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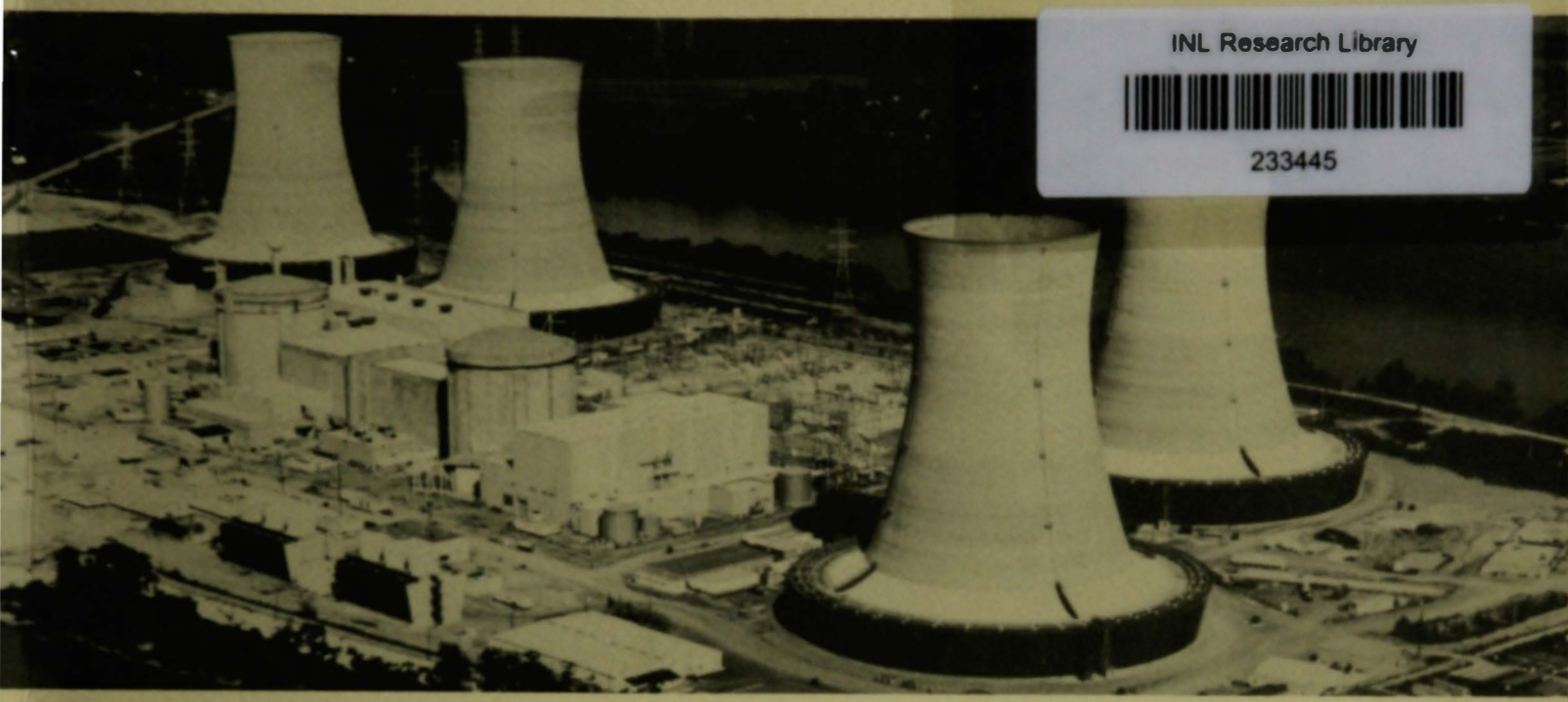

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EXAMINATION OF CONCRETE SAMPLES FROM THE TMI-2 REACTOR BUILDING BASEMENT

Douglas W. Akers

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Prepared for the
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Three Mile Island Operations Office
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ABSTRACT

Core samples were obtained from the concrete walls of the TMI-2 reactor building basement which had been submerged for up to three years in reactor coolant which leaked from the damaged reactor. The concrete samples were obtained in 1985 and 1986 using a Rover robot equipped with a drilling attachment. Three samples were sent to the Idaho National Engineering Laboratory (INEL) for examination to determine the leachability and total retention of fission products in the concrete. These data are to be used in the evaluation of methods for decontaminating the reactor building basement. It was determined that for some radionuclides (e.g., ^{90}Sr) up to 90 percent of the total activity can be removed by leaching.

