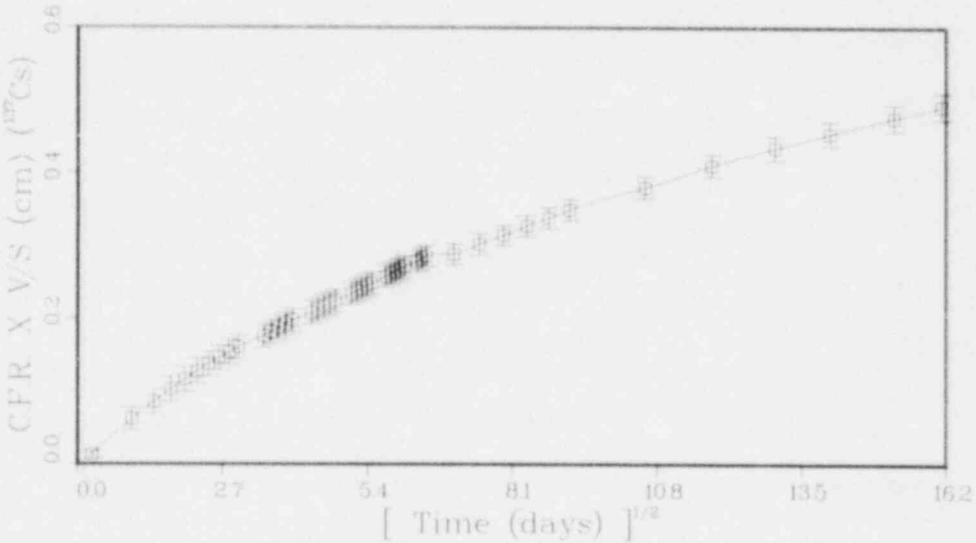

Figure 4 Volume/surface area normalized average CFR of ^{137}Cs vs (time)$^{1/2}$ from 2-inch-diameter x 2-inch-high resin waste composites (w/c = 0.6; V/S = 0.784 cm for the three samples).

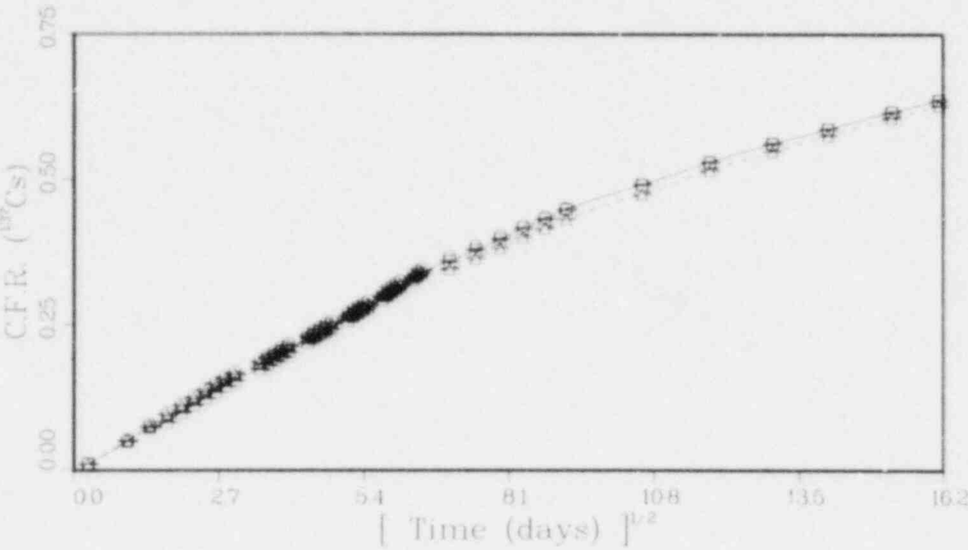

Figure 5 ^{137}Cs cumulative fractional release vs $(time)^{1/2}$ from 2-inch-diameter x 4-inch-high resin waste composites (w/c = 0.6).

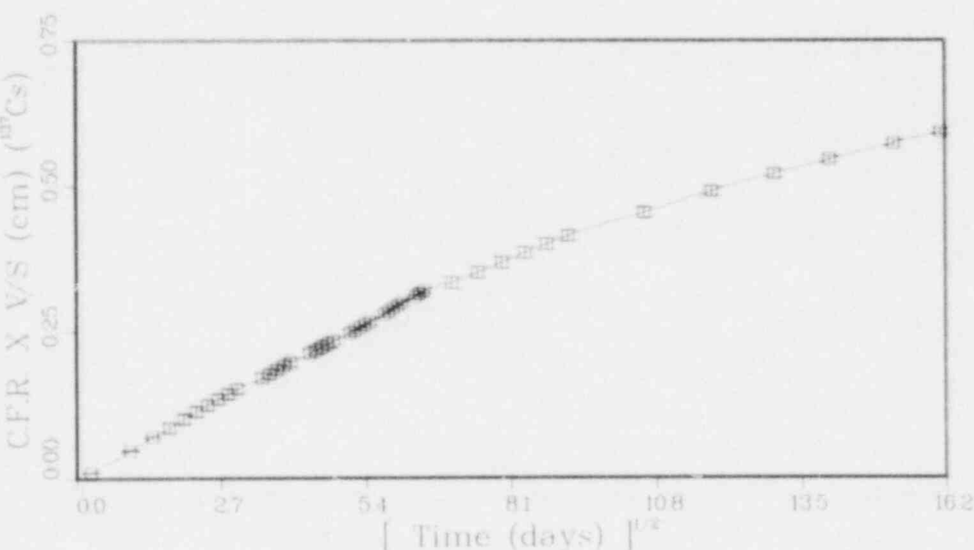

Figure 6 Volume/surface area normalized average CFR of ^{137}Cs vs $(time)^{1/2}$ from 2-inch-diameter x 4-inch-high resin waste composites (w/c = 0.6; V/S = 0.936 cm for the three samples).

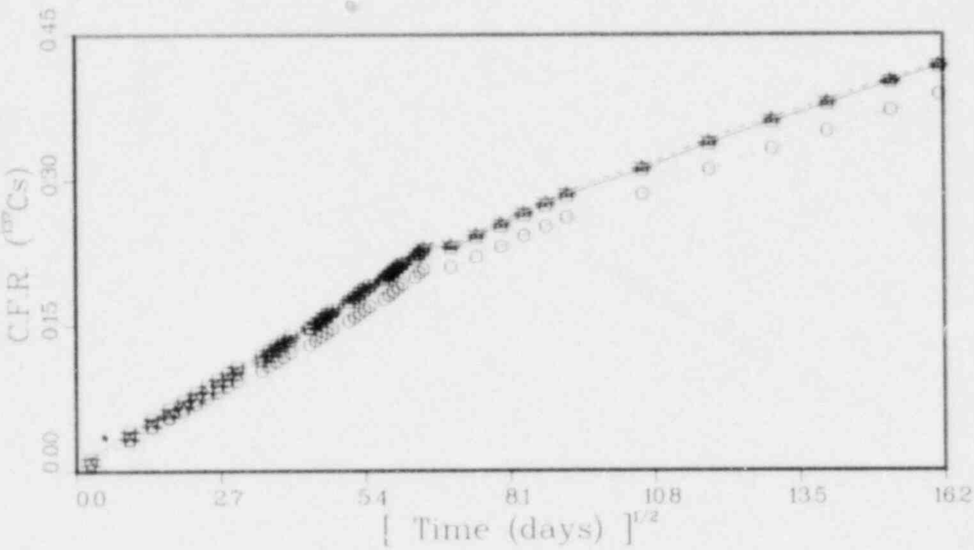

Figure 7 ^{137}Cs cumulative fractional release vs $(time)^{1/2}$ from 3-inch-diameter x 3-inch-high resin waste composites (w/c = 0.6).

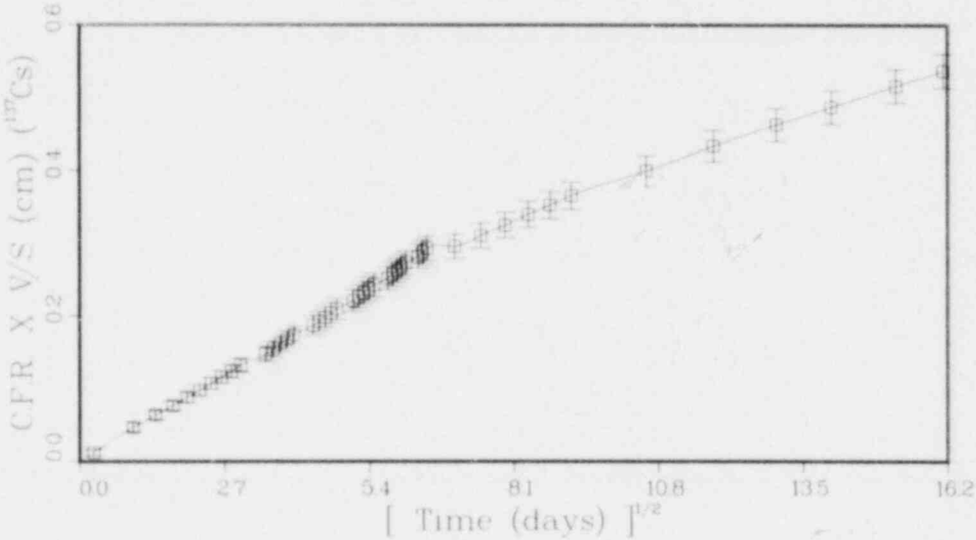

Figure 8 Volume/surface area normalized average CFR of ^{137}Cs vs $(time)^{1/2}$ from 3-inch-diameter x 3-inch-high resin waste composites (w.c. = 0.6; V/S = 1.32 cm for the three samples).

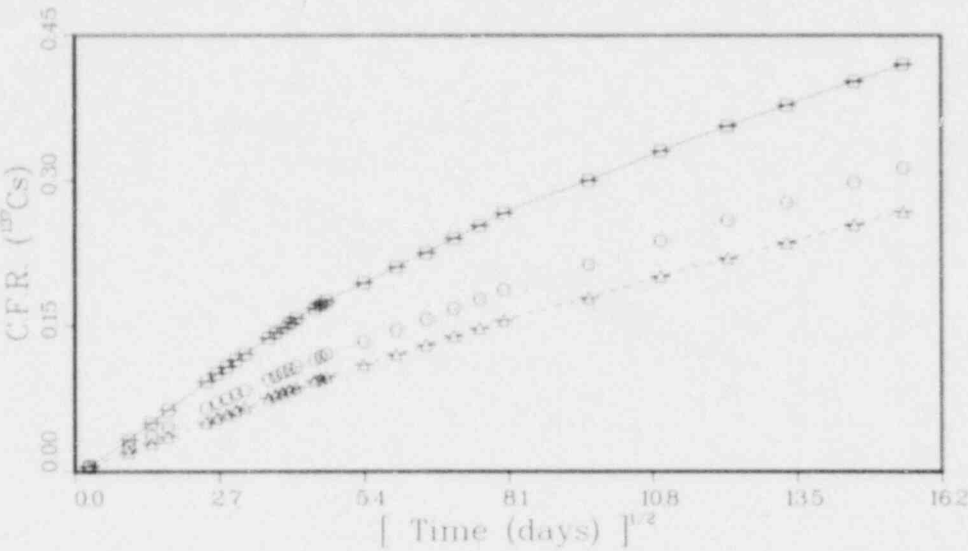

Figure 9 ^{137}Cs cumulative fractional release vs $(time)^{1/2}$ from 6-inch-diameter x 6-inch-high resin waste composites (w/c = 0.6). The form denoted by □ partially disintegrated during the first four weeks of leaching.

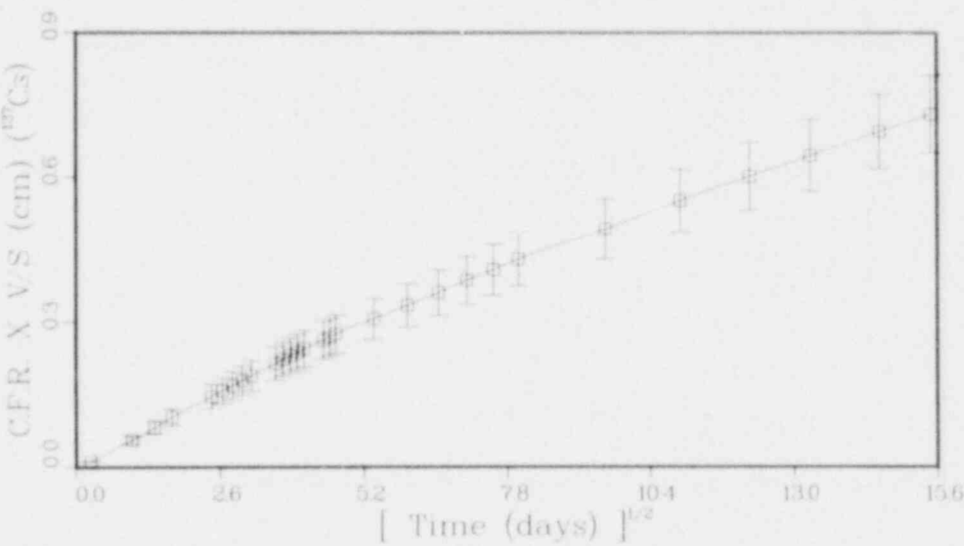

Figure 10 Volume/surface area normalized average CFR of ^{137}Cs vs $(time)^{1/2}$ from the two intact 6-inch-diameter x 6-inch-high resin waste composites as denoted by o and Δ in Figure 9 (w/c = 0.6; V/S = 2.53, 2.52, and 2.51 cm for the three samples).

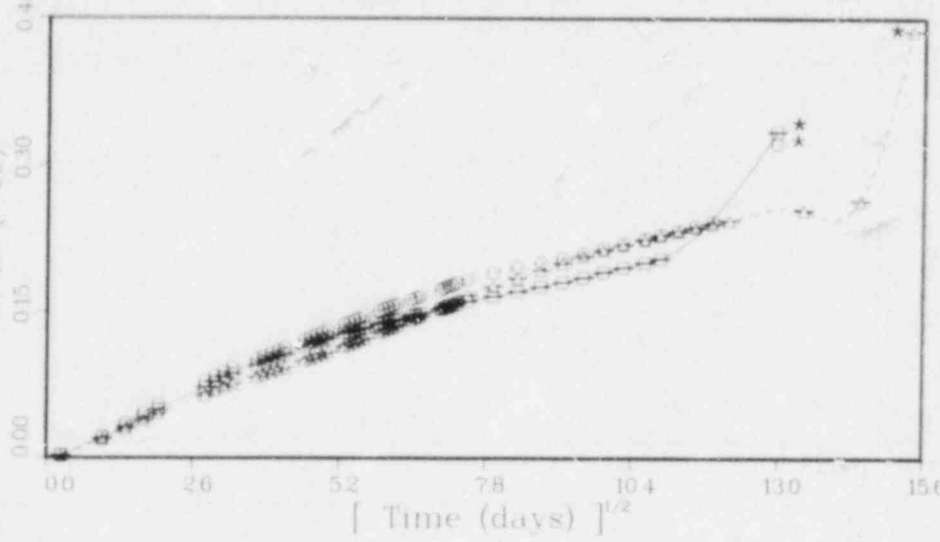

Figure 11 ^{137}Cs cumulative fractional release vs (time)$^{1/2}$ from 6-inch-diameter x 12-inch high resin waste composites (w/c = 0.6). *Indicates excessive release due to catastrophic failure of waste forms.

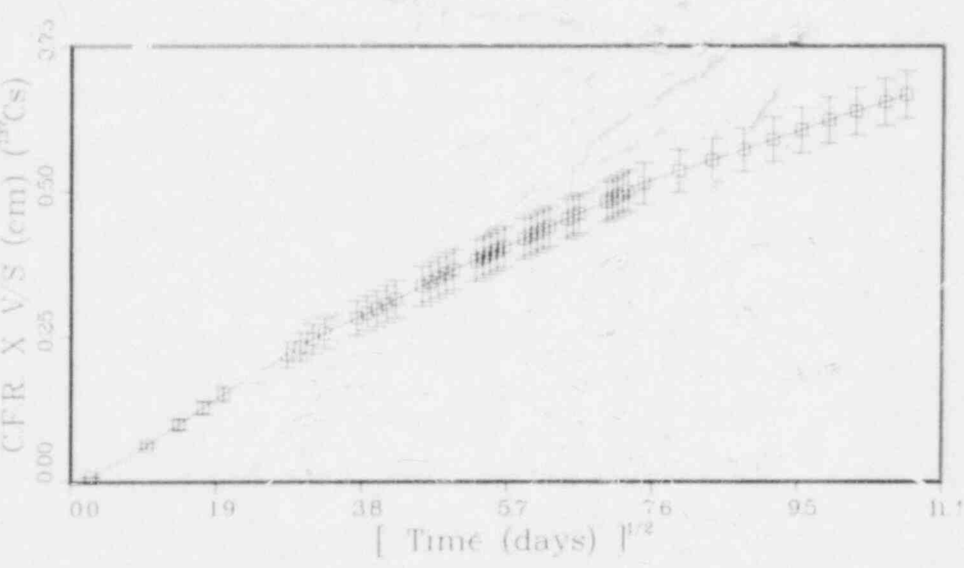

Figure 12 Volume/surface area normalized average CFR of ^{137}Cs vs (time)$^{1/2}$ from 6-inch-diameter x 12-inch-high resin waste composites (w/c = 0.6; V/S = 3.03, 3.07, and 3.00 cm for the three samples). The average CFR plot is based on the data for the time periods during which forms were intact. Data beyond 119 days, shown in Figure 11, were not considered.

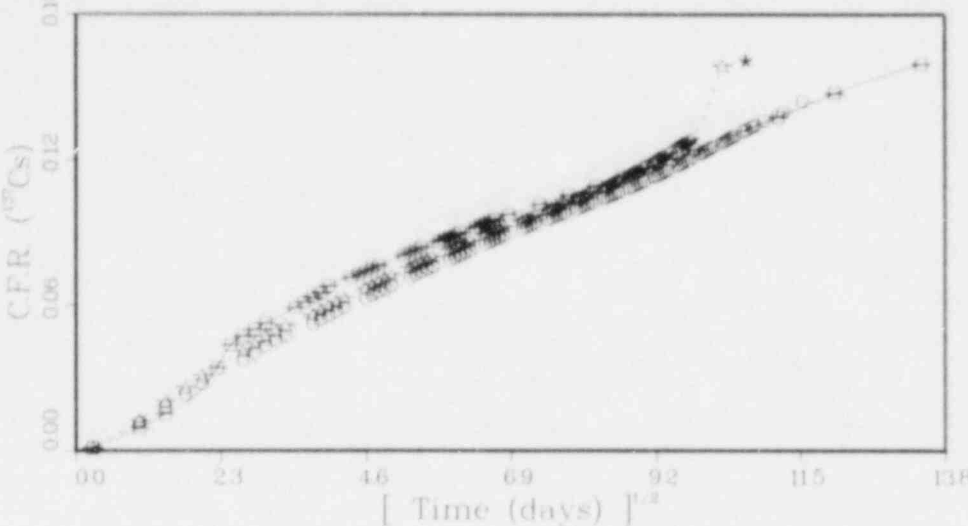

Figure 13 ^{137}Cs cumulative fractional release vs $(time)^{1/2}$ from 12-inch-diameter x 12-inch high resin waste composites (w/c = 0.6). *Indicates excessive release due to catastropic failure of waste forms. The composite represented by ☐ was observed to disintegrate during the early period of the experiment.

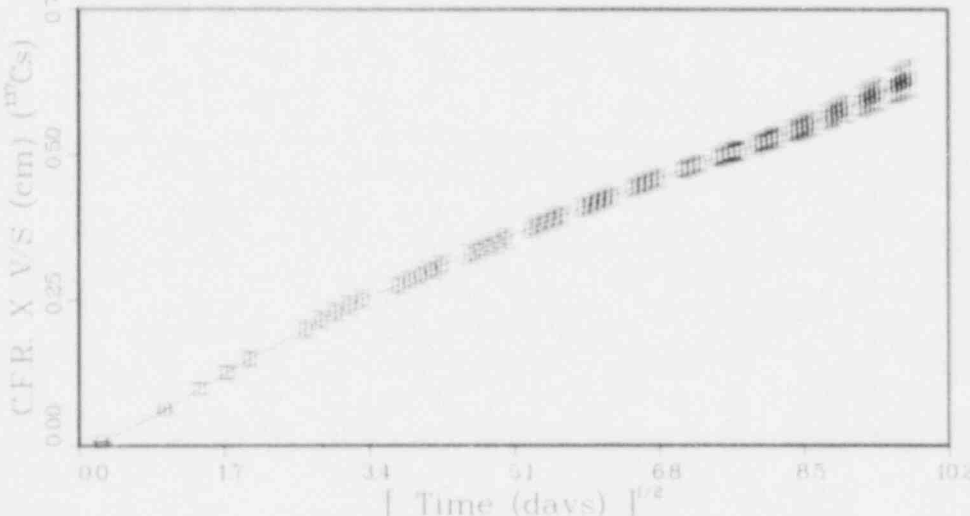

Figure 14 Volume/surface area normalized average CFR of ^{137}Cs vs $(time)^{1/2}$ from 12-inch-diameter x 12-inch-high resin waste composites (w/c = 0.6; V/S = 5.14, 5.09, and 5.09 cm for the three samples). The average was calculated for the time period during which forms were intact. The composite denoted by ☐ in Figure 13 was not included in the average CFR plot because it does not represent the release curve for a truly intact form. Data beyond 96 days, shown in Figure 13, were not considered.

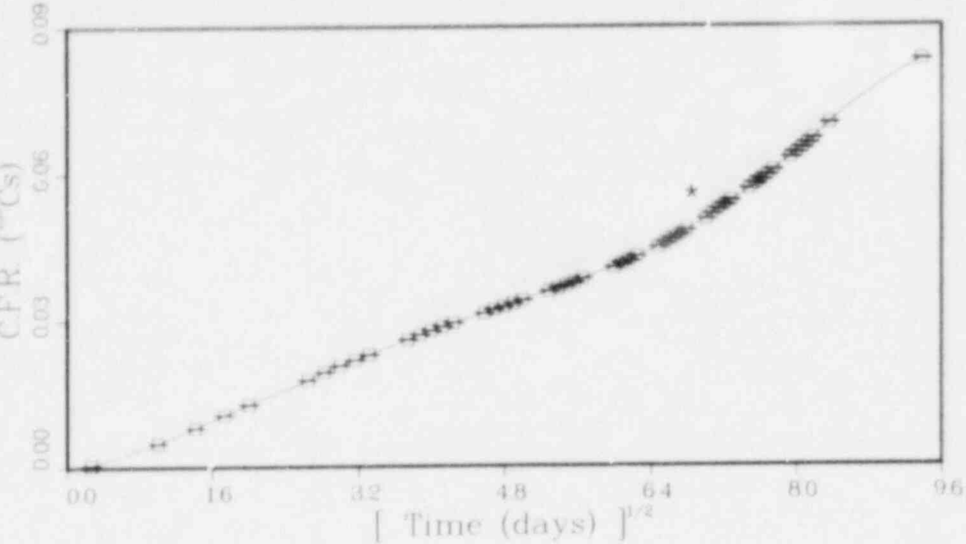

Figure 15 ^{137}Cs cumulative fractional release vs (time)$^{1/2}$ from 22-inch-diameter x 22-inch high resin waste composite (w/c = 0.6). Waste forms began to distintegrate after 42 days. *Indicates time at which form failed catastrophically. For this particular size, only one form was tested.

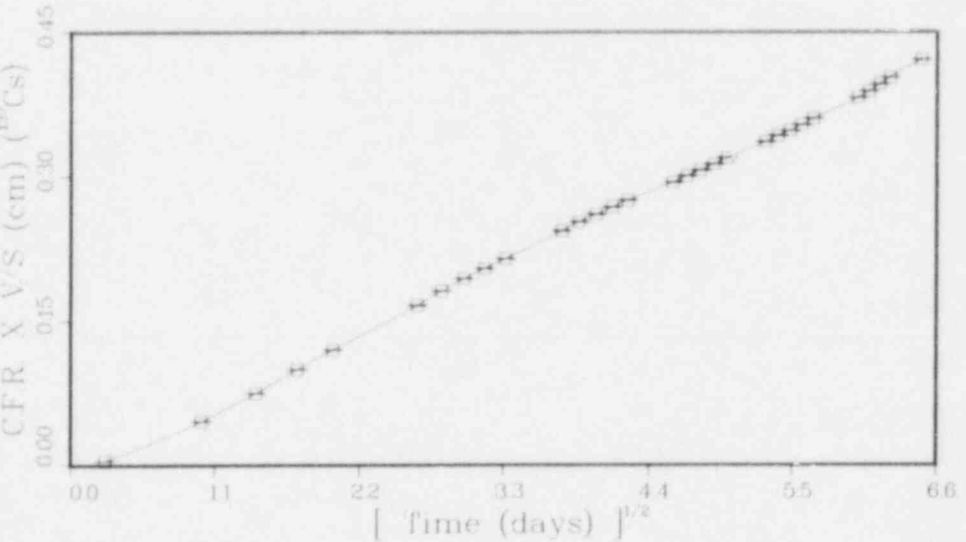

Figure 16 Volume/surface area normalized average CFR of ^{137}Cs vs (time)$^{1/2}$ from 22-inch-diameter x 22-inch-high resin waste composite (w/c = 0.6; V/S = 9.10 cm). Data beyond 42 days, shown in Figure 15, were not considered.

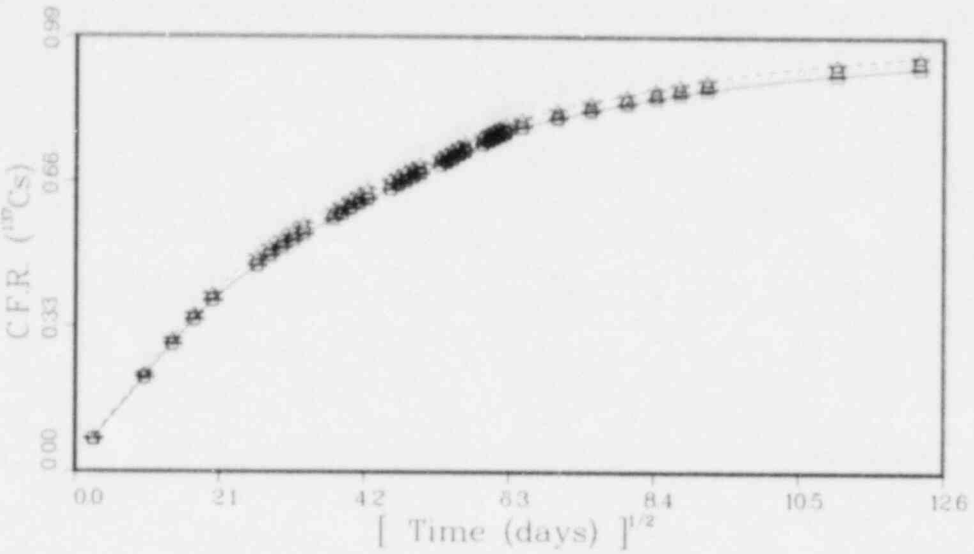

Figure 17 ^{137}Cs cumulative fractional release vs $(time)^{1/2}$ from 1-inch-diameter x 1-inch-high boric acid waste composites (w/c = 0.7).

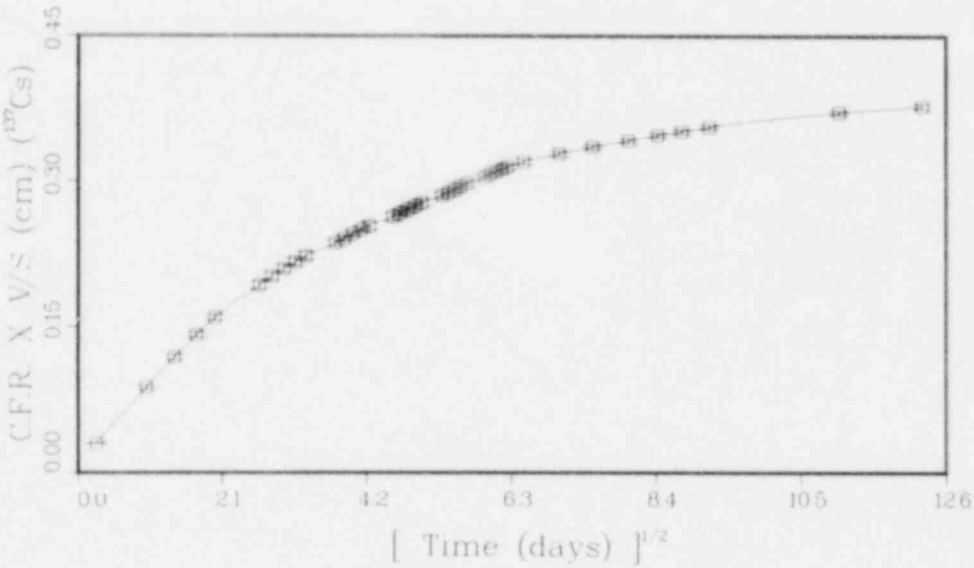

Figure 18 Volume/surface area normalized average CFR of ^{137}Cs vs $(time)^{1/2}$ from 1-inch-diameter x 1-inch-high boric acid waste composites (w/c = 0.7; V/S = 0.408, 0.405, and 0.402 cm for the three samples).

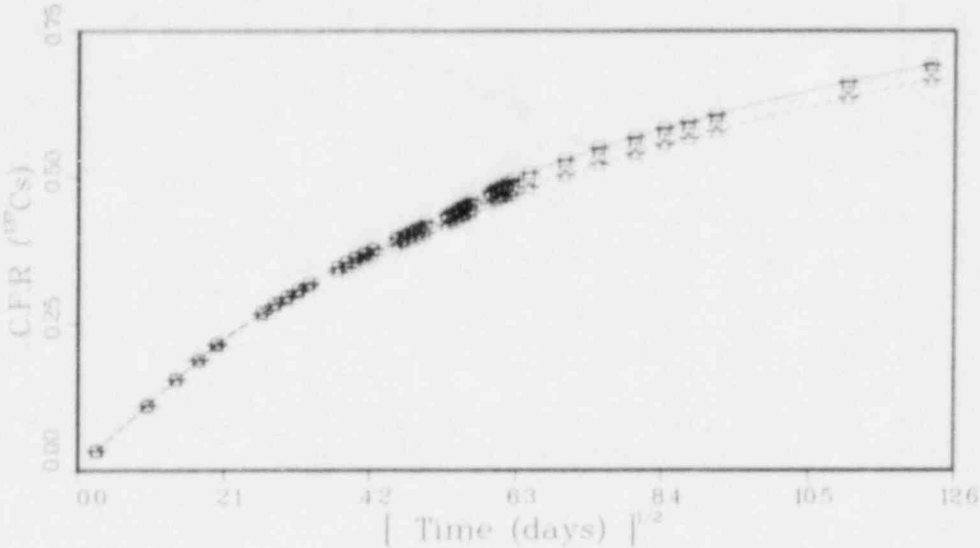

Figure 19 ^{137}Cs cumulative fractional release vs $(time)^{1/2}$ from 2-inch-diameter x 2-inch-high boric acid waste composites (w/c = 0.7).

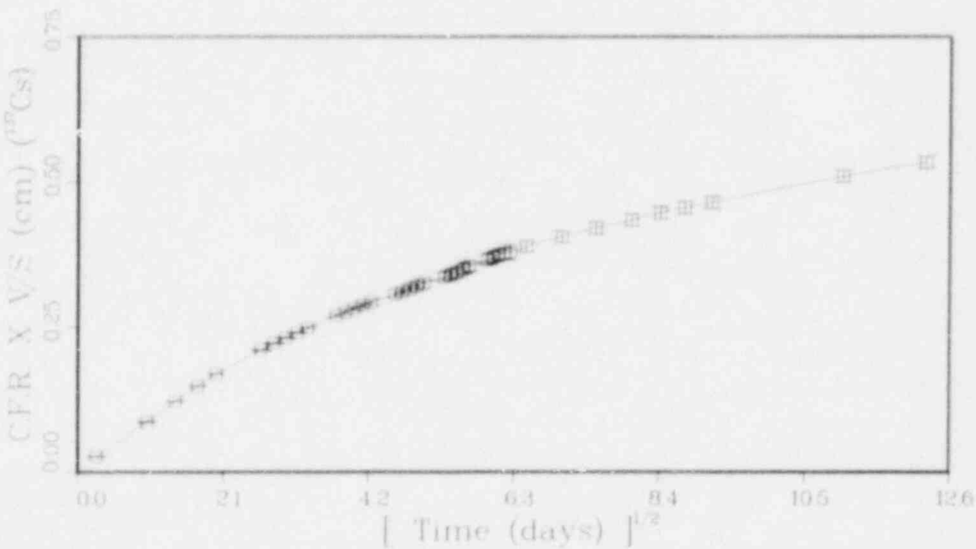

Figure 20 Volume/surface area normalized average CFR of ^{137}Cs vs $(time)^{1/2}$ from 2-inch-diameter x 2-inch-high boric acid waste composites (w/c = 0.7; V/S = 0.783 cm for the three samples).

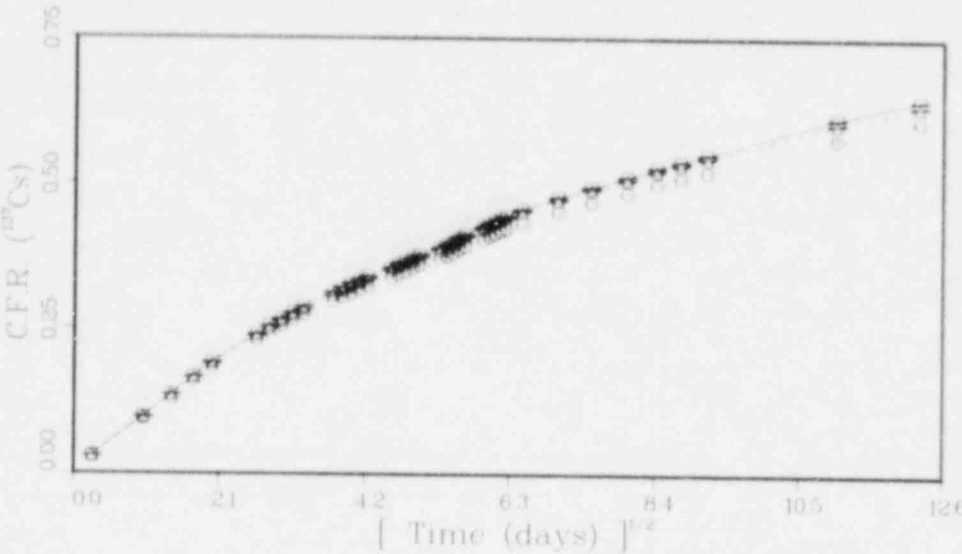

Figure 21 ^{137}Cs cumulative fractional release vs $(time)^{1/2}$ from 2-inch-diameter x 4-inch-high boric acid waste composites (w/c = 0.7).

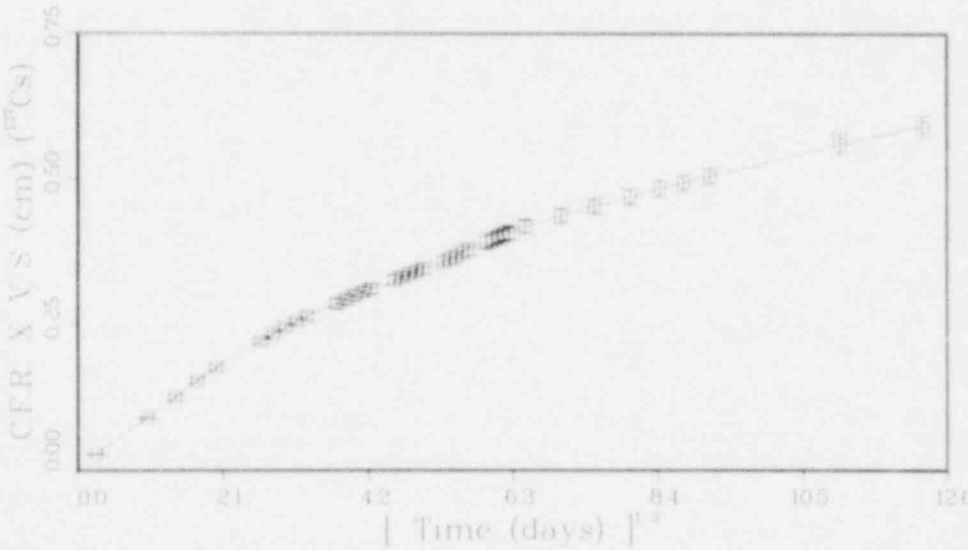

Figure 22 Volume/surface area normalized average CFR of ^{137}Cs vs $(time)^{1/2}$ from 2-inch-diameter x 4-inch-high boric acid waste composites (w/c = 0.7; V/S = 0.939, 0.939, and 0.937 cm for the three samples).

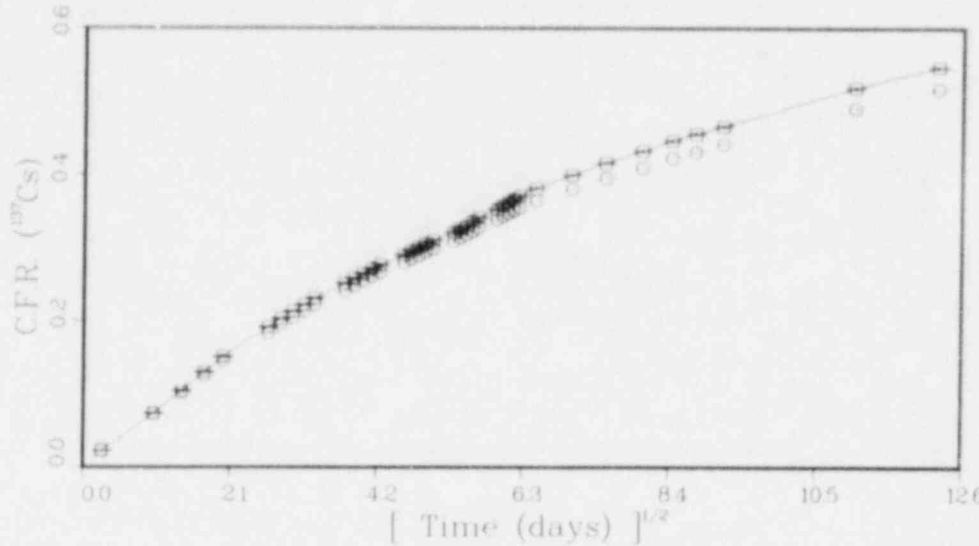

Figure 23 ^{137}Cs cumulative fractional release vs (time)$^{1/2}$ from 3-inch-diameter x 3-inch-high boric acid waste composites (w/c = 0.7).