SUMMARY

Approximately 2.4 million liters of reactor coolant were deposited in the reactor building basement during the accident at TMI-2. The water level eventually reached a depth of 2.56 m and quantities of radionuclides (principally ^{137}Cs and ^{90}Sr) were absorbed into the concrete walls of the basement. There are three principal types of concrete present in the basement: 3000-psi unpainted concrete, 5000-psi painted concrete, and concrete blocks used for structures in the basement. Samples of each type of concrete were shipped to the INEL for examination. The objectives of these examinations were to determine the quantity, distribution, and leachability of radionuclides absorbed into the concrete from the accident water.

The three concrete bore samples shipped to the INEL were A1 (3000-psi unpainted concrete), B2 (5000-psi painted concrete), and Sub-2 (unpainted concrete block). The first examination performed on the concrete bores was a gamma spectroscopy analysis to determine the distribution of gamma ray emitting radionuclides (i.e., ^{137}Cs) in the bores. This analysis indicated that much of the radionuclide content of Samples A1 and B2 was deposited near the sample surface exposed to the accident water and that paint appears to substantially restrict the uptake of fission products by the concrete. However, for Sub-2 (the concrete block sample) the activity was much more evenly deposited through the sample, probably due to the substantially greater porosity of this material as compared to the 3000 and 5000 psi concrete samples.

Following the gamma spectroscopy analysis, a 4 month leaching study was performed to determine the leachability of the radionuclides absorbed into the concrete. The leaching study used simulated reactor coolant containing 5000 ppm boron and 1500 ppm sodium at a pH of 7.6. Samples of the leach solution were removed periodically and analyzed to determine the radionuclide content of the material. The three measurable radionuclides were ^{134}Cs, ^{137}Cs, and ^{90}Sr. Also, the leach solution was changed at predetermined times to evaluate the effects of fresh solution on the leach

behavior of the radionuclides. Following the leaching study, the concrete bores were dissolved to determine the total radionuclide content of the material.

The leaching study indicated that up to 78% of the cesium and 93% of the strontium inventories of the concrete bores could be removed by leaching during the 4 month period. Also, the data suggested that longer leach periods with fresh coolant would desorb additional quantities of fission products from the concrete.

The dissolution of the concrete samples also provided additional information concerning the behavior of cesium and strontium in concrete. The dissolution data indicated that differential absorption of cesium and strontium occurs (i.e., that they are absorbed at different rates) and that substantial quantities of ^{90}Sr were available for absorption into the concrete up to 20 months after the accident.

ACKNOWLEDGMENTS

Several organizations and a number of people contributed to the examination of the concrete bore samples. Individuals in applied physics and chemistry who contributed to the examination effort were A. W. Marley, L. A. Weinrich, and the Radiation Measurements Laboratory staff. A significant amount of information on leaching behavior was obtained from S. T. Croney, who is currently assigned to Safeguards and Security. Suggestions on the leaching procedure and the GPU data requirements were provided by G. R. Eidam and C. Distenfeld, of Bechtel National Corporation.

CONTENTS

FIGURES

TABLES

EXAMINATION OF CONCRETE SAMPLES FROM THE TMI-2 REACTOR BUILDING BASEMENT

INTRODUCTION

During the first 3 days following the accident at the Three Mile Island Unit 2 (TMI-2), an estimated one million liters of contaminated reactor coolant escaped from the reactor coolant system (RCS) to the reactor building basement. The pressure spike from the hydrogen burn in the containment caused an additional 64,000 L of water to be sprayed into the reactor building from the reactor building spray system. After this initial influx of water, additional water continued to leak into the reactor building basement from the RCS and from leaks in the river water cooling system which was supplying water to the reactor building air cooling assembly. The water in the basement eventually reached a depth of 2.59 m (~2,400,000 L) on September 23, 1981, when water processing through the EPICOR and submerged demineralizer systems began.[1,2]

Shortly after the accident, four organizations interested in both plant recovery and accident data acquisition formally agreed to cooperate in obtaining and distributing information in these areas. The organizations, commonly referred to as the GEND group,[a] are currently involved in reactor recovery and data acquisition activities. As part of these acquisition activities, a sampling and analysis program was developed which includes sampling of many of the materials present in the reactor building.