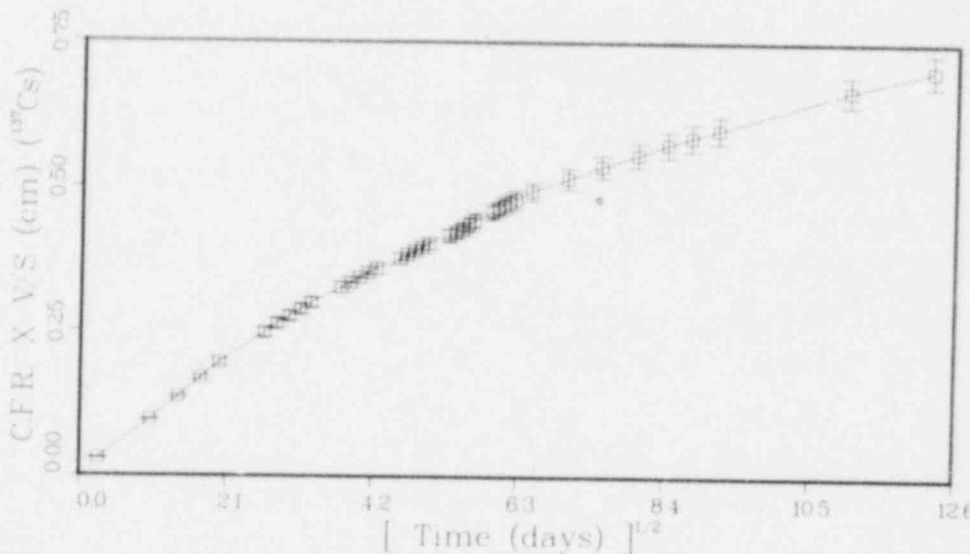

Figure 24 Volume/surface area normalized average CFR of ^{137}Cs vs (time)$^{1/2}$ from 3-inch-diameter x 3-inch-high boric acid waste composites (w/c = 0.7; V/S = 1.32 cm for the two samples).

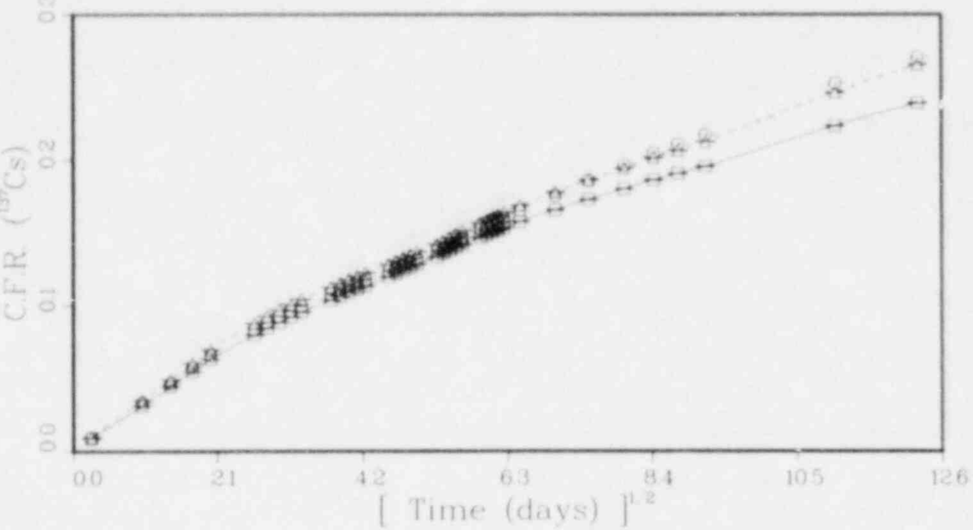

Figure 25 ^{137}Cs cumulative fractional release vs $(time)^{1/2}$ from 6-inch-diameter x 6-inch-high boric acid waste composites (w/c = 0.7).

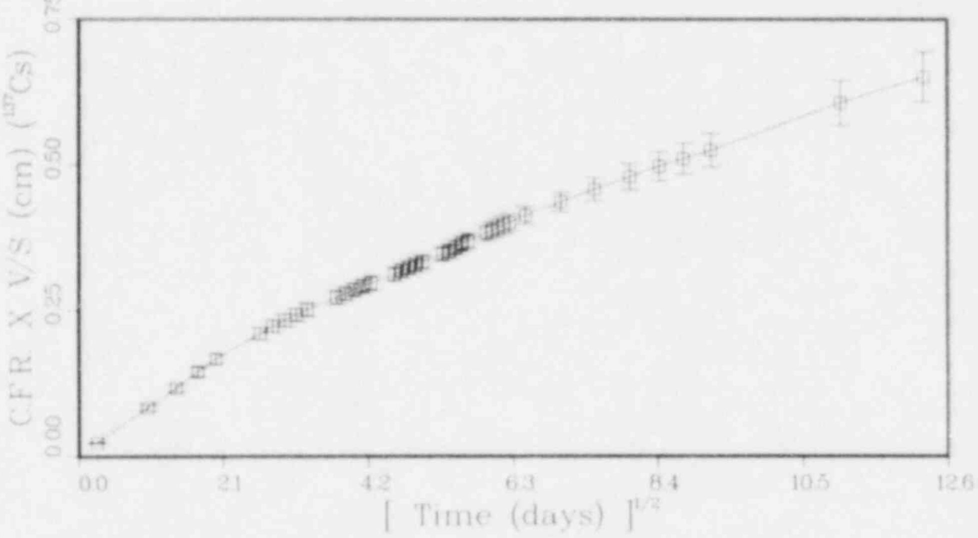

Figure 26 Volume/surface area normalized average CFR of ^{137}Cs vs $(time)^{1/2}$ from 6-inch-diameter x 6-inch-high boric acid waste composites (w/c = 0.7; V/S = 2.52, 2.51, and 2.53 cm for the three samples).

3.2 Sample Failure During Leaching

As mentioned in Section 3.1, some of the organic ion exchange resin/cement composites failed during the course of the leaching experiment. In particular, two of the 1 x 1, and one of the 6 x 6 composites partially disintegrated during the first three weeks of leaching. The cause of the deterioration of the 1 x 1 samples is not known. However, in the case of the 6 x 6 sample, the deterioration occurred mainly along a line on the sample which corresponds to a crack in the mold used in the fabrication of this sample.

In addition, the 6 x 12, 12 x 12, and 22 x 22 samples deteriorated after approximately 150, 120, and 70 days of leaching, respectively. The physical disintegration of these forms appeared initially as hair-line radial cracks on the surface (see Figures 27-29). These cracks widened gradually with time, resulting in a catastrophic failure that usually occurred between sampling periods. The samples then appeared as if they exploded from the core. The resulting cylindrical pie-shaped fragments were hard and "non-crumbly" except for those resulting from the 22 x 22 sample.

Three samples (6 x 6, 6 x 12, and 12 x 12) with identical formulation as the leaching samples were prepared. Calibrated thermocouples were inserted in the centers of the samples immediately after mixing. The temperature was followed for a 20-hour period. The data are shown in Figure 30.

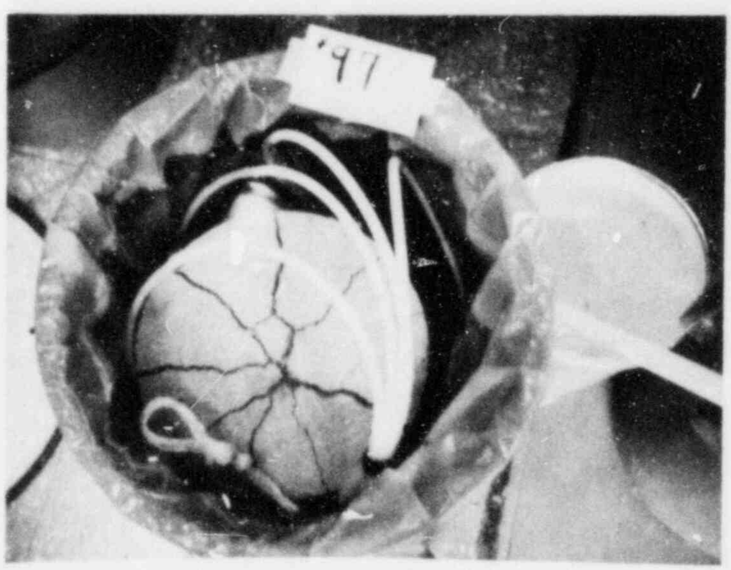

Figure 27 Top view of a 12 x 12 waste form showing radial cracks after 180 days of leaching.

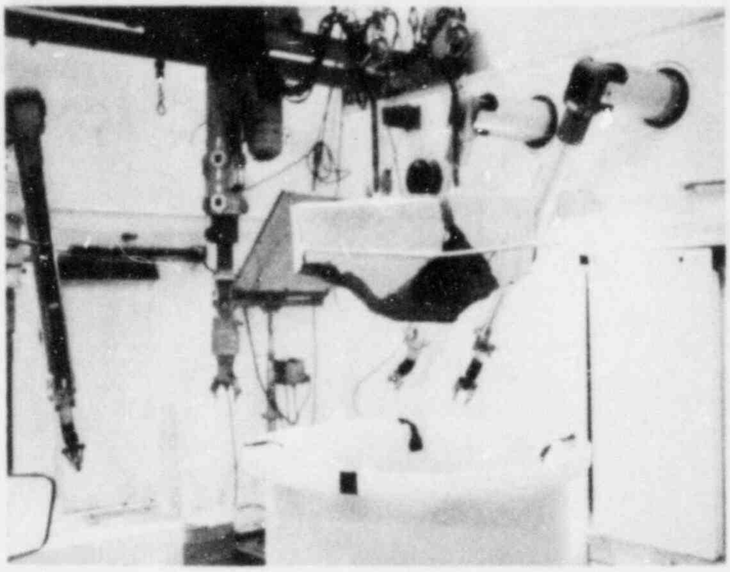

Figure 28 Top portion of the 22 x 22 form after catastrophic failure.

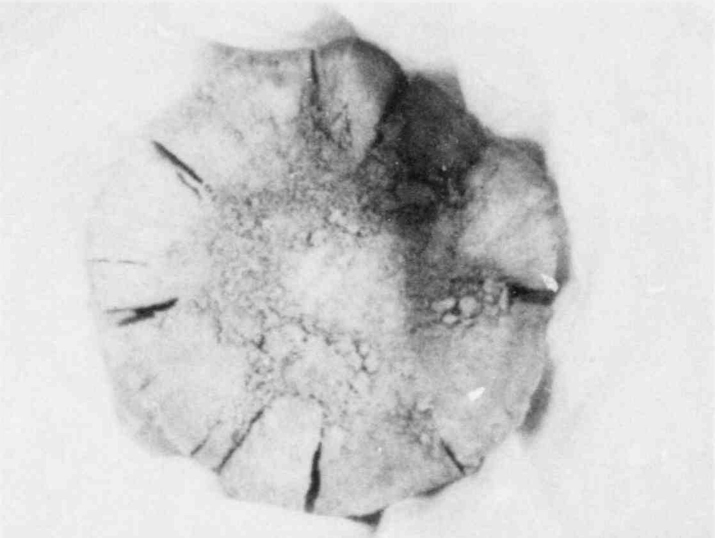

Figure 29 Bottom portion of the 22 x 22 form after catastrophic failure. Note radial cracks.

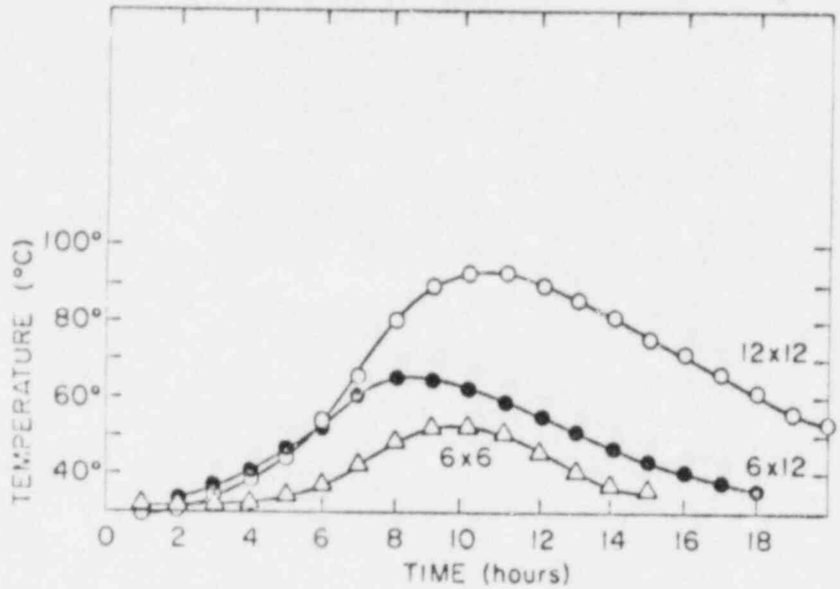

Figure 30 Temperature changes of 6 x 6, 6 x 12, and 12 x 12 forms over a 20-hour period starting immediately after mixing the forms.

The maximum temperature measured at the center of the forms were: 52°, 66°, and 92°C for the 6 x 6, 6 x 12, and 12 x 12, respectively. This excessive rise in the temperature of the central part of the large forms may have affected the hydration at the core of the specimens and may be related to their disintegration after leaching.

3.3 Analysis of Leach Data

As discussed in an earlier report,(1) a semi-empirical approach based on the semi-infinite plane source diffusion model is presented to analyze the leach data. This approach is applied to both the organic ion exchange resin/cement composites and the boric acid/cement composites.

3.3.1 Analysis of Leach Data From Organic Ion Exchange Resin/Cement Composites

Rewriting Equation (2) given on Page 2 yields:

$$f = [S/V \cdot 2(D/\pi)^{1/2}] \times t^{1/2} + \alpha \qquad (3)$$

This relationship describes a straight line with slope = $S/V \cdot 2(D/\pi)^{1/2}$ and intercept α when f is plotted vs $t^{1/2}$.

Appropriate linear regions of the ^{137}Cs release curves displayed in Figures 1-16 were selected visually. The selection was based on the fact that the dominant diffusional mass transport reaction occurs in the linear regions summarized in Table 3 and that the initial reactions are primarily surface-controlled and not representative of the overall release curve.

Table 3

Linear Regions of CFR vs $t^{1/2}$ Data From IRN-77 Resin/Cement Composites

Size	S/V (cm^{-1})	Linear Region[a] of CFR vs $t^{1/2}$
2x2	1.28	Beyond 36 days of leaching
2x4	1.07	" 36 " " "
3x3	0.76	" 36 " " "
6x6	0.40	" 16 " " "
6x12	0.33	" 49 " " "
12x12	0.19	" 9 " " "
22x22	0.11	" 7 " " "

[a]Linear regions of CFR vs $t^{1/2}$ in Figures 1-16.

The average CFR's from the intact forms for each size studied were calculated for the regions outlined in Table 3 and were plotted vs $t^{1/2}$ as shown in Figure 31. The data from the 1 x 1 forms were not considered since they did not fit the diffusion model. The surface-to-volume ratio was the largest for this size (2.53 cm^{-1}). As a result, the surface effects will be most pronounced in this particular size relative to the other sample sizes.

A least squares linear regression was performed on these lines to determine the best fit, slopes and intercepts. The results of these calculations are summarized in Table 4, together with the coefficients of determination as defined by:

$$R^2_{(S/V)} = \left(\frac{\alpha\Sigma(CFR)_i + b\Sigma(t^{1/2})_i \times (CFR)_i - 1/n(\Sigma(CFR)_i)^2}{\Sigma(CFR)_i^2 - 1/n(\Sigma(CFR)_i)^2} \right)_{(S/V)} \quad (4)$$

where the coefficients α and b are derived coefficients from the relationship: $(CFR)_{(S/V)} = [\alpha + b \times t^{1/2}]_{(S/V)}$ for each sample size studied.

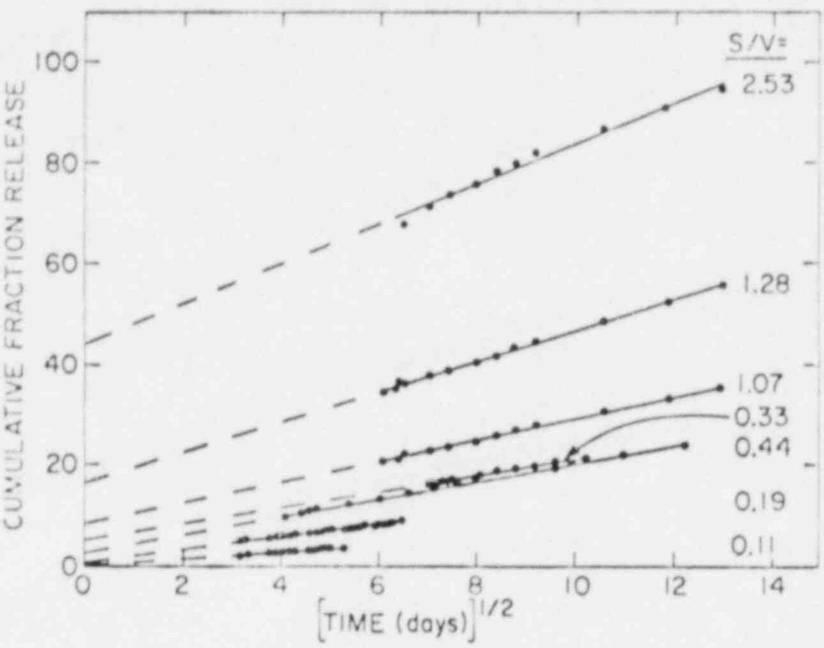

Figure 31 Solid lines represent least squares linear regression fits through average CFR's for resin/cement composites of varying sizes. Dashed lines represent extrapolation of the best fit lines to determine α, the intercept.

Table 4

Summary of Slopes and Intercepts of CFR vs $t^{1/2}$ for Resin/Cement Composites

Size	S/V (cm^{-1})	Slope[a]	Intercept[a] (α)	Coefficient of Determination[b]
2 x 2	1.28	3.03	16.4	1.0
2 x 4	1.07	3.45	11.8	0.99
3 x 3	0.76	2.10	8.15	1.0
6 x 6	0.40	1.77	2.73	1.0
6 x 12	0.33	1.58	1.58	1.0
12 x 12	0.19	1.20	0.95	1.0
22 x 22	0.11	0.66	0.11	1.0

[a]Slopes and intercepts are obtained from the general relationship CFR = $\alpha + b(t)^{1/2}$ using data in the linear region as explained in the text.
[b]The coefficient of determination is defined in Equation 4.

Since the slopes of the lines (Table 3) are represented by $[S/V \times 2(D/\pi)]^{1/2}$, plotting these slopes as a function of S/V would yield a line with a slope equal to $2(D/\pi)^{1/2}$, i.e., for $z = (S/V)$, then $d(\text{slope})/dz = 2(D/\pi)^{1/2}$. A plot of these slopes vs S/V is shown in Figure 32, indicating a linear relationship. A least squares linear regression on the points (slopes, S/V) (Table 4) yields an expression of the form: slope = a + bx, with $R^2 = 0.90$, $a = 0.75$, $b = 2.07$, where $b = 2(D/\pi)^{1/2}$.

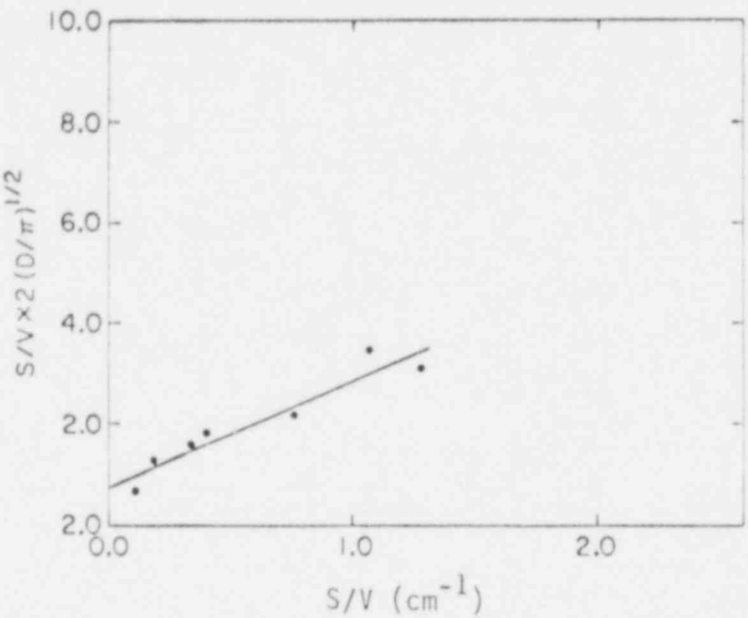

Figure 32 Plot of $[S/V \cdot 2(D/\pi)^{1/2}]$, representing slopes of the lines shown in Figure 31, vs (S/V) for resin/cement composites. The solid line is a least squares linear regression on the points for S/V less than 2.53 (i.e., forms larger than 1 x 1).

Therefore, the slope or $[S/V \cdot d(D/\pi)^{1/2}]$ could be calculated for any S/V ratio using the relationship:

$$(\text{slope})_{(S/V)} = 2.07 \times \frac{S}{V} + 0.75 \tag{5}$$

A similar fit was performed on the intercepts of the lines, shown in Figure 31, and the S/V ratios, resulting in the relationship:

$$(\alpha)_{S/V} = 1.80 + 12.6 \frac{S}{V} \tag{6}$$

A plot of these intercepts $[(\alpha)_{S/V}]$ versus their corresponding S/V ratios is shown in Figure 33.

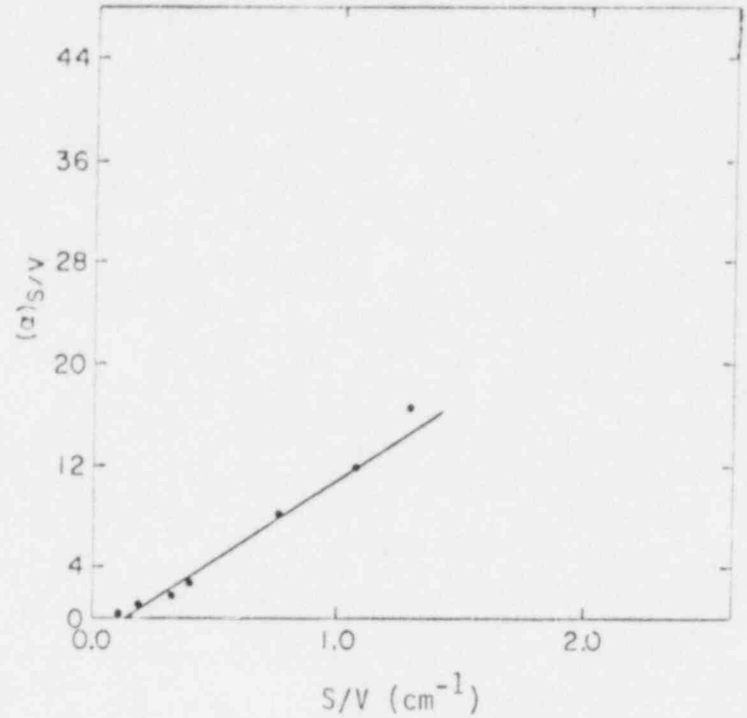

Figure 33 Plot of the intercepts $[(\alpha)_{S/V}]$ of the lines shown in Figure 31 vs S/V for resin/cement composites. The solid line is a least-squares linear regression on the points for S/V less than 2.53 (i.e., forms larger than 1 x 1).

Combining Equations (5) and (6) yields

$$(CFR) = (2.07 \cdot S/V + 0.75)t^{1/2} + (12.6 \cdot S/V - 1.80) \qquad (7)$$

Thus, the cumulative fractional release for a given time t from a sample with a geometric surface-to-volume ratio of S/V can be calculated using Equation (7). The cumulative fractional release calculated for several S/V values for different time intervals are summarized in Table 5, together with the experimental data. A good agreement is observed between the calculated values and the experimental data measured over the linear region of CFR vs $t^{1/2}$.

Table 5

Experimental and Calculated CFR Data in Percent For IRN-77/Cement Composites

Dimension	S/V (cm^{-1})	Mode	Cumulative Fractional Release Time (Days) 4	5	9	15	21	30	42	47	56	88	105	112	126	169	180	240	260
2 x 2	1.28	Expt.				24.5	27.6	31.7	36.3	*	38.6	*		48.5	*	55.4	*	*	62.7
		Calc.				27.5	29.9	32.9	36.4		39.8			50.3		58.6			66.1
2 x 4	1.07	Expt.				20.5	23.9	28.6	34.2	*	37.6	*		48.6	*	55.7	*	*	63.3
		Calc.				23.2	25.3	27.9	30.9		33.9			43.1		50.3			59.5
3 x 3	0.76	Expt.				12.8	15.0	18.4	22.2	*	23.6	*		30.3	*	35.2	*	*	40.8
		Calc.				16.8	18.4	20.5	22.9		25.2			32.4		38.0			45.3
6 x 6	0.40	Expt.			7.20	9.20	10.7	12.2	14.4	*	16.3	*		19.6	*	24.0	*	29.1	*
		Calc.			7.98	9.36	10.5	11.9	13.5		15.1			19.9		23.8		27.7	
6 x 12	0.33	Expt.		5.00	7.70	9.60	11.2	13.0	15.0	*	17.0	*	21.3	*	23.3	*	*	*	*
		Calc.		5.57	6.66	7.91	8.93	10.2	11.7		13.1		17.1		20.9				
12 x 12	0.19	Expt.		3.40	5.30	6.50	7.38	8.40	9.37	9.73	*	*	*	*	*	*	15.95	*	*
		Calc.		3.15	4.03	5.03	5.84	6.86	8.01	8.44							15.94		
22 x 22	0.11	Expt.	1.28	*	2.07	2.70	3.13	3.70	4.49	*	*	8.30	*	*	*	*	*	*	*
		Calc.	1.54		2.52	3.37	4.7	4.94	5.92			8.76							

*Experimental data not available for these time periods.

3.3.2 Analysis of Leach Data From Boric Acid/Cement Composites

The CFR from the boric/acid cement composites are shown as a function of $t^{1/2}$ in Figure 34. Data from the 2 x 4, 3 x 3, and 6 x 6 samples, after 9 days of leaching, represent the main diffusion-controlled mass transport reaction. This set of data for the post 9-day linear regions is used in calculating CFR's for the boric acid waste/cement composites. The 1 x 1 and 2 x 2 leach data were not considered here for the same reasons given for the 1 x 1 resin/cement composites (see Page 25).

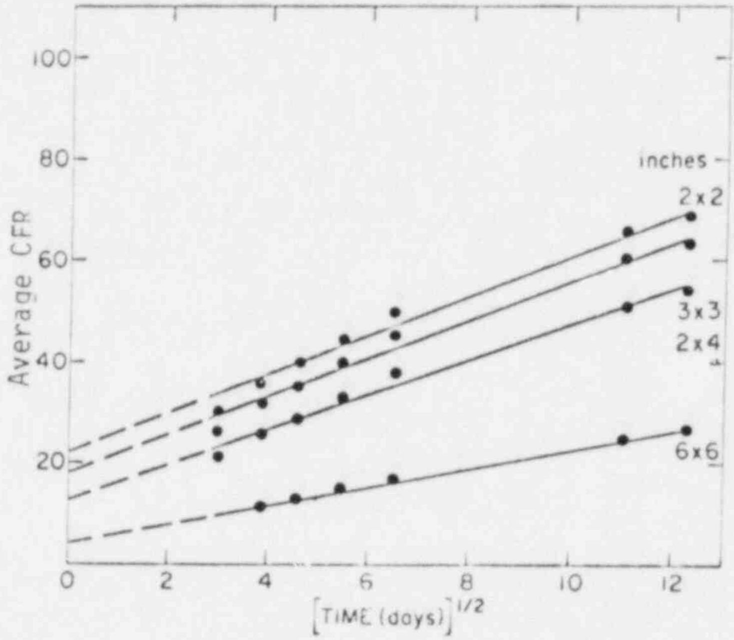

Figure 34 Solid lines represent least squares linear regression fits through average CFR's for boric acid/cement composites of varying sizes. Dashed lines represent extrapolation of the best fit lines to determine α, the intercept.

The slopes, intercepts, and coefficients of determination based on the data from the 2 x 4, 3 x 3, and 6 x 6 samples for 9 days of leaching and beyond are summarized in Table 6. Fitting the slopes and intercepts given in Table 6 versus S/V for form sizes 2 x 4, 3 x 3, and 6 x 6 yields:

$$(\text{Slope})_{(S/V)} = 3.15 \cdot S/V + 0.70 \qquad (8)$$

and

$$(\alpha)_{S/V} = 18.69 \cdot S/V - 2.63 \qquad (9)$$

Combining Equations (8) and (9) yields:

$$CFR = (3.15 \cdot S/V + 0.70)t^{1/2} + (18.69\ S/V - 2.63) \qquad (10)$$

Table 6

Summary of Slopes and Intercepts of CFR vs $t^{1/2}$ for Boric Acid/Cement Composites

Size	S/V (cm^{-1})	Slope[a]	Intercepts[a]	Coefficient of Determination[b]
2 x 2	1.28	4.05	20.2	0.98
2 x 4	1.07	3.89	16.7	0.99
3 x 3	0.76	3.41	12.7	0.99
6 x 6	0.40	1.79	4.2	1.00

[a]Slopes and intercepts are obtained from the general relationship $CFR = \alpha + b(t)^{1/2}$, using leach data beyond 9 days.

[b]The coefficient of determination is defined in Equation 4.

Using Equation (10), the CFR for several V/S ratios at different time intervals were calculated for boric acid/cement composites. These values are summarized in Table 7, together with their corresponding experimental values. A reasonably good agreement between the calculated and experimental data is observed.

Table 7

Experimental and Calculated CFR Data in Percent for Boric Acid/Cement Composites

Dimension	S/V (cm^{-1})	Mode	CFR in Days						
			9	15	21	30	42	122	150
2 x 2	1.28	Expt.	29.6	35.2	39.1	43.9	49.7	65.1	68.1
		Calc.	35.5	39.6	43.0	37.2	52.0	73.6	79.3
2 x 4	1.07	Expt.	26.1	31.2	34.7	39.5	44.7	59.8	63.0
		Calc.	29.6	33.1	36.0	39.7	43.8	62.3	67.2
3 x 3	0.76	Expt.	20.9	25.3	28.5	32.5	37.3	50.4	53.2
		Calc.	20.9	23.6	25.8	28.6	31.6	45.8	49.5
6 x 6	0.40	Expt.	9.3	11.1	12.4	14.2	16.4	24.1	25.9
		Calc.	10.7	12.4	13.8	15.6	17.6	26.5	28.9

3.4 Diffusion Coefficients of ^{137}Cs in Resin/Cement and Boric Acid/Cement Composites

The effective bulk diffusion coefficients of ^{137}Cs (D_e) in resin/cement and boric acid cement composites were estimated for each waste form size considered. Using appropriate values of S/V for each size and their respective slopes $[S/V \cdot 2(D/\pi)^{1/2}]$ derived from linear regression fits of the lines shown in Figures 31 (resin/cement composites) and 32 (boric acid/cement composites), we arrived at the D_e values summarized below in Table 8.

Table 8

Calculated Diffusion Coefficients for the Various Waste Form Sizes

Waste Form Matrix	Nominal Form Size	S/V (cm-1)	Slope	D_e (10^{-8} cm^2/s)
Resin/Cement Composites	2 x 2	1.28	3.03	0.5
	2 x 4	1.07	3.45	0.9
	3 x 3	0.76	2.10	0.7
	6 x 6	0.40	1.77	1.8
	6 x 12	0.33	1.58	2.1
	12 x 12	0.19	1.20	3.6
	22 x 22	0.11	0.66	3.3
Boric Acid/Cement Composites	2 x 2	1.28	4.05	0.9
	2 x 4	1.07	3.89	1.2
	3 x 3	0.76	3.41	1.8
	6 x 6	0.40	1.79	1.8

Figure 35 shows the dependence of D_e on S/V for both matrices. The value of D_e is observed to increase with the size of the waste form. The D_e in the resin/cement matrix varies from 0.5×10^{-8} to 3.3×10^{-8} cm^2/s for 2 x 2 and 22 x 22 samples sizes, respectively. The maximum variation being less than an order of magnitude. Comparison of D_e values for similar waste form sizes of the two matrices indicates that the matrix type does not appear to affect ^{137}Cs diffusion rate. The observed increase in D_e with increasing waste form size for both matrices could be attributed to variations in the degree of curing of large forms as compared to the smaller forms. It is worth noting that the observed dependence applies to both matrices.

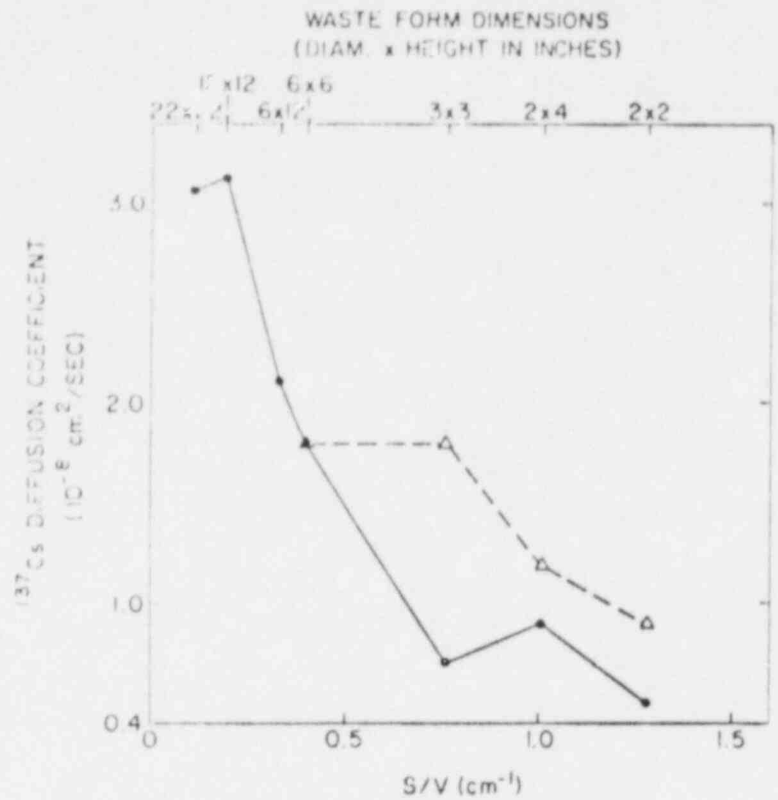

Figure 35. Calculated ^{137}Cs diffusion coefficients for resin/cement (●) and boric acid/cement (△) composites vs S/V.

4. Conclusions

The observed ^{137}Cs leach data for resin/cement and boric acid/cement can be represented by a diffusional mass transport relationship. This semi-empirical relationship can be used to estimate the cumulative fractional releases from forms varying in size from 2 x 2 to 22 x 22 for a given leaching period. The effective bulk diffusion coefficients (D_e) for ^{137}Cs in the two waste form matrices are on the order of 10^{-8} cm^2/s. D_e was observed to increase with increasing waste form size. This dependence could be attributed to variations in the degree of curing of large forms as compared to the smaller forms. Larger forms (6 x 12 and larger) were observed to disintegrate during the course of the experiment. The disintegration of these large forms may also be due to variations in curing.

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APPENDIX A

LEACH DATA FOR RESIN/CEMENT AND BORIC ACID/CEMENT COMPOSITES

Tables A.1 through A.8 present ^{137}Cs incremental and cumulative fractional release data for the various sizes of resin/cement composites.

Tables A.9 through A.13 present ^{137}Cs incremental and cumulative fractional release data for the various sizes of boric acid/cement composites.

Numerical entries under "Incremental Fraction Released x 100" column heading, represent the incremental fractional releases, followed by the 1σ percent counting uncertainty in parentheses. Numerical entries under "Cumulative Fraction Released x 100" column heading, represent the cumulative fractional releases, followed by the absolute error propagated through the summing process; (+/-) means ($\pm$).

Table A.1

^{137}Cs Incremental and Cumulative Fractional Releases From 1x1 Resin/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	10.87 (1.05)	10.87 +/- .11
1	28.03 (.65)	38.90 +/- .22
2	10.30 (1.09)	49.21 +/- .24
3	6.38 (1.38)	55.58 +/- .26
4	4.79 (1.58)	60.37 +/- .27
5	3.72 (1.81)	64.09 +/- .28
6	2.94 (2.01)	67.03 +/- .28
7	2.49 (2.18)	69.52 +/- .29
8	1.94 (2.48)	71.46 +/- .29
9	1.82 (2.58)	73.28 +/- .30
12	3.38 (1.89)	76.67 +/- .30
13	1.11 (3.35)	77.78 +/- .31
14	1.12 (3.32)	78.91 +/- .31
15	.94 (3.59)	79.84 +/- .31
16	.92 (3.66)	80.77 +/- .31
19	1.90 (2.53)	82.67 +/- .32
20	.80 (2.71)	83.47 +/- .32
21	.77 (2.80)	84.24 +/- .32
22	.69 (2.96)	84.93 +/- .32
23	.65 (3.14)	85.58 +/- .32
26	1.37 (2.98)	86.96 +/- .32
27	.60 (4.43)	87.56 +/- .32
28	.58 (3.33)	88.13 +/- .32
29	.61 (3.14)	88.75 +/- .32
30	.56 (3.25)	89.30 +/- .32
33	1.25 (2.22)	90.55 +/- .32
34	.56 (3.25)	91.11 +/- .33
35	.54 (3.37)	91.64 +/- .33
36	.49 (2.21)	92.14 +/- .33
37	.44 (2.49)	92.57 +/- .33
40	.83 (1.74)	93.40 +/- .33
41	.49 (2.23)	93.89 +/- .33
42	.45 (2.42)	94.33 +/- .33
49	1.30 (.93)	95.63 +/- .33
56	1.11 (1.52)	96.74 +/- .33
63	1.02 (1.53)	97.76 +/- .33
70	1.10 (1.53)	98.86 +/- .33
77	.88 (1.65)	99.74 +/- .33
84	.80 (1.81)	100.53 +/- .33
112	1.62 (2.75)	102.15 +/- .33
140	1.34 (.99)	103.49 +/- .33
169	.76 (2.85)	104.25 +/- .33
197	.57 (3.35)	104.83 +/- .33

Table A.1, Continued

^{137}Cs Incremental and Cumulative Fractional Releases From 1x1 Resin/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	4.19 (1.70)	4.19 +/- .07
1	25.25 (.69)	29.44 +/- .19
2	12.12 (.99)	41.56 +/- .22
3	7.77 (1.24)	49.33 +/- .24
4	5.90 (1.43)	55.23 +/- .26
5	4.67 (1.60)	59.89 +/- .27
6	3.87 (1.77)	63.77 +/- .28
7	3.32 (1.92)	67.09 +/- .28
8	2.77 (2.09)	69.86 +/- .29
9	2.28 (2.32)	72.14 +/- .29
12	4.75 (1.60)	76.89 +/- .30
13	1.51 (2.87)	78.40 +/- .31
14	1.44 (2.92)	79.84 +/- .31
15	1.23 (3.13)	81.07 +/- .31
16	1.20 (3.21)	82.27 +/- .31
19	2.19 (2.37)	84.46 +/- .32
20	.84 (3.73)	85.30 +/- .32
21	.85 (3.84)	86.15 +/- .32
22	.76 (2.83)	86.91 +/- .32
23	.75 (2.88)	87.66 +/- .32
26	1.58 (2.74)	89.24 +/- .33
27	.72 (2.84)	89.96 +/- .33
28	.66 (3.09)	90.62 +/- .33
29	.60 (3.21)	91.23 +/- .33
30	.54 (3.36)	91.76 +/- .33
33	1.24 (1.36)	93.00 +/- .33
34	.54 (2.21)	93.55 +/- .33
35	.51 (2.12)	94.06 +/- .33
36	.49 (2.20)	94.55 +/- .33
37	.47 (2.32)	95.02 +/- .33
40	.85 (1.70)	95.87 +/- .33
41	.45 (2.42)	96.32 +/- .33
42	.44 (2.47)	96.76 +/- .33
49	1.15 (1.04)	97.91 +/- .33
56	.89 (1.62)	98.80 +/- .33
63	.77 (1.72)	99.57 +/- .33
70	.88 (1.63)	100.45 +/- .33
77	.51 (2.11)	100.96 +/- .33
84	.76 (1.74)	101.72 +/- .33
112	.65 (4.26)	102.37 +/- .33
140	.51 (1.43)	102.88 +/- .33
169	.36 (4.01)	103.24 +/- .33
197	.30 (4.45)	103.53 +/- .33