Sampling of the water in the reactor building basement, particulate debris, and surfaces in the containment occurred from August 1979 until the present. As part of the reactor building sampling program, concrete samples were removed from the reactor building basement walls on November 26, 1985, and early in 1986. Examination of these concrete bores

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a. The GEND group is comprised of GPU Nuclear, Electric Power Research Institute, the U.S. Nuclear Regulatory Commission, and the U.S. Department of Energy.

is important, as the bores provide information on the accident behavior of radionuclides in the reactor coolant, on the reactor building surfaces, and on requirements for decontamination of the reactor building basement. Both the accident information and building decontamination requirements were addressed in the examination plan developed for the concrete bore examinations.

SAMPLE ACQUISITION AND EXAMINATION PLAN

This section discusses the acquisition of the concrete bores and the examination plan developed to meet the examination objectives. The accident-related objectives were to determine the distribution and quantity of radionuclides in the concrete, and the decontamination objective was to determine the leachability of radionuclides from the various types of concrete samples. Acquisition of the samples was performed using a Rover robot equipped with a drilling apparatus.[3]

The three samples submitted to EG&G for analysis were selected to represent three categories of concrete surfaces that were submerged in water resulting from the accident: unpainted 3000-psi concrete, painted 5000-psi concrete, and unpainted concrete block. Table 1 lists the sample identifications, descriptions, locations, and dimensions. Figure 1 shows where the samples were obtained in the reactor building basement. From Table 1, it is apparent that samples A1 and Sub-2 were removed from elevations in the reactor building which were near the high water level (2.59 m). Reference 4 indicates that these two locations were only below the water level from approximately January through October 1981; however, the B2 sample was exposed to the accident water from the beginning of the accident until water processing was nearly complete (i.e., January 1982).

The examination plan developed for the concrete bores consisted of four parts: (a) a photovisual examination; (b) initial characterization of the concrete bores using gamma spectroscopy to determine the depth of radionuclide penetration into the concrete; (c) a leaching analysis using simulated accident water to determine the quantity of material that could be leached from the concrete using uncontaminated borated water; and (d) dissolution and radiochemical analysis of the bores to determine the actual inventories of fission products deposited in the concrete. Prior to beginning the gamma spectroscopy and leaching, a layer of wax was applied to the sides of the bore and the bottom ends of A1 and B2 to cause all leaching from the bore to occur through the surface or surfaces that had been originally exposed to the accident water. The initial sample handling and preparation procedures are listed in Appendix A.

TABLE 1. TMI-2 REACTOR BUILDING CONCRETE CORE SAMPLE ACQUISITION INFORMATION

Sample Identification	Acquisition Date	Description	Sample Length (cm)	Elevation Above Floor (m)	Radiation Field (Rad/h)	
					Beta/Gamma	Gamma
A1[a]	11/26/85	A 2.5-cm-diameter bore obtained from the 3000-psi unpainted concrete wall near the reactor building air cooling assembly and elevator access area.	1.3	2.5	1.6	1.1
B2[a]	11/26/85	A 2.5-cm-diameter bore obtained from the 5000-psi painted concrete "D" ring near the stairwell.	2.2	0.8	0.37	0.03
Sub-2[b]	3/86	A 2.5-cm-diameter bore obtained from the concrete block wall surrounding the elevator.	3.2	2.5	2.0	2.0

a. This sample was wrapped in two layers of plastic sheeting.

b. This sample was contained in a plastic coin tube inside a plastic bag.