Table A.1, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 1x1 Resin/Cement Composite #3

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	2.94 (2.01)	2.94 +/- .06
1	12.09 (1.00)	15.03 +/- .13
2	6.37 (1.38)	21.39 +/- .16
3	4.61 (1.62)	26.01 +/- .18
4	3.63 (1.82)	29.64 +/- .19
5	2.87 (2.06)	32.51 +/- .20
6	2.49 (2.22)	35.00 +/- .21
7	2.05 (2.41)	37.05 +/- .21
8	1.79 (2.62)	38.83 +/- .22
9	1.68 (2.[illegible]4)	40.52 +/- .22
12	3.65 (1.81)	44.17 +/- .23
13	1.27 (3.14)	45.44 +/- .23
14	1.39 (2.95)	46.82 +/- .24
15	1.20 (3.20)	48.03 +/- .24
16	1.24 (3.09)	49.27 +/- .24
19	2.47 (2.19)	51.74 +/- .25
20	1.03 (3.38)	52.77 +/- .25
21	.98 (3.57)	53.75 +/- .25
22	.86 (3.77)	54.62 +/- .26
23	.92 (3.66)	55.54 +/- .26
26	2.06 (2.40)	57.59 +/- .26
27	.87 (3.72)	58.47 +/- .27
28	.82 (2.65)	59.29 +/- .27
29	.84 (2.73)	60.12 +/- .27
30	.81 (2.67)	60.94 +/- .27
33	1.87 (1.16)	62.81 +/- .27
34	.79 (1.82)	63.60 +/- .27
35	.74 (1.80)	64.34 +/- .27
36	.69 (1.92)	65.03 +/- .27
37	.67 (1.96)	65.70 +/- .27
40	1.49 (.97)	67.19 +/- .27
41	.73 (1.49)	67.92 +/- .27
42	.67 (1.97)	68.59 +/- .27
49	2.53 (.71)	71.12 +/- .27
56	2.35 (1.02)	73.47 +/- .27
63	2.36 (1.02)	75.83 +/- .27
70	2.26 (1.01)	78.09 +/- .27
77	1.82 (1.12)	79.91 +/- .28
84	1.78 (1.15)	81.69 +/- .28
112	4.74 (1.57)	86.44 +/- .29
140	4.33 (.53)	90.76 +/- .29
169	3.22 (1.38)	93.98 +/- .29
197	2.21 (1.64)	96.19 +/- .29
232	2.44 (1.58)	98.63 +/- .30
260	1.41 (2.05)	100.04 +/- .30

Table A.2

^{137}Cs Incremental and Cumulative Fractional Releases From 2x2 Resin/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	1.16 (1.99)	1.16 +/- .02
1	5.24 (.94)	6.40 +/- .05
2	3.13 (1.21)	9.52 +/- .07
3	2.21 (1.40)	11.73 +/- .07
4	1.83 (1.58)	13.57 +/- .08
5	1.51 (1.74)	15.08 +/- .08
6	1.30 (1.88)	16.38 +/- .09
7	1.15 (2.01)	17.52 +/- .09
8	1.05 (2.10)	18.57 +/- .09
9	.89 (2.29)	19.46 +/- .09
12	2.11 (1.48)	21.57 +/- .10
13	.72 (2.57)	22.29 +/- .10
14	.76 (2.48)	23.05 +/- .10
15	.66 (2.66)	23.71 +/- .10
16	.66 (2.64)	24.37 +/- .11
19	1.50 (1.75)	25.87 +/- .11
20	.56 (2.87)	26.43 +/- .11
21	.56 (2.88)	26.99 +/- .11
22	.53 (2.97)	27.52 +/- .11
23	.50 (3.06)	28.01 +/- .11
26	1.39 (1.82)	29.40 +/- .12
27	.53 (2.96)	29.93 +/- .12
28	.52 (3.02)	30.45 +/- .12
29	.51 (2.96)	30.96 +/- .12
30	.48 (3.10)	31.44 +/- .12
33	1.34 (.83)	32.78 +/- .12
34	.50 (1.37)	33.28 +/- .12
35	.32 (1.99)	33.61 +/- .12
36	.32 (2.03)	33.92 +/- .12
37	.46 (1.40)	34.38 +/- .12
40	1.09 (.93)	35.47 +/- .12
41	.48 (1.34)	35.95 +/- .12
42	.45 (1.44)	36.40 +/- .12
49	.41 (1.46)	36.81 +/- .12
56	1.89 (.71)	38.70 +/- .12
63	1.78 (.72)	40.49 +/- .12
70	1.81 (.71)	42.30 +/- .12
77	1.49 (.77)	43.79 +/- .12
84	1.55 (.77)	45.33 +/- .13
112	4.33 (1.03)	49.66 +/- .13
140	4.14 (.33)	53.80 +/- .13
169	3.26 (.85)	57.07 +/- .14
197	2.69 (.92)	59.76 +/- .14
232	3.10 (.86)	62.86 +/- .14
260	2.10 (1.05)	64.96 +/- .14

Table A.2, Continued

^{137}Cs Incremental and Cumulative Fractional Releases From 2x2 Resin/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	1.54 (1.74)	1.54 +/- .03
1	5.70 (.90)	7.24 +/- .06
2	2.73 (.41)	9.96 +/- .06
3	2.04 (1.51)	12.01 +/- .07
4	1.67 (1.66)	13.68 +/- .07
5	1.40 (1.81)	15.08 +/- .08
6	1.20 (1.96)	16.28 +/- .08
7	1.08 (2.08)	17.36 +/- .08
8	.90 (2.26)	18.26 +/- .09
9	.87 (2.32)	19.13 +/- .09
12	1.94 (1.54)	21.07 +/- .09
13	.66 (2.67)	21.73 +/- .09
14	.66 (2.63)	22.39 +/- .10
15	.63 (2.70)	23.02 +/- .10
16	.57 (2.82)	23.60 +/- .10
19	1.35 (1.84)	24.95 +/- .10
20	.53 (2.97)	25.47 +/- .10
21	.50 (2.94)	25.97 +/- .10
22	.49 (3.13)	26.46 +/- .11
23	.49 (3.08)	26.95 +/- .11
26	1.20 (1.95)	28.16 +/- .11
27	.44 (3.23)	28.60 +/- .11
28	.43 (3.32)	29.03 +/- .11
29	.44 (3.22)	29.47 +/- .11
30	.40 (3.44)	29.88 +/- .11
33	1.16 (.87)	31.04 +/- .11
34	.48 (1.43)	31.52 +/- .11
35	.43 (1.50)	31.95 +/- .11
36	.41 (1.46)	32.36 +/- .11
37	.39 (1.53)	32.75 +/- .11
40	.92 (1.00)	33.67 +/- .11
41	.44 (1.47)	34.11 +/- .11
42	.49 (1.41)	34.60 +/- .11
49	.34 (1.61)	34.94 +/- .11
56	1.61 (.80)	36.56 +/- .12
63	1.58 (.76)	38.14 +/- .12
70	1.56 (.77)	39.70 +/- .12
77	1.37 (.80)	41.08 +/- .12
84	1.37 (.80)	42.45 +/- .12
112	3.86 (1.10)	46.31 +/- .12
140	3.75 (.36)	50.06 +/- .13
169	3.00 (.88)	53.06 +/- .13
197	2.50 (.96)	55.56 +/- .13
232	2.74 (.92)	58.30 +/- .13
260	2.01 (1.08)	60.31 +/- .13

Table A.2, Continued

^{137}Cs Incremental and Cumulative Fractional Releases From 2x2 Resin/Cement Composite #3

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	2.32 (1.41)	2.32 +/- .03
1	7.71 (.77)	10.04 +/- .07
2	3.31 (1.18)	13.35 +/- .08
3	2.26 (1.43)	15.61 +/- .08
4	1.76 (1.62)	17.37 +/- .09
5	1.45 (1.78)	18.82 +/- .09
6	1.23 (1.95)	20.05 +/- .10
7	1.09 (2.06)	21.14 +/- .10
8	.92 (2.26)	22.06 +/- .10
9	.86 (2.31)	22.92 +/- .10
12	1.89 (1.56)	24.80 +/- .11
13	.73 (2.53)	25.53 +/- .11
14	.71 (2.53)	26.24 +/- .11
15	.60 (2.78)	26.84 +/- .11
16	.57 (2.82)	27.41 +/- .11
19	1.35 (1.84)	28.76 +/- .12
20	.55 (2.84)	29.31 +/- .12
21	.51 (2.96)	29.82 +/- .12
22	.47 (3.13)	30.29 +/- .12
23	.50 (3.03)	30.79 +/- .12
26	1.19 (1.97)	31.99 +/- .12
27	.48 (3.07)	32.47 +/- .12
28	.42 (3.32)	32.89 +/- .12
29	.43 (3.25)	33.31 +/- .12
30	.42 (3.30)	33.73 +/- .12
33	1.12 (.91)	34.84 +/- .12
34	.48 (1.43)	35.33 +/- .13
35	.43 (1.51)	35.76 +/- .13
36	.38 (1.57)	36.14 +/- .13
37	.39 (1.54)	36.53 +/- .13
40	.94 (.98)	37.47 +/- .13
41	.44 (1.48)	37.91 +/- .13
42	.37 (1.60)	38.28 +/- .13
43	.34 (1.64)	38.62 +/- .13
56	1.65 (.75)	40.27 +/- .13
63	1.31 (.84)	41.58 +/- .13
70	1.71 (.73)	43.29 +/- .13
77	1.30 (.85)	44.60 +/- .13
84	1.32 (.84)	45.91 +/- .13
112	3.58 (1.13)	49.50 +/- .14
140	3.50 (.37)	52.99 +/- .14
169	2.92 (.88)	55.92 +/- .14
197	2.38 (.99)	58.30 +/- .14
232	2.56 (.95)	60.06 +/- .14
260	1.97 (1.07)	62.84 +/- .14

Table A.3

^{137}Cs Incremental and Cumulative Fractional Releases From 2x4 Resin/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	1.00 (2.74)	1.00 +/- .03
1	4.13 (1.34)	5.13 +/- .06
2	2.46 (1.75)	7.59 +/- .08
3	2.01 (1.92)	9.60 +/- .08
4	1.58 (2.15)	11.18 +/- .09
5	1.37 (2.33)	12.55 +/- .10
6	1.21 (2.50)	13.77 +/- .10
7	1.09 (2.59)	14.86 +/- .11
8	.90 (2.88)	15.76 +/- .11
9	.85 (2.95)	16.61 +/- .11
12	1.99 (1.94)	18.60 +/- .12
13	.76 (3.12)	19.36 +/- .12
14	.75 (3.17)	20.11 +/- .12
15	.71 (3.24)	20.82 +/- .12
16	.66 (3.39)	21.47 +/- .13
19	1.57 (2.17)	23.04 +/- .13
20	.57 (3.64)	23.61 +/- .13
21	.60 (3.47)	24.21 +/- .13
22	.57 (3.66)	24.78 +/- .14
23	.57 (3.66)	25.35 +/- .14
26	1.23 (2.47)	26.57 +/- .14
27	.53 (3.76)	27.11 +/- .14
28	.51 (2.76)	27.61 +/- .14
29	.54 (3.73)	28.15 +/- .14
30	.47 (2.97)	28.63 +/- .14
33	1.33 (1.06)	29.96 +/- .15
34	.56 (1.59)	30.52 +/- .15
35	.53 (1.67)	31.05 +/- .15
36	.51 (1.73)	31.56 +/- .15
37	.47 (1.72)	32.04 +/- .15
40	1.11 (1.14)	33.14 +/- .15
41	.52 (1.71)	33.66 +/- .15
42	.48 (1.70)	34.14 +/- .15
49	.40 (1.87)	34.54 +/- .15
56	1.90 (.90)	36.43 +/- .15
63	1.78 (.91)	38.22 +/- .15
70	1.83 (.89)	40.05 +/- .15
77	1.57 (.99)	41.62 +/- .15
84	1.57 (.99)	43.19 +/- .15
112	4.31 (1.31)	47.50 +/- .16
140	4.10 (.43)	51.60 +/- .16
169	3.26 (1.07)	54.86 +/- .17
197	2.71 (1.17)	57.57 +/- .17
232	3.04 (1.10)	60.61 +/- .17
260	2.10 (1.34)	62.71 +/- .18

Table A.3, Continued

^{137}Cs Incremental and Cumulative Fractional Releases From 2x4 Resin/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	1.06 (2.66)	1.06 +/- .03
1	4.15 (1.34)	5.21 +/- .06
2	2.55 (1.71)	7.76 +/- .08
3	2.02 (1.90)	9.78 +/- .09
4	1.62 (2.15)	11.40 +/- .09
5	1.42 (2.29)	12.83 +/- .10
6	1.20 (2.46)	14.03 +/- .10
7	1.06 (2.64)	15.09 +/- .11
8	.93 (2.85)	16.03 +/- .11
9	.91 (2.86)	16.93 +/- .11
12	2.00 (1.92)	18.94 +/- .12
13	.76 (3.10)	19.70 +/- .12
14	.76 (3.11)	20.46 +/- .12
15	.69 (3.33)	21.15 +/- .13
16	.61 (3.41)	21.76 +/- .13
19	1.58 (2.16)	23.34 +/- .13
20	.61 (3.52)	23.95 +/- .13
21	.59 (3.49)	24.54 +/- .13
22	.58 (3.58)	25.12 +/- .14
23	.54 (3.72)	25.66 +/- .14
26	1.32 (2.35)	26.98 +/- .14
27	.55 (3.61)	27.54 +/- .14
28	.52 (3.87)	28.05 +/- .14
29	.56 (2.64)	28.62 +/- .15
30	.53 (2.64)	29.15 +/- .15
33	1.35 (1.04)	30.50 +/- .15
34	.55 (1.60)	31.05 +/- .15
35	.52 (1.72)	31.57 +/- .15
36	.51 (1.74)	32.08 +/- .15
37	.46 (1.78)	32.54 +/- .15
40	1.07 (1.17)	33.61 +/- .15
41	.53 (1.69)	34.14 +/- .15
42	.47 (1.73)	34.61 +/- .15
49	1.99 (1.93)	36.60 +/- .15
56	1.87 (.87)	38.48 +/- .15
63	1.75 (.93)	40.22 +/- .16
70	1.78 (.91)	42.01 +/- .16
77	1.52 (.98)	43.52 +/- .16
84	1.49 (.99)	45.02 +/- .16
112	4.04 (1.36)	49.06 +/- .17
140	3.84 (.44)	52.90 +/- .17
169	3.18 (1.07)	56.08 +/- .17
197	2.56 (1.21)	58.64 +/- .17
232	2.96 (1.13)	61.60 +/- .18
260	2.03 (1.35)	63.63 +/- .18

Table A.3, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 2x4 Resin/Cement Composite #3

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	1.14 (2.54)	1.14 +/- .03
1	3.81 (1.38)	4.95 +/- .06
2	2.40 (1.76)	7.35 +/- .07
3	.95 (3.98)	8.30 +/- .08
4	1.60 (2.13)	9.90 +/- .09
5	1.32 (2.36)	11.21 +/- .09
6	1.16 (2.56)	12.37 +/- .10
7	1.08 (2.61)	13.45 +/- .10
8	.99 (2.77)	14.44 +/- .11
9	.98 (2.72)	15.42 +/- .11
12	2.00 (1.92)	17.42 +/- .12
13	.73 (3.17)	18.15 +/- .12
14	.77 (3.07)	18.92 +/- .12
15	.71 (3.25)	19.62 +/- .12
16	.69 (3.30)	20.32 +/- .13
19	1.59 (2.14)	21.91 +/- .13
20	.63 (3.43)	22.53 +/- .13
21	.59 (3.51)	23.13 +/- .13
22	.58 (3.57)	23.71 +/- .13
23	.60 (3.58)	24.31 +/- .14
26	1.45 (2.24)	25.76 +/- .14
27	.58 (3.55)	26.34 +/- .14
28	.57 (3.65)	26.91 +/- .14
29	.53 (3.75)	27.45 +/- .14
30	.52 (3.74)	27.96 +/- .15
33	1.40 (1.01)	29.36 +/- .15
34	.56 (1.58)	29.92 +/- .15
35	.53 (1.66)	30.46 +/- .15
36	.53 (1.68)	30.99 +/- .15
37	.53 (1.69)	31.51 +/- .15
40	1.22 (1.09)	32.74 +/- .15
41	.56 (1.60)	33.29 +/- .15
42	.52 (1.72)	33.81 +/- .15
49	2.10 (1.87)	35.91 +/- .15
56	1.99 (.86)	37.89 +/- .15
63	1.85 (.88)	39.74 +/- .16
70	1.86 (.88)	41.60 +/- .16
77	1.60 (.97)	43.20 +/- .16
84	1.59 (.98)	44.79 +/- .16
112	4.32 (1.30)	49.11 +/- .17
140	3.87 (.44)	52.97 +/- .17
169	3.16 (1.08)	56.14 +/- .17
197	2.55 (1.22)	58.68 +/- .18
232	2.92 (1.12)	61.61 +/- .18
260	2.08 (1.32)	63.68 +/- .18

Table A.4

^{137}Cs Incremental and Cumulative Fractional Releases From 3x3 Resin/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.62 (4.45)	.62 +/- .03
1	2.65 (2.19)	3.27 +/- .06
2	1.35 (3.09)	4.62 +/- .08
3	1.01 (3.49)	5.63 +/- .08
4	.90 (5.30)	6.53 +/- .10
5	.80 (5.68)	7.33 +/- .11
6	.76 (5.80)	8.09 +/- .12
7	.71 (6.05)	8.80 +/- .12
8	.62 (6.48)	9.43 +/- .13
9	.67 (6.21)	10.10 +/- .14
12	1.26 (3.19)	11.36 +/- .14
13	.56 (6.73)	11.92 +/- .15
14	.59 (6.64)	12.51 +/- .15
15	.53 (6.95)	13.04 +/- .16
16	.48 (7.39)	13.52 +/- .16
19	1.17 (4.65)	14.68 +/- .17
20	.44 (11.97)	15.13 +/ .18
21	.44 (11.97)	15.57 +/- .19
22	.44 (12.07)	16.01 +/- .19
23	.46 (11.88)	16.47 +/- .20
26	.97 (8.09)	17.43 +/- .22
27	.43 (12.09)	17.86 +/- .22
28	.40 (12.58)	18.26 +/- .23
29	.43 (12.21)	18.70 +/- .23
30	.42 (12.24)	19.12 +/- .24
33	.79 (1.75)	19.91 +/- .24
34	.42 (2.38)	20.33 +/- .24
35	.40 (2.56)	20.73 +/- .24
36	.41 (2.44)	21.14 +/- .24
37	.38 (2.68)	21.52 +/- .24
40	.76 (1.84)	22.28 +/- .24
41	.45 (2.24)	22.73 +/- .24
42	.40 (2.52)	23.13 +/- .24
49	.24 (3.21)	23.36 +/- .24
56	1.14 (1.44)	24.51 +/- .24
63	1.12 (1.46)	25.63 +/- .24
70	1.18 (1.50)	26.81 +/- .24
77	.98 (1.55)	27.78 +/- .24
84	.97 (1.56)	28.75 +/- .24
112	2.64 (2.20)	31.40 +/- .25
140	2.70 (.70)	34.09 +/- .25
169	2.26 (1.68)	36.35 +/- .25
197	1.83 (1.86)	38.18 +/- .26
232	2.16 (1.70)	40.33 +/- .26
260	1.61 (1.95)	41.95 +/- .26

Table A.4, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 3x3 Resin/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.91 (3.73)	.91 +/- .03
1	2.40 (2.31)	3.32 +/- .07
2	1.23 (3.19)	4.54 +/- .08
3	.90 (3.78)	5.44 +/- .08
4	.78 (2.91)	6.22 +/- .09
5	.69 (3.13)	6.91 +/- .09
6	.67 (3.04)	7.57 +/- .09
7	.58 (3.24)	8.16 +/- .09
8	.58 (3.25)	8.74 +/- .10
9	.53 (3.56)	9.27 +/- .10
12	1.10 (3.46)	10.37 +/- .10
13	.48 (3.67)	10.85 +/- .11
14	.45 (3.63)	11.30 +/- .11
15	.45 (3.64)	11.75 +/- .11
16	.44 (3.69)	12.19 +/- .11
19	.81 (2.80)	13.01 +/- .11
20	.42 (2.39)	13.43 +/- .11
21	.41 (2.45)	13.84 +/- .11
22	.41 (2.48)	14.25 +/- .11
23	.42 (2.41)	14.67 +/- .11
26	.77 (1.81)	15.44 +/- .11
27	.39 (2.59)	15.83 +/- .11
28	.39 (2.59)	16.22 +/- .12
29	.40 (2.56)	16.61 +/- .12
30	.37 (2.69)	16.99 +/- .12
33	.70 (1.97)	17.69 +/- .12
34	.41 (2.45)	18.10 +/- .12
35	.38 (2.66)	18.48 +/- .12
36	.38 (2.67)	18.86 +/- .12
37	.38 (2.65)	19.24 +/- .12
40	.72 (1.92)	19.96 +/- .12
41	.45 (2.23)	20.42 +/- .12
42	.37 (2.70)	20.79 +/- .12
49	.19 (3.95)	20.98 +/- .12
56	1.08 (1.52)	22.06 +/- .12
63	1.06 (1.56)	23.12 +/- .12
70	1.12 (1.46)	24.24 +/- .12
77	.93 (1.63)	25.17 +/- .12
84	.95 (1.60)	26.12 +/- .13
112	2.40 (2.32)	28.51 +/- .14
140	2.53 (.70)	31.05 +/- .14
169	2.14 (1.71)	33.19 +/- .14
197	1.83 (1.87)	35.01 +/- .15
232	2.15 (1.70)	37.16 +/- .15
260	1.57 (2.00)	38.74 +/- .16

Table A.4, Continued

^{137}Cs Incremental and Cumulative Fractional Releases From 3x3 Resin/Cement Composite #3

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	1.30 (3.10)	1.30 +/- .04
1	2.77 (2.14)	4.07 +/- .07
2	1.30 (3.11)	5.37 +/- .08
3	1.00 (3.54)	6.36 +/- .09
4	.88 (2.73)	7.24 +/- .09
5	.81 (2.80)	8.05 +/- .10
6	.72 (2.99)	8.77 +/- .10
7	.66 (3.07)	9.43 +/- .10
8	.67 (3.02)	10.10 +/- .10
9	.63 (3.21)	10.73 +/- .10
12	1.16 (3.25)	11.89 +/- .11
13	.54 (3.49)	12.43 +/- .11
14	.52 (3.38)	12.96 +/- .11
15	.49 (3.58)	13.45 +/- .11
16	.47 (3.78)	13.92 +/- .12
19	.90 (2.68)	14.81 +/- .12
20	.46 (2.49)	15.27 +/- .12
21	.47 (2.42)	15.74 +/- .12
22	.43 (2.37)	16.16 +/- .12
23	.43 (2.37)	16.59 +/- .12
26	.85 (1.79)	17.44 +/- .12
27	.42 (2.40)	17.86 +/- .12
28	.39 (2.61)	18.25 +/- .12
29	.42 (2.38)	18.67 +/- .12
30	.41 (2.49)	19.08 +/- .12
33	.64 (2.17)	19.71 +/- .12
34	.40 (2.19)	20.12 +/- .12
35	.41 (2.47)	20.53 +/- .12
36	.38 (2.64)	20.91 +/- .13
37	.40 (2.55)	21.31 +/- .13
40	.64 (2.15)	21.95 +/- .13
41	.41 (2.46)	22.36 +/- .13
42	.40 (2.53)	22.76 +/- .13
49	.23 (3.26)	22.99 +/- .13
56	1.14 (1.44)	24.13 +/- .13
63	1.09 (1.51)	25.22 +/- .13
70	1.13 (1.45)	26.35 +/- .13
77	1.01 (1.63)	27.36 +/- .13
84	.98 (1.55)	28.34 +/- .13
112	2.69 (2.16)	31.02 +/- .14
140	2.67 (.71)	33.70 +/- .15
169	2.26 (1.68)	35.95 +/- .15
197	1.84 (1.85)	37.80 +/- .15
232	2.25 (1.68)	40.05 +/- .16
260	1.61 (1.96)	41.66 +/- .16

Table A.5

^{137}Cs Incremental and Cumulative Fractional Releases
From 6x6 Resin/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.58 (.90)	.58 +/- .01
1	2.71 (.42)	3.29 +/- .01
2	1.72 (.52)	5.01 +/- .02
3	1.35 (.59)	6.36 +/- .02
6	2.91 (.40)	9.27 +/- .02
7	.83 (1.07)	10.10 +/- .02
8	.67 (1.20)	10.77 +/- .02
9	.73 (1.14)	11.50 +/- .03
10	.63 (1.23)	12.13 +/- .03
13	1.63 (.34)	13.76 +/- .03
14	.56 (.57)	14.32 +/- .03
15	.51 (.61)	14.84 +/- .03
16	.48 (.63)	15.32 +/- .03
17	.43 (.66)	15.75 +/- .03
20	1.07 (.43)	16.82 +/- .03
21	.38 (.70)	17.20 +/- .03
22	.36 (.74)	17.56 +/- .03
29	1.85 (.72)	19.41 +/- .03
36	1.65 (.34)	21.06 +/- .03
43	1.47 (.36)	22.53 +/- .03
50	1.49 (.36)	24.02 +/- .03
57	1.31 (.38)	25.33 +/- .03
64	1.28 (.39)	26.61 +/- .03
92	3.40 (.53)	30.01 +/- .04
120	3.05 (.18)	33.06 +/- .04
149	2.57 (.43)	35.63 +/- .04
177	2.16 (.47)	37.79 +/- .04
212	2.45 (.44)	40.24 +/- .04
240	1.76 (.52)	42.00 +/- .04

Table A.5, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 6x6 Resin/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.49 (.99)	.49 +/- .00
1	1.95 (.49)	2.44 +/- .01
2	1.19 (.63)	3.63 +/- .01
3	.94 (.71)	4.58 +/- .01
6	1.94 (.49)	6.52 +/- .02
7	.53 (1.33)	7.05 +/- .02
8	.45 (1.45)	7.51 +/- .02
9	.47 (1.41)	7.98 +/- .02
10	.41 (1.53)	8.39 +/- .02
13	1.09 (.42)	9.47 +/- .02
14	.37 (.72)	9.84 +/- .02
15	.33 (.74)	10.17 +/- .02
16	.32 (.77)	10.49 +/- .02
17	.29 (.83)	10.78 +/- .02
20	.74 (.51)	11.52 +/- .02
21	.28 (.82)	11.80 +/- .02
22	.26 (.87)	12.06 +/- .02
29	1.31 (.85)	13.37 +/- .03
36	1.19 (.40)	14.56 +/- .03
43	1.09 (.42)	15.65 +/- .03
50	1.11 (.41)	16.76 +/- .03
57	.96 (.44)	17.73 +/- .03
64	.95 (.45)	18.68 +/- .03
92	2.64 (.60)	21.32 +/- .03
120	2.43 (.20)	23.75 +/- .03
149	2.15 (.47)	25.90 +/- .03
177	1.84 (.51)	27.74 +/- .04
212	2.04 (.48)	29.78 +/- .04
240	1.52 (.56)	31.30 +/- .04

Table A.5, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 6x6 Resin/Cement Composite #3

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.47 (1.01)	.47 +/- .00
1	1.55 (.56)	2.02 +/- .01
2	.88 (.74)	2.90 +/- .01
3	.71 (.82)	3.61 +/- .01
6	1.50 (.56)	5.11 +/- .02
7	.43 (1.47)	5.54 +/- .02
8	.36 (1.63)	5.90 +/- .02
9	.41 (1.54)	6.30 +/- .02
10	.34 (1.67)	6.64 +/- .02
13	.94 (.45)	7.58 +/- .02
14	.32 (.78)	7.90 +/- .02
15	.29 (.83)	8.18 +/- .02
16	.26 (.87)	8.45 +/- .02
17	.25 (.87)	8.70 +/- .02
20	.65 (.54)	9.34 +/- .02
21	.24 (.90)	9.59 +/- .02
22	.23 (.90)	9.82 +/- .02
29	1.20 (.89)	11.02 +/- .02
36	1.05 (.43)	12.06 +/- .02
43	.96 (.44)	13.03 +/- .02
50	.93 (.45)	13.95 +/- .02
57	.79 (.49)	14.75 +/- .03
64	.80 (.49)	15.55 +/- .03
92	2.32 (.64)	17.87 +/- .03
120	2.23 (.21)	20.10 +/- .03
149	1.88 (.50)	21.98 +/- .03
177	1.61 (.54)	23.59 +/- .03
212	1.88 (.50)	25.47 +/- .03
240	1.35 (.59)	26.82 +/- .03

Table A.6

^{137}Cs Incremental and Cumulative Fractional Releases
From 6x12 Resin/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.30 (1.68)	.30 +/- .01
1	1.76 (.71)	2.07 +/- .01
2	1.18 (.86)	3.24 +/- .02
3	.95 (.97)	4.19 +/- .02
4	.78 (1.06)	4.97 +/- .02
8	2.31 (.62)	7.28 +/- .03
9	.52 (1.31)	7.79 +/- .03
10	.48 (1.37)	8.27 +/- .03
11	.36 (1.56)	8.63 +/- .03
14	.89 (1.00)	9.53 +/- .03
15	.28 (1.77)	9.81 +/- .03
16	.27 (1.81)	10.08 +/- .03
17	.28 (1.79)	10.36 +/- .03
18	.27 (1.81)	10.63 +/- .03
21	.76 (1.08)	11.39 +/- .03
22	.25 (1.89)	11.63 +/- .03
23	.25 (1.87)	11.88 +/- .03
24	.22 (2.01)	12.10 +/- .03
25	.20 (2.06)	12.30 +/- .03
28	.46 (1.40)	12.76 +/- .03
29	.14 (2.44)	12.91 +/- .03
30	.16 (2.35)	13.06 +/- .03
31	.16 (2.38)	13.22 +/- .03
32	.14 (2.56)	13.36 +/- .03
35	.36 (1.56)	13.72 +/- .03
36	.14 (2.49)	13.87 +/- .03
37	.12 (2.70)	13.99 +/- .04
38	.13 (2.66)	14.11 +/- .04
39	.13 (2.54)	14.24 +/- .04
42	.32 (1.67)	14.56 +/- .04
43	.12 (2.68)	14.68 +/- .04
44	.12 (2.75)	14.80 +/- .04
49	.48 (1.35)	15.28 +/- .04
50	.12 (2.75)	15.40 +/- .04
51	.12 (2.74)	15.52 +/- .04
52	.13 (2.55)	15.65 +/- .04
53	.12 (2.81)	15.77 +/- .04
56	.28 (1.79)	16.05 +/- .04
63	.53 (1.29)	16.57 +/- .04
70	.50 (1.32)	17.07 +/- .04
77	.49 (1.35)	17.56 +/- .04
84	.47 (1.36)	18.04 +/- .04
91	.47 (1.36)	18.51 +/- .04
98	.55 (1.26)	19.06 +/- .04
105	.48 (1.35)	19.53 +/- .04
113	.51 (1.31)	20.04 +/- .04
119	.40 (1.47)	20.44 +/- .04
168	13.00 (.18)	33.44 +/- .05

Table A.6, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 6x12 Resin/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.29 (1.76)	.29 +/- .01
1	1.96 (.67)	2.25 +/- .01
2	1.33 (.82)	3.58 +/- .02
3	1.05 (.92)	4.62 +/- .02
4	.86 (1.00)	5.49 +/- .02
8	2.43 (.60)	7.92 +/- .03
9	.51 (1.31)	8.43 +/- .03
10	.46 (1.39)	8.89 +/- .03
11	.36 (1.56)	9.25 +/- .03
14	.92 (.98)	10.17 +/- .03
15	.30 (1.70)	10.46 +/- .03
16	.27 (1.81)	10.73 +/- .03
17	.29 (1.72)	11.03 +/- .03
18	.29 (1.76)	11.31 +/- .03
21	.80 (1.05)	12.11 +/- .03
22	.27 (1.83)	12.38 +/- .03
23	.26 (1.84)	12.64 +/- .03
24	.25 (1.89)	12.88 +/- .03
25	.23 (1.92)	13.12 +/- .03
28	.59 (1.22)	13.70 +/- .03
29	.20 (2.12)	13.90 +/- .03
30	.22 (1.98)	14.12 +/- .04
31	.22 (2.01)	14.33 +/- .04
32	.20 (2.06)	14.53 +/- .04
35	.54 (1.28)	15.07 +/- .04
36	.20 (2.07)	15.27 +/- .04
37	.18 (2.17)	15.45 +/- .04
38	.17 (2.27)	15.63 +/- .04
39	.17 (2.24)	15.80 +/- .04
42	.45 (1.39)	16.25 +/- .04
43	.17 (2.29)	16.42 +/- .04
44	.16 (2.30)	16.58 +/- .04
49	.69 (1.12)	17.27 +/- .04
50	.17 (2.24)	17.45 +/- .04
51	.16 (2.35)	17.61 +/- .04
52	.18 (2.26)	17.78 +/- .04
53	.15 (2.40)	17.93 +/- .04
56	.39 (1.50)	18.32 +/- .04
63	.69 (1.13)	19.01 +/- .04
70	.53 (1.29)	19.55 +/- .04
77	.48 (1.35)	20.03 +/- .04
84	.47 (1.37)	20.50 +/- .04
91	.47 (1.37)	20.97 +/- .04
98	.54 (1.28)	21.51 +/- .04
105	.50 (1.33)	22.01 +/- .04
113	.51 (1.32)	22.52 +/- .04
119	.43 (1.45)	22.94 +/- .04
126	.44 (1.41)	23.39 +/- .05
133	.45 (.99)	23.84 +/- .05
140	.40 (1.05)	24.24 +/- .05
168	7.98 (.24)	32.22 +/- .05

Table A.6, Continued

^{137}Cs Incremental and Cumulative Fractional Releases From 6x12 Resin/Cement Composite #3

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.28 (1.77)	.28 +/- .00
1	1.68 (.72)	1.96 +/- .01
2	1.07 (.90)	3.04 +/- .02
3	.86 (1.00)	3.90 +/- .02
4	.70 (1.11)	4.60 +/- .02
8	1.92 (.68)	6.52 +/- .02
9	.39 (1.50)	6.91 +/- .02
10	.37 (1.53)	7.28 +/- .03
11	.29 (1.73)	7.57 +/- .03
14	.76 (1.08)	8.32 +/- .03
15	.25 (1.85)	8.58 +/- .03
16	.23 (1.95)	8.81 +/- .03
17	.24 (1.92)	9.05 +/- .03
18	.24 (1.90)	9.29 +/- .03
21	.67 (1.15)	9.96 +/- .03
22	.24 (1.90)	10.20 +/- .03
23	.24 (1.92)	10.44 +/- .03
24	.23 (1.95)	10.67 +/- .03
25	.21 (2.01)	10.88 +/- .03
28	.56 (1.25)	11.44 +/- .03
29	.19 (2.[illegible]1)	11.63 +/- .03
30	.2[illegible] ([illegible])	11.85 +/- .03
31	.2[illegible] (1.[illegible])	12.07 +/- .03
32	.2[illegible] (2.04)	12.28 +/- .03
35	.57 (1.23)	12.85 +/- .03
36	.23 (1.94)	13.08 +/- .03
37	.19 (2.16)	13.27 +/- .03
38	.19 (2.11)	13.46 +/- .03
39	.20 (2.12)	13.66 +/- .03
42	.51 (1.30)	14.16 +/- .04
43	.20 (2.08)	14.37 +/- .04
44	.19 (2.16)	14.56 +/- .04
49	.79 (1.06)	15.35 +/- .04
50	.21 (2.02)	15.57 +/- .04
51	.19 (2.13)	15.76 +/- .04
52	.22 (1.99)	15.98 +/- .04
53	.19 (2.15)	16.17 +/- .04
56	.50 (1.34)	16.67 +/- .04
63	.95 (.97)	17.62 +/- .04
70	.84 (1.03)	18.46 +/- .04
77	.79 (1.06)	19.25 +/- .04
84	.76 (1.07)	20.01 +/- .04
91	.68 (1.13)	20.70 +/- .04
98	.61 (1.19)	21.31 +/- .04
105	.56 (1.26)	21.87 +/- .04
113	.53 (1.30)	22.40 +/- .04
119	.44 (1.42)	22.84 +/- .04
126	.42 (1.46)	23.26 +/- .05
133	.40 (1.05)	23.66 +/- .05
140	.36 (1.11)	24.03 +/- .05
147	.35 (.80)	24.38 +/- .05
181	1.06 (.65)	25.44 +/- .05
209	.97 (.67)	26.41 +/- .05
237	17.31 (.16)	43.72 +/- .05

Table A.7

^{137}Cs Incremental and Cumulative Fractional Releases
From 12x12 Resin/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.12 (1.28)	.12 +/- .00
1	.83 (.48)	.94 +/- .00
2	.58 (.58)	1.53 +/- .01
5	1.89 (.32)	3.42 +/- .01
6	.95 (.45)	4.37 +/- .01
7	.35 (.75)	4.71 +/- .01
8	.29 (.83)	5.00 +/- .01
9	.25 (.87)	5.25 +/- .01
12	.64 (.55)	5.89 +/- .01
13	.23 (.92)	6.12 +/- .01
14	.19 (1.02)	6.31 +/- .01
15	.17 (1.06)	6.48 +/- .01
16	.30 (.80)	6.78 +/- .01
19	.36 (.73)	7.14 +/- .01
20	.12 (1.27)	7.26 +/- .01
21	.12 (1.24)	7.38 +/- .01
22	.12 (1.26)	7.51 +/- .01
23	.12 (1.26)	7.63 +/- .01
27	.42 (.68)	8.05 +/- .01
28	.11 (1.30)	8.16 +/- .01
29	.11 (1.35)	8.27 +/- .01
30	.11 (1.33)	8.38 +/- .01
33	.24 (.89)	8.62 +/- .01
34	.09 (1.49)	8.71 +/- .01
35	.09 (1.50)	8.80 +/- .01
36	.09 (1.46)	8.89 +/- .01
37	.09 (1.47)	8.98 +/- .01
40	.22 (.94)	9.20 +/- .01
41	.09 (1.47)	9.29 +/- .01
42	.08 (1.59)	9.37 +/- .01
43	.08 (1.55)	9.45 +/- .01
44	.09 (1.49)	9.53 +/- .01
47	.20 (.98)	9.73 +/- .01
54	.43 (.67)	10.16 +/- .01
61	.38 (.71)	10.54 +/- .01
68	.38 (.71)	10.93 +/- .01
75	.37 (.72)	11.30 +/- .01
82	.37 (.73)	11.66 +/- .02
89	.36 (.74)	12.02 +/- .02
96	.40 (.69)	12.42 +/- .02
124	1.35 (.38)	13.77 +/- .02
145	.97 (.45)	14.74 +/- .02
180	1.21 (.28)	15.95 +/- .02

Table A.7, Continued

^{137}Cs Incremental and Cumulative Fractional Releases From 12x12 Resin/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.15 (1.26)	.15 +/- .00
1	1.01 (.48)	1.15 +/- .01
2	.65 (.60)	1.81 +/- .01
3	.51 (.68)	2.32 +/- .01
4	.44 (.73)	2.75 +/- .01
7	.96 (.49)	3.72 +/- .01
8	.32 (.85)	4.04 +/- .01
9	.27 (.93)	4.31 +/- .01
10	.22 (1.04)	4.53 +/- .01
11	.20 (1.09)	4.73 +/- .01
14	.49 (.69)	5.22 +/- .01
15	.18 (1.14)	5.40 +/- .01
16	.17 (1.19)	5.57 +/- .01
[illegible]	[illegible]	[illegible]
18	.15 (1.24)	5.88 +/- .01
21	.37 (.79)	6.25 +/- .01
22	.15 (1.25)	6.40 +/- .01
23	.13 (1.33)	6.54 +/- .01
24	.11 (1.47)	6.65 +/- .01
25	.13 (1.33)	6.78 +/- .01
28	.36 (.80)	7.14 +/- .01
29	.11 (1.43)	7.26 +/- .01
30	.11 (1.47)	7.36 +/- .01
31	.11 (1.48)	7.47 +/- .01
32	.10 (1.52)	7.57 +/- .01
35	.28 (.91)	7.86 +/- .01
36	.09 (1.59)	7.95 +/- .01
37	.09 (1.57)	8.04 +/- .01
38	.09 (1.57)	8.14 +/- .01
39	.10 (1.55)	8.23 +/- .01
42	.28 (.91)	8.51 +/- .01
43	.09 (1.64)	8.60 +/- .01
44	.08 (1.71)	8.68 +/- .01
45	.08 (1.67)	8.76 +/- .01
46	.08 (1.65)	8.85 +/- .01
50	.30 (.88)	9.15 +/- .01
51	.08 (1.75)	9.22 +/- .01
52	.07 (1.82)	9.29 +/- .01
53	.07 (1.76)	9.37 +/- .01
56	.18 (1.16)	9.54 +/- .01
57	.07 (1.86)	9.61 +/- .02
58	.07 (1.82)	9.69 +/- .02
59	.05 (2.12)	9.74 +/- .02
60	.05 (2.11)	9.79 +/- .02
63	.15 (1.24)	9.94 +/- .02
64	.10 (1.08)	10.04 +/- .02
65	.07 (1.29)	10.11 +/- .02
66	.06 (1.37)	10.17 +/- .02
67	.06 (1.42)	10.23 +/- .02
70	.17 (.82)	10.40 +/- .02
71	.06 (1.35)	10.47 +/- .02
72	.06 (1.39)	10.53 +/- .02
73	.06 (1.39)	10.59 +/- .02
74	.06 (1.34)	10.66 +/- .02
77	.18 (.82)	10.83 +/- .02
78	.07 (1.26)	10.91 +/- .02
79	.07 (1.31)	10.98 +/- .02
80	.07 (1.30)	11.04 +/- .02
81	.07 (1.29)	11.11 +/- .02
84	.18 (.80)	11.30 +/- .02
85	.07 (1.31)	11.37 +/- .02
86	.08 (1.23)	11.44 +/- .02
87	.06 (1.34)	11.51 +/- .02
88	.07 (1.33)	11.57 +/- .02
91	.19 (.79)	11.76 +/- .02
92	.07 (1.29)	11.83 +/- .02
93	.07 (1.32)	11.90 +/- .02
94	.07 (1.31)	11.97 +/- .02
95	.08 (1.23)	12.04 +/- .02
98	.20 (.76)	12.25 +/- .02
99	.08 (1.25)	12.32 +/- .02
100	.07 (1.26)	12.39 +/- .02
101	.07 (1.29)	12.46 +/- .02
102	.07 (1.35)	12.53 +/- .02
105	.18 (.81)	12.71 +/- .02
106	.07 (1.26)	12.78 +/- .02
107	.07 (1.32)	12.85 +/- .02
108	.07 (1.30)	12.92 +/- .02
109	.07 (1.29)	12.99 +/- .02
112	.18 (.80)	13.17 +/- .02
113	.07 (1.30)	13.24 +/- .02
115	.12 (.99)	13.36 +/- .02
116	.07 (1.31)	13.43 +/- .02
119	.17 (.82)	13.61 +/- .02
126	.38 (.56)	13.98 +/- .02
133	.43 (.52)	14.41 +/- .02

Table A.7, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 12x12 Resin/Cement Composite #3

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.12 (1.47)	.12 +/- .00
1	1.14 (.48)	1.26 +/- .01
2	.79 (.58)	2.05 +/- .01
3	.58 (.67)	2.63 +/- .01
4	.48 (.74)	3.12 +/- .01
7	1.02 (.51)	4.13 +/- .01
8	.33 (.90)	4.46 +/- .01
9	.27 (.99)	4.73 +/- .01
10	.23 (1.08)	4.96 +/- .01
11	.21 (1.12)	5.17 +/- .01
14	.44 (.77)	5.61 +/- .01
15	.19 (1.18)	5.80 +/- .01
16	.17 (1.24)	5.96 +/- .01
17	.16 (1.28)	6.12 +/- .01
18	.19 (1.19)	6.31 +/- .01
21	.39 (.82)	6.70 +/- .01
22	.14 (1.36)	6.84 +/- .01
23	.13 (1.42)	6.98 +/- .01
24	.14 (1.39)	7.11 +/- .01
25	.13 (1.44)	7.24 +/- .01
28	.32 (.90)	7.56 +/- .01
29	.11 (1.56)	7.67 +/- .01
30	.10 (1.60)	7.77 +/- .01
31	.12 (1.48)	7.89 +/- .01
32	.10 (1.58)	8.00 +/- .01
35	.28 (.96)	8.28 +/- .01
36	.10 (1.65)	8.38 +/- .01
37	.09 (1.69)	8.47 +/- .01
38	.09 (1.70)	8.56 +/- .02
39	.09 (1.69)	8.65 +/- .02
42	.27 (.98)	8.92 +/- .02
43	.08 (1.83)	9.00 +/- .02
44	.08 (1.78)	9.09 +/- .02
45	.08 (1.78)	9.17 +/- .02
46	.08 (1.80)	9.25 +/- .02
50	.26 (1.00)	9.51 +/- .02
51	.08 (1.84)	9.59 +/- .02
52	.08 (1.82)	9.67 +/- .02
53	.07 (1.95)	9.74 +/- .02
56	.20 (1.13)	9.95 +/- .02
57	.08 (1.83)	10.02 +/- .02
58	.08 (1.81)	10.10 +/- .02
59	.06 (2.11)	10.16 +/- .02
60	.06 (2.12)	10.22 +/- .02
63	.17 (1.24)	10.39 +/- .02
64	.08 (1.31)	10.47 +/- .02
65	.09 (1.24)	10.56 +/- .02
66	.07 (1.38)	10.63 +/- .02
67	.07 (1.40)	10.69 +/- .02
70	.19 (.83)	10.88 +/- .02
71	.08 (1.33)	10.96 +/- .02
72	.07 (1.41)	11.03 +/- .02
73	.07 (1.35)	11.10 +/- .02
74	.09 (1.23)	11.19 +/- .02
77	.22 (.77)	11.41 +/- .02
78	.09 (1.21)	11.49 +/- .02
79	.08 (1.24)	11.58 +/- .02
80	.08 (1.25)	11.66 +/- .02
81	.08 (1.27)	11.74 +/- .02
84	.23 (.77)	11.97 +/- .02
85	.09 (1.23)	12.06 +/- .02
86	.08 (1.28)	12.14 +/- .02
87	.08 (1.29)	12.22 +/- .02
88	.09 (1.18)	12.31 +/- .02
91	.24 (.74)	12.54 +/- .02
92	.09 (1.25)	12.63 +/- .02
93	.09 (1.23)	12.72 +/- .02
94	.08 (1.26)	12.80 +/- .02
95	.09 (1.20)	12.89 +/- .02
105	3.01 (.21)	15.90 +/- .02

Table A.8

^{137}Cs Incremental and Cumulative Fractional Releases From 22x22 Resin/Cement Composite

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.05 (2.85)	.05 +/- .00
1	.44 (.94)	.48 +/- .00
2	.31 (1.11)	.80 +/- .01
3	.26 (1.21)	1.06 +/- .01
4	.22 (1.34)	1.28 +/- .01
7	.49 (.89)	1.77 +/- .01
8	.16 (1.54)	1.93 +/- .01
9	.14 (1.68)	2.07 +/- .01
10	.11 (1.86)	2.18 +/- .01
11	.11 (1.89)	2.29 +/- .01
14	.31 (1.12)	2.60 +/- .01
15	.10 (2.01)	2.69 +/- .01
16	.08 (2.16)	2.78 +/- .01
17	.08 (2.16)	2.86 +/- .01
18	.08 (2.19)	2.94 +/- .01
21	.20 (1.40)	3.13 +/- .01
22	.07 (2.38)	3.20 +/- .01
23	.06 (2.50)	3.26 +/- .01
24	.07 (2.43)	3.33 +/- .01
25	.07 (2.38)	3.40 +/- .01
28	.18 (1.47)	3.58 +/- .01
29	.07 (2.38)	3.65 +/- .01
30	.05 (2.68)	3.70 +/- .01
31	.07 (2.42)	3.77 +/- .01
32	.07 (2.36)	3.84 +/- .01
36	.23 (1.30)	4.07 +/- .01
37	.07 (2.33)	4.14 +/- .01
38	.07 (2.29)	4.21 +/- .01
39	.08 (2.27)	4.29 +/- .01
42	.20 (1.40)	4.49 +/- .01
43	.09 (1.85)	4.57 +/- .01
44	.08 (2.19)	4.66 +/- .01
45	.08 (2.19)	4.74 +/- .01
46	.08 (2.17)	4.82 +/- .01
49	.24 (1.27)	5.06 +/- .01
50	.10 (1.37)	5.16 +/- .01
51	.10 (1.42)	5.25 +/- .01
52	.09 (1.46)	5.34 +/- .01
53	.08 (1.51)	5.43 +/- .01
56	.24 (.89)	5.67 +/- .01
57	.11 (1.34)	5.78 +/- .01
58	.08 (1.58)	5.86 +/- .01
59	.10 (1.42)	5.95 +/- .01
60	.10 (1.40)	6.05 +/- .01
63	.26 (.87)	6.31 +/- .01
64	.09 (1.46)	6.41 +/- .01
65	.10 (1.36)	6.51 +/- .01
66	.09 (1.46)	6.60 +/- .01
67	.10 (1.38)	6.70 +/- .02
70	.31 (.79)	7.01 +/- .02
88	1.29 (.39)	8.30 +/- .02

Table A.9

^{137}Cs Incremental and Cumulative Fractional Releases
From 1x1 Boric Acid/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	7.39 (.91)	7.39 +/- .07
1	14.14 (.66)	21.53 +/- .11
2	7.57 (.90)	29.10 +/- .13
3	5.60 (1.05)	34.70 +/- .15
4	4.33 (1.18)	39.03 +/- .15
7	7.87 (.89)	46.90 +/- .17
8	2.19 (1.67)	49.09 +/- .17
9	1.84 (1.79)	50.92 +/- .18
10	1.67 (1.90)	52.59 +/- .18
11	1.47 (2.07)	54.07 +/- .18
14	3.42 (1.89)	57.49 +/- .19
15	1.20 (3.24)	58.69 +/- .20
16	1.31 (3.06)	60.00 +/- .20
17	1.11 (3.30)	61.11 +/- .20
18	.97 (3.51)	62.08 +/- .21
21	2.29 (1.65)	64.37 +/- .21
22	.97 (2.50)	65.35 +/- .21
23	.86 (2.68)	66.21 +/- .21
24	.92 (2.53)	67.12 +/- .21
25	.82 (2.69)	67.94 +/- .22
28	1.95 (2.50)	69.89 +/- .22
29	.72 (2.89)	70.60 +/- .22
30	.71 (2.90)	71.32 +/- .22
31	.92 (2.53)	72.23 +/- .22
32	.73 (2.83)	72.96 +/- .23
35	1.59 (1.22)	74.56 +/- .23
36	.71 (1.90)	75.26 +/- .23
37	.64 (1.90)	75.90 +/- .23
38	.60 (1.83)	76.50 +/- .23
39	.61 (1.99)	77.11 +/- .23
42	1.28 (1.43)	78.39 +/- .23
49	2.06 (1.07)	80.45 +/- .23
56	1.67 (1.25)	82.12 +/- .23
64	1.56 (1.95)	83.68 +/- .23
71	1.31 (1.39)	84.99 +/- .23
77	.89 (1.64)	85.89 +/- .23
84	1.05 (1.51)	86.94 +/- .23
122	3.68 (1.29)	90.61 +/- .24
150	1.65 (1.92)	92.26 +/- .24

Table A.9, Continued

^{137}Cs Incremental and Cumulative Fractional Releases From 1x1 Boric Acid/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	7.51 (.91)	7.51 +/- .07
1	13.62 (.67)	21.13 +/- .11
2	7.58 (.90)	28.71 +/- .13
3	5.64 (1.04)	34.35 +/- .15
4	4.48 (1.17)	38.83 +/- .15
7	8.27 (.86)	47.11 +/- .17
8	2.33 (1.62)	49.44 +/- .17
9	1.94 (1.76)	51.37 +/- .18
10	1.72 (1.91)	53.09 +/- .18
11	1.51 (2.01)	54.61 +/- .18
14	3.37 (1.92)	57.98 +/- .19
15	1.19 (3.18)	59.16 +/- .20
16	1.13 (3.34)	60.29 +/- .20
17	1.07 (3.41)	61.37 +/- .20
18	.84 (3.77)	62.20 +/- .21
21	2.14 (1.71)	64.35 +/- .21
22	.98 (2.48)	65.33 +/- .21
23	.93 (2.61)	66.26 +/- .21
24	.89 (2.59)	67.15 +/- .21
25	.84 (2.75)	68.00 +/- .22
28	1.78 (.28)	69.78 +/- .22
29	.77 (2.86)	70.54 +/- .22
30	.71 (2.92)	71.25 +/- .22
31	.99 (2.46)	72.24 +/- .22
32	.79 (2.79)	73.02 +/- .22
35	1.65 (1.25)	74.68 +/- .22
36	.72 (1.87)	75.39 +/- .22
37	.65 (1.87)	76.04 +/- .22
38	.57 (2.12)	76.62 +/- .22
39	.64 (1.91)	77.26 +/- .22
42	1.31 (1.39)	78.57 +/- .22
49	2.16 (1.08)	80.73 +/- .22
56	1.81 (1.14)	82.54 +/- .23
64	1.61 (1.97)	84.15 +/- .23
71	1.45 (1.26)	85.60 +/- .23
77	.97 (1.63)	86.57 +/- .23
84	1.17 (1.46)	87.74 +/- .23
122	4.12 (1.21)	91.87 +/- .24
150	1.84 (1.85)	93.71 +/- .24

Table A.9, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 1x1 Boric Acid/Cement Composite #3

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	7.69 (.89)	7.69 +/- .07
1	14.70 (.65)	22.39 +/- .12
2	7.95 (.88)	30.34 +/- .14
3	5.75 (1.04)	36.09 +/- .15
4	4.55 (1.15)	40.64 +/- .16
7	8.48 (.85)	49.12 +/- .17
8	2.34 (1.62)	51.46 +/- .18
9	1.95 (1.75)	53.41 +/- .18
10	1.73 (1.90)	55.14 +/- .18
11	1.53 (1.99)	56.67 +/- .19
14	3.06 (1.99)	59.74 +/- .20
15	1.20 (3.24)	60.94 +/- .20
16	1.30 (2.82)	62.24 +/- .20
17	1.11 (3.30)	63.34 +/- .21
18	1.10 (3.31)	64.45 +/- .21
21	2.21 (1.66)	66.65 +/- .21
22	.93 (2.62)	67.58 +/- .21
23	.93 (2.63)	68.51 +/- .22
24	.89 (2.61)	69.40 +/- .22
25	.81 (2.85)	70.21 +/- .22
28	1.78 (.28)	71.99 +/- .22
29	.77 (2.83)	72.76 +/- .22
30	.73 (2.84)	73.49 +/- .22
31	.93 (2.63)	74.42 +/- .22
32	.73 (2.82)	75.15 +/- .22
35	1.55 (1.26)	76.70 +/- .22
36	.69 (1.94)	77.39 +/- .22
37	.69 (1.93)	78.08 +/- .22
38	.58 (2.12)	78.66 +/- .22
39	.58 (2.11)	79.23 +/- .22
42	1.28 (1.43)	80.52 +/- .23
49	2.06 (1.07)	82.57 +/- .23
56	1.72 (1.20)	84.30 +/- .23
64	1.54 (1.98)	85.83 +/- .23
71	1.42 (1.29)	87.25 +/- .23
77	.93 (1.58)	88.18 +/- .23
84	1.11 (1.54)	89.29 +/- .23
122	3.82 (1.28)	93.11 +/- .24
150	1.74 (1.89)	94.85 +/- .24

Table A.10

^{137}Cs Incremental and Cumulative Fractional Releases
From 2x2 Boric Acid/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	3.30 (.62)	3.30 +/- .02
1	7.81 (.41)	11.11 +/- .04
2	4.38 (.54)	15.49 +/- .04
3	3.25 (.62)	18.74 +/- .05
4	2.64 (.69)	21.38 +/- .05
7	5.37 (.49)	26.75 +/- .06
8	1.55 (.90)	28.29 +/- .06
9	1.26 (.99)	29.55 +/- .06
10	1.19 (1.02)	30.74 +/- .06
11	1.16 (1.03)	31.90 +/- .06
14	2.72 (.95)	34.62 +/- .07
15	.82 (1.71)	35.44 +/- .07
16	.87 (1.67)	36.31 +/- .07
17	.75 (1.81)	37.07 +/- .07
18	.73 (1.82)	37.80 +/- .07
21	1.93 (.80)	39.73 +/- .08
22	.68 (1.36)	40.41 +/- .08
23	.64 (1.37)	41.05 +/- .08
24	.64 (1.36)	41.69 +/- .08
25	.57 (1.44)	42.27 +/- .08
28	1.46 (1.30)	43.72 +/- .08
29	.56 (2.02)	44.29 +/- .08
30	.54 (2.12)	44.83 +/- .08
31	.71 (1.85)	45.53 +/- .08
32	.61 (1.98)	46.14 +/- .08
35	1.44 (.60)	47.59 +/- .08
36	.61 (.88)	48.20 +/- .08
37	.50 (.98)	48.70 +/- .08
38	.44 (1.05)	49.14 +/- .08
39	.46 (1.01)	49.60 +/- .08
42	1.20 (.66)	50.80 +/- .09
49	2.18 (.48)	52.98 +/- .09
56	2.09 (.50)	55.07 +/- .09
64	1.79 (.83)	56.86 +/- .09
71	1.58 (.56)	58.45 +/- .09
77	1.04 (.69)	59.48 +/- .09
84	1.23 (.64)	60.72 +/- .09
122	5.51 (.49)	66.23 +/- .09
150	2.99 (.65)	69.22 +/- .09

Table A.10, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 2x2 Boric Acid/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	3.37 (.61)	3.37 +/- .02
1	7.54 (.42)	10.92 +/- .04
2	4.67 (.52)	15.59 +/- .04
3	3.62 (.59)	19.21 +/- .05
4	2.62 (.70)	21.83 +/- .05
7	5.20 (.50)	27.03 +/- .06
8	1.49 (.90)	28.52 +/- .06
9	1.23 (1.01)	29.75 +/- .06
10	1.14 (1.05)	30.89 +/- .06
11	1.08 (1.06)	31.97 +/- .06
14	2.72 (.95)	34.68 +/- .07
15	.85 (1.68)	35.54 +/- .07
16	.74 (1.82)	36.28 +/- .07
17	.67 (1.93)	36.95 +/- .07
18	.65 (1.93)	37.60 +/- .07
21	1.74 (.84)	39.34 +/- .08
22	.62 (1.40)	39.96 +/- .08
23	.62 (1.42)	40.58 +/- .08
24	.58 (1.47)	41.16 +/- .08
25	.53 (1.52)	41.69 +/- .08
28	1.40 (1.32)	43.08 +/- .08
29	.52 (2.16)	43.60 +/- .08
30	.54 (2.12)	44.14 +/- .08
31	.72 (1.85)	44.86 +/- .08
32	.60 (2.02)	45.46 +/- .08
35	1.44 (.59)	46.90 +/- .08
36	.54 (.95)	47.44 +/- .08
37	.51 (.96)	47.94 +/- .08
38	.43 (1.08)	48.37 +/- .08
39	.20 (2.32)	48.57 +/- .08
42	1.20 (.66)	49.77 +/- .08
49	2.15 (.49)	51.92 +/- .09
56	1.84 (.53)	53.76 +/- .09
64	1.80 (.83)	55.56 +/- .09
71	1.62 (.57)	57.18 +/- .09
77	1.06 (.70)	58.24 +/- .09
84	1.20 (.66)	59.44 +/- .09
122	5.98 (.47)	65.42 +/- .09
150	3.12 (.63)	68.54 +/- .09

Table A.10, Continued

^{137}Cs Incremental and Cumulative Fractional Releases From 2x2 Boric Acid/Cement Composite #3

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	3.49 (.60)	3.49 +/- .02
1	7.70 (.41)	11.19 +/- .04
2	4.41 (.54)	15.60 +/- .04
3	3.30 (.62)	18.90 +/- .05
4	2.68 (.68)	21.59 +/- .05
7	5.21 (.50)	26.80 +/- .06
8	1.45 (.93)	28.25 +/- .06
9	1.19 (1.03)	29.43 +/- .06
10	1.08 (1.06)	30.51 +/- .06
11	1.00 (1.10)	31.51 +/- .06
14	2.51 (.99)	34.02 +/- .07
15	.71 (1.85)	34.73 +/- .07
16	.76 (1.79)	35.49 +/- .07
17	.60 (2.02)	36.09 +/- .07
18	.60 (2.01)	36.69 +/- .07
21	1.64 (.86)	38.33 +/- .07
22	.61 (1.42)	38.95 +/- .07
23	.57 (1.45)	39.52 +/- .08
24	.54 (1.48)	40.06 +/- .08
25	.50 (1.54)	40.56 +/- .08
28	1.34 (1.34)	41.90 +/- .08
29	.52 (2.17)	42.42 +/- .08
30	.51 (2.19)	42.93 +/- .08
31	.67 (1.93)	43.60 +/- .08
32	.61 (1.98)	44.21 +/- .08
35	1.41 (.46)	45.63 +/- .08
36	.53 (.74)	46.15 +/- .08
37	.50 (.79)	46.65 +/- .08
38	.25 (1.43)	46.91 +/- .08
39	.27 (1.33)	47.18 +/- .08
42	1.18 (.65)	48.36 +/- .08
49	2.09 (.50)	50.45 +/- .08
56	1.90 (.51)	52.35 +/- .08
64	1.79 (.83)	54.14 +/- .09
71	1.55 (.57)	55.69 +/- .09
77	1.06 (.70)	56.75 +/- .09
84	1.20 (.64)	57.94 +/- .09
122	5.69 (.48)	63.63 +/- .09
150	2.99 (.65)	66.62 +/- .09

Table A.11

^{137}Cs Incremental and Cumulative Fractional Releases From 2x4 Boric Acid/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	3.11 (.83)	3.11 +/- .03
1	6.72 (.59)	9.83 +/- .05
2	3.80 (.76)	13.63 +/- .06
3	3.07 (.84)	16.70 +/- .06
4	2.49 (.91)	19.19 +/- .07
7	4.90 (.68)	24.08 +/- .07
8	1.43 (1.67)	25.51 +/- .08
9	1.19 (1.31)	26.70 +/- .08
10	1.09 (1.35)	27.79 +/- .08
11	1.01 (1.42)	28.79 +/- .08
14	2.49 (1.28)	31.28 +/- .09
15	.71 (2.39)	31.99 +/- .09
16	.72 (2.35)	32.71 +/- .09
17	.60 (2.54)	33.31 +/- .09
18	.60 (2.55)	33.91 +/- .09
21	1.59 (1.14)	35.50 +/- .09
22	.61 (1.82)	36.11 +/- .10
23	.56 (1.91)	36.67 +/- .10
24	.56 (1.90)	37.23 +/- .10
25	.51 (2.01)	37.74 +/- .10
28	1.26 (1.79)	38.99 +/- .10
29	.51 (2.76)	39.51 +/- .10
30	.50 (2.84)	40.00 +/- .10
31	.70 (2.36)	40.70 +/- .10
32	.57 (2.62)	41.27 +/- .10
35	1.33 (.81)	42.60 +/- .10
36	.51 (1.25)	43.11 +/- .10
37	.48 (1.33)	43.59 +/- .11
38	.41 (1.45)	44.00 +/- .11
39	.44 (1.34)	44.45 +/- .11
42	1.14 (.86)	45.59 +/- .11
49	2.07 (.65)	47.66 +/- .11
56	1.78 (.70)	49.44 +/- .11
64	1.73 (1.09)	51.18 +/- .11
71	1.59 (.73)	52.76 +/- .11
77	1.09 (.90)	53.85 +/- .11
84	1.18 (.86)	55.03 +/- .11
122	6.22 (.61)	61.25 +/- .12
150	3.25 (.81)	64.50 +/- .12

Table A.11, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 2x4 Boric Acid/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	2.94 (.85)	2.94 +/- .02
1	6.54 (.60)	9.48 +/- .05
2	3.38 (.80)	12.86 +/- .05
3	3.02 (.84)	15.88 +/- .06
4	2.39 (.93)	18.27 +/- .06
7	4.75 (.69)	23.02 +/- .07
8	1.36 (1.24)	24.38 +/- .07
9	1.13 (1.34)	25.51 +/- .07
10	1.01 (1.41)	26.52 +/- .08
11	.97 (1.43)	27.49 +/- .08
14	2.12 (1.39)	29.61 +/- .08
15	.70 (2.35)	30.31 +/- .08
16	.66 (2.43)	30.98 +/- .09
17	.65 (2.47)	31.63 +/- .09
18	.59 (2.61)	32.22 +/- .09
21	1.48 (1.16)	33.70 +/- .09
22	.58 (1.85)	34.27 +/- .09
23	.57 (1.88)	34.84 +/- .09
24	.51 (2.00)	35.36 +/- .09
25	.49 (2.08)	35.85 +/- .09
28	1.13 (1.88)	36.98 +/- .10
29	.50 (2.85)	37.48 +/- .10
30	.49 (2.83)	37.97 +/- .10
31	.64 (2.51)	38.61 +/- .10
32	.53 (2.73)	39.14 +/- .10
35	1.22 (.84)	40.36 +/- .10
36	.49 (1.30)	40.85 +/- .10
37	.46 (1.30)	41.31 +/- .10
38	.41 (1.36)	41.72 +/- .10
39	.41 (1.35)	42.13 +/- .10
42	1.06 (.88)	43.19 +/- .10
49	1.90 (.68)	45.09 +/- .10
56	1.69 (.71)	46.79 +/- .10
64	1.66 (1.11)	48.45 +/- .10
71	1.50 (.77)	49.95 +/- .11
77	1.02 (.91)	50.97 +/- .11
84	1.09 (.89)	52.07 +/- .11
122	5.66 (.64)	57.72 +/- .11
150	3.05 (.83)	60.78 +/- .11

Table A.11, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 2x4 Boric Acid/Cement Composite #3

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	3.03 (.84)	3.03 +/- .03
1	6.69 (.59)	9.72 +/- .05
2	3.84 (.75)	13.56 +/- .06
3	2.98 (.85)	16.55 +/- .06
4	2.37 (.94)	18.92 +/- .06
7	4.77 (.69)	23.69 +/- .07
8	1.37 (1.22)	25.06 +/- .07
9	1.18 (1.32)	26.24 +/- .08
10	1.07 (1.49)	27.30 +/- .08
11	.98 (1.42)	28.28 +/- .08
14	2.43 (1.30)	30.71 +/- .08
15	.74 (2.30)	31.44 +/- .09
16	.75 (2.32)	32.19 +/- .09
17	.66 (2.43)	32.86 +/- .09
18	.61 (2.54)	33.46 +/- .09
21	1.58 (1.14)	35.04 +/- .09
22	.61 (1.82)	35.65 +/- .09
23	.60 (1.86)	36.24 +/- .09
24	.54 (1.90)	36.78 +/- .09
25	.51 (2.00)	37.29 +/- .10
28	1.25 (1.80)	38.55 +/- .10
29	.51 (2.78)	39.06 +/- .10
30	.49 (2.87)	39.55 +/- .10
31	.74 (2.30)	40.29 +/- .10
32	.57 (2.61)	40.86 +/- .10
35	1.30 (.82)	42.16 +/- .10
36	.51 (1.25)	42.67 +/- .10
37	.48 (1.33)	43.15 +/- .10
38	.43 (1.38)	43.58 +/- .10
39	.43 (1.38)	44.01 +/- .10
42	1.14 (.86)	45.15 +/- .10
49	2.04 (.66)	47.19 +/- .11
56	1.81 (.69)	49.00 +/- .11
64	1.70 (1.11)	50.70 +/- .11
71	1.52 (.76)	52.22 +/- .11
77	1.05 (.89)	53.27 +/- .11
84	1.11 (.88)	54.38 +/- .11
122	5.97 (.62)	60.36 +/- .12
150	3.11 (.83)	63.47 +/- .12

Table A.12

^{137}Cs Incremental and Cumulative Fractional Releases
From 3x3 Boric Acid/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	2.23 (1.38)	2.23 +/- .03
1	5.15 (1.01)	7.38 +/- .06
2	3.10 (1.21)	10.48 +/- .07
3	2.52 (1.30)	13.00 +/- .08
4	2.09 (1.40)	15.10 +/- .08
7	4.04 (1.10)	19.13 +/- .09
8	1.17 (1.79)	20.30 +/- .10
9	1.01 (1.92)	21.31 +/- .10
10	.89 (2.07)	22.21 +/- .10
11	.89 (2.08)	23.09 +/- .10
14	2.05 (1.92)	25.14 +/- .11
15	.67 (3.28)	25.82 +/- .11
16	.67 (3.22)	26.49 +/- .11
17	.66 (3.26)	27.14 +/- .12
18	.53 (3.64)	27.67 +/- .12
21	1.34 (1.68)	29.01 +/- .12
22	.56 (2.50)	29.57 +/- .12
23	.51 (2.59)	30.09 +/- .12
24	.49 (2.73)	30.57 +/- .12
25	.46 (2.74)	31.03 +/- .12
28	1.12 (2.57)	32.15 +/- .13
29	.47 (2.83)	32.61 +/- .13
30	.40 (3.15)	33.01 +/- .13
31	.62 (2.38)	33.63 +/- .13
32	.52 (2.67)	34.15 +/- .13
35	1.13 (1.23)	35.28 +/- .13
36	.49 (1.76)	35.77 +/- .13
37	.46 (1.85)	36.24 +/- .13
38	.42 (1.87)	36.66 +/- .13
39	.42 (1.88)	37.08 +/- .13
42	1.03 (1.27)	38.11 +/- .13
49	1.82 (1.04)	39.93 +/- .13
56	1.66 (1.08)	41.60 +/- .13
64	1.60 (1.56)	43.20 +/- .14
71	1.43 (1.16)	44.63 +/- .14
77	.95 (1.35)	45.59 +/- .14
84	1.01 (1.29)	46.60 +/- .14
122	5.22 (1.00)	51.82 +/- .15
150	2.85 (1.25)	54.67 +/- .15

Table A.12, Continued

^{137}Cs Incremental and Cumulative Fractional Releases
From 3x3 Boric Acid/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	2.32 (1.34)	2.32 +/- .03
1	4.97 (1.01)	7.29 +/- .06
2	2.93 (1.22)	10.22 +/- .07
3	2.34 (1.36)	12.56 +/- .08
4	1.94 (1.46)	14.51 +/- .08
7	3.83 (1.11)	18.34 +/- .09
8	1.15 (1.91)	19.49 +/- .09
9	1.01 (1.91)	20.50 +/- .10
10	.87 (2.03)	21.37 +/- .10
11	.82 (2.15)	22.20 +/- .10
14	1.94 (1.95)	24.14 +/- .11
15	.63 (3.37)	24.77 +/- .11
16	.65 (3.30)	25.42 +/- .11
17	.65 (3.31)	26.07 +/- .11
[illegible]	.51 (3.66)	26.58 +/- .11
[illegible]	1.32 (1.71)	27.89 +/- .12
22	.54 (2.60)	28.43 +/- .12
23	.52 (2.58)	28.95 +/- .12
24	.47 (2.83)	29.41 +/- .12
25	.45 (2.80)	29.86 +/- .12
28	1.02 (2.66)	30.88 +/- .12
29	.47 (2.83)	31.35 +/- .12
30	.42 (3.00)	31.77 +/- .12
31	.52 (2.81)	32.29 +/- .12
32	.49 (2.71)	32.78 +/- .13
35	1.09 (1.27)	33.86 +/- .13
36	.45 (1.90)	34.32 +/- .13
37	.42 (1.87)	34.74 +/- .13
38	.38 (2.05)	35.12 +/- .13
39	.35 (2.20)	35.47 +/- .13
42	.94 (1.37)	36.41 +/- .13
49	1.63 (1.06)	38.04 +/- .13
56	1.47 (1.18)	39.51 +/- .13
64	1.44 (1.67)	40.95 +/- .13
71	1.31 (1.20)	42.26 +/- .13
77	.86 (1.40)	43.12 +/- .13
84	1.01 (1.29)	44.13 +/- .13
122	4.94 (1.02)	49.07 +/- .14
150	2.60 (1.30)	51.67 +/- .15

Table A.13

^{137}Cs Incremental and Cumulative Fractional Releases From 6x6 Boric Acid/Cement Composite #1

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.97 (.78)	.97 +/- .01
1	2.53 (.67)	3.50 +/- .02
2	1.42 (.72)	4.92 +/- .02
3	1.14 (.75)	6.06 +/- .02
4	.89 (.79)	6.95 +/- .02
7	1.82 (.70)	8.77 +/- .03
8	.50 (.92)	9.27 +/- .03
9	.43 (.96)	9.71 +/- .03
10	.37 (1.01)	10.08 +/- .03
11	.35 (1.04)	10.43 +/- .03
14	.84 (.98)	11.26 +/- .03
15	.24 (1.55)	11.51 +/- .03
16	.27 (1.50)	11.78 +/- .03
17	.25 (1.55)	12.02 +/- .03
18	.21 (1.64)	12.24 +/- .03
21	.60 (.87)	12.84 +/- .03
22	.24 (1.19)	13.08 +/- .03
23	.21 (1.24)	13.29 +/- .03
24	.20 (1.26)	13.49 +/- .03
25	.19 (1.30)	13.68 +/- .03
28	.53 (1.14)	14.21 +/- .03
29	.20 (1.72)	14.41 +/- .03
30	.26 (1.53)	14.67 +/- .03
31	.25 (1.54)	14.92 +/- .03
32	.22 (1.64)	15.14 +/- .03
35	.54 (.74)	15.68 +/- .03
36	.20 (.92)	15.88 +/- .03
37	.19 (.93)	16.07 +/- .03
38	.17 (.98)	16.24 +/- .03
39	.17 (.96)	16.42 +/- .03
42	.47 (.75)	16.89 +/- .03
49	.90 (.68)	17.79 +/- .03
56	.84 (.68)	18.63 +/- .03
64	.81 (.81)	19.44 +/- .03
71	.73 (.70)	20.16 +/- .04
77	.49 (.74)	20.65 +/- .04
84	.59 (.72)	21.25 +/- .04
122	3.40 (.65)	24.65 +/- .04
150	1.92 (.69)	26.56 +/- .04

Table A.13, Continued

^{137}Cs Incremental and Cumulative Fractional Releases From 6x6 Boric Acid/Cement Composite #2

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.90 (.79)	.90 +/- .01
1	2.22 (.67)	3.11 +/- .02
2	1.32 (.73)	4.44 +/- .02
3	1.03 (.76)	5.47 +/- .02
4	.85 (.80)	6.32 +/- .02
7	1.66 (.70)	7.98 +/- .02
8	.47 (.93)	8.45 +/- .03
9	.40 (.99)	8.85 +/- .03
10	.36 (1.02)	9.22 +/- .03
11	.35 (1.03)	9.56 +/- .03
14	.81 (.98)	10.37 +/- .03
15	.28 (1.48)	10.65 +/- .03
16	.26 (1.51)	10.91 +/- .03
17	.23 (1.60)	11.14 +/- .03
18	.19 (1.72)	11.33 +/- .03
21	.64 (.86)	11.97 +/- .03
22	.24 (1.18)	12.21 +/- .03
23	.21 (1.25)	12.43 +/- .03
24	.21 (1.24)	12.63 +/- .03
25	.19 (1.30)	12.82 +/- .03
28	.52 (1.14)	13.34 +/- .03
29	.20 (1.69)	13.55 +/- .03
30	.21 (1.67)	13.75 +/- .03
31	.22 (1.61)	13.97 +/- .03
32	.19 (1.73)	14.17 +/- .03
35	.50 (.73)	14.67 +/- .03
36	.19 (.94)	14.85 +/- .03
37	.17 (.96)	15.03 +/- .03
38	.15 (1.00)	15.18 +/- .03
39	.16 (.94)	15.34 +/- .03
42	.43 (.75)	15.77 +/- .03
49	.80 (.68)	16.57 +/- .03
56	.71 (.69)	17.28 +/- .03
64	.74 (.82)	18.02 +/- .03
71	.61 (.71)	18.63 +/- .03
77	.43 (.76)	19.06 +/- .03
84	.50 (.74)	19.56 +/- .03
122	2.78 (.65)	22.34 +/- .04
150	1.57 (.71)	23.91 +/- .04

Table A.13, Continued

^{137}Cs Incremental and Cumulative Fractional Releases From 6x6 Boric Acid/Cement Composite #3

TIME DAYS	INCREMENTAL FRACTION RELEASED X 100	CUMULATIVE FRACTION RELEASED X 100
.07	.94 (.78)	.94 +/- .01
1	2.37 (.66)	3.31 +/- .02
2	1.34 (.72)	4.65 +/- .02
3	1.08 (.75)	5.74 +/- .02
4	.87 (.79)	6.60 +/- .02
7	1.74 (.69)	8.34 +/- .03
8	.48 (.93)	8.82 +/- .03
9	.41 (.97)	9.24 +/- .03
10	.36 (1.02)	9.59 +/- .03
11	.34 (1.04)	9.93 +/- .03
14	.87 (.95)	10.80 +/- .03
15	.26 (1.50)	11.07 +/- .03
16	.25 (1.53)	11.32 +/- .03
17	.23 (1.59)	11.55 +/- .03
18	.22 (1.62)	11.77 +/- .03
21	.59 (.87)	12.36 +/- .03
22	.22 (1.21)	12.58 +/- .03
23	.21 (1.25)	12.79 +/- .03
24	.20 (1.27)	12.98 +/- .03
25	.19 (1.29)	13.18 +/- .03
28	.56 (1.12)	13.73 +/- .03
29	.20 (1.70)	13.93 +/- .03
30	.29 (1.44)	14.22 +/- .03
31	.24 (1.54)	14.47 +/- .03
32	.21 (1.66)	14.68 +/- .03
35	.56 (.72)	15.24 +/- .03
36	.20 (.91)	15.44 +/- .03
37	.20 (.93)	15.63 +/- .03
38	.18 (.95)	15.82 +/- .03
39	.19 (.93)	16.01 +/- .03
42	.52 (.72)	16.53 +/- .03
49	1.01 (.66)	17.54 +/- .03
56	1.08 (.65)	18.61 +/- .03
64	1.03 (.76)	19.64 +/- .03
71	.84 (.67)	20.48 +/- .03
77	.60 (.71)	21.08 +/- .04
84	.66 (.70)	21.74 +/- .04
122	3.52 (.64)	25.26 +/- .04
150	1.81 (.69)	27.07 +/- .04

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