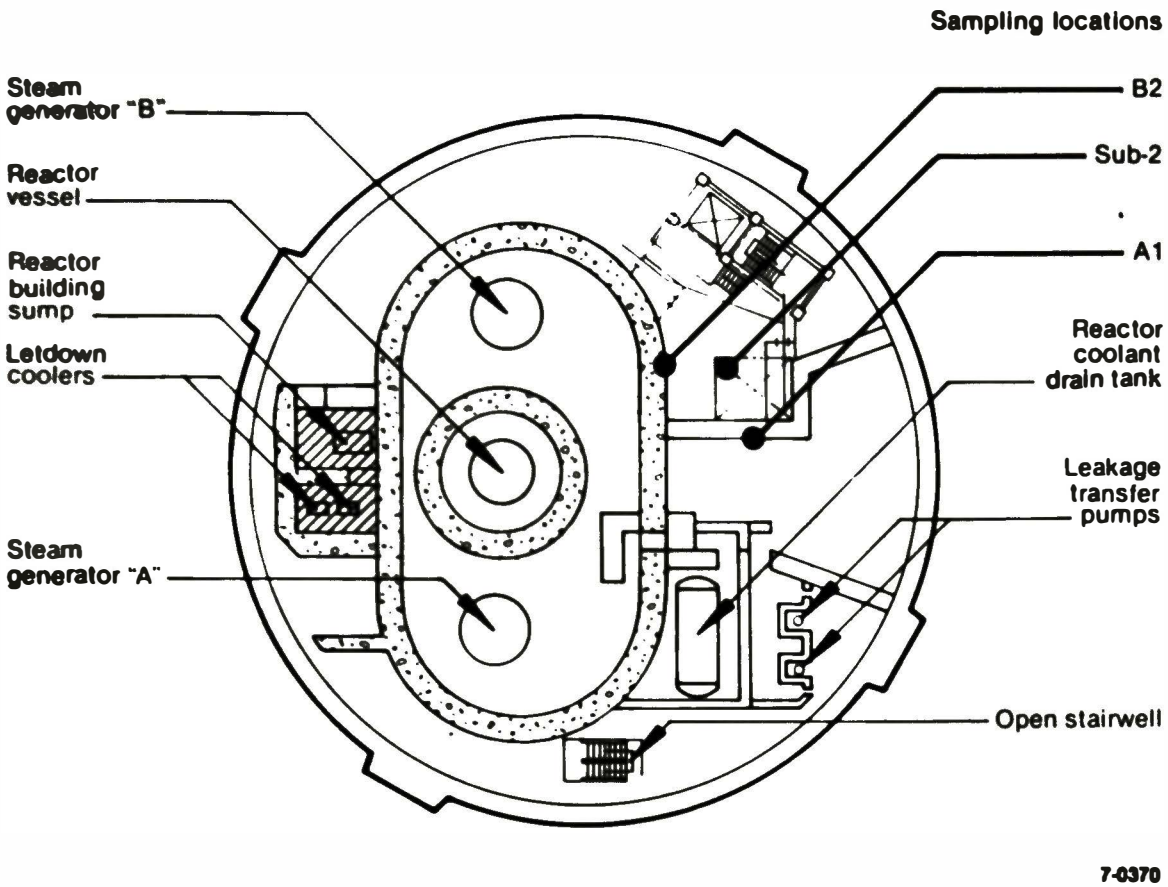


Figure 1. Concrete bore sample locations.

Photovisual Examination

The photovisual examination of the concrete bores was performed at the INEL to characterize the exposed front and back surfaces of the concrete bores.

Concrete Bore Gamma Scans

The front and back faces of the concrete bores were analyzed by radiochemical methods to evaluate total radionuclide content, and collimated gamma scans were taken along the length of the bore to determine how far the radionuclides had penetrated into the bores. The gamma spectroscopy characterization of the concrete bores was performed using a specialized collimator (Figure 2), a Davidson multichannel analyzer system, and a Princeton Gammatech intrinsic germanium detector. For the front and back scans, the samples were placed as shown in Figure 2a so that only the face of the sample was exposed to the detector. Calibration of the system was performed using standards from the National Bureau of Standards. These measurements were performed only to semiquantitatively estimate the amount of activity deposited in the concrete bores. The individual bore were analyzed at different distances, because of variations in the total activity present in the bores. The distance from the front face of the bore to the detector for each concrete bore was: A1 (100 cm), B2 (11 cm), and Sub-2 (300 cm).

Measurement of the depth of radionuclide penetration into the bores was performed by translating the concrete bore through the lead plug at 0.16-cm increments (Figure 2a) and obtaining a gamma ray spectrum at each increment. Following acquisition, the spectra were transferred to the Radiation Measurements Laboratory (RML), where they were analyzed on the VAX computer system using GAP.[5]

Leaching Analysis

The plan for the leaching analysis performed on the concrete core samples was developed to meet the specific requirements of GPU/Bechtel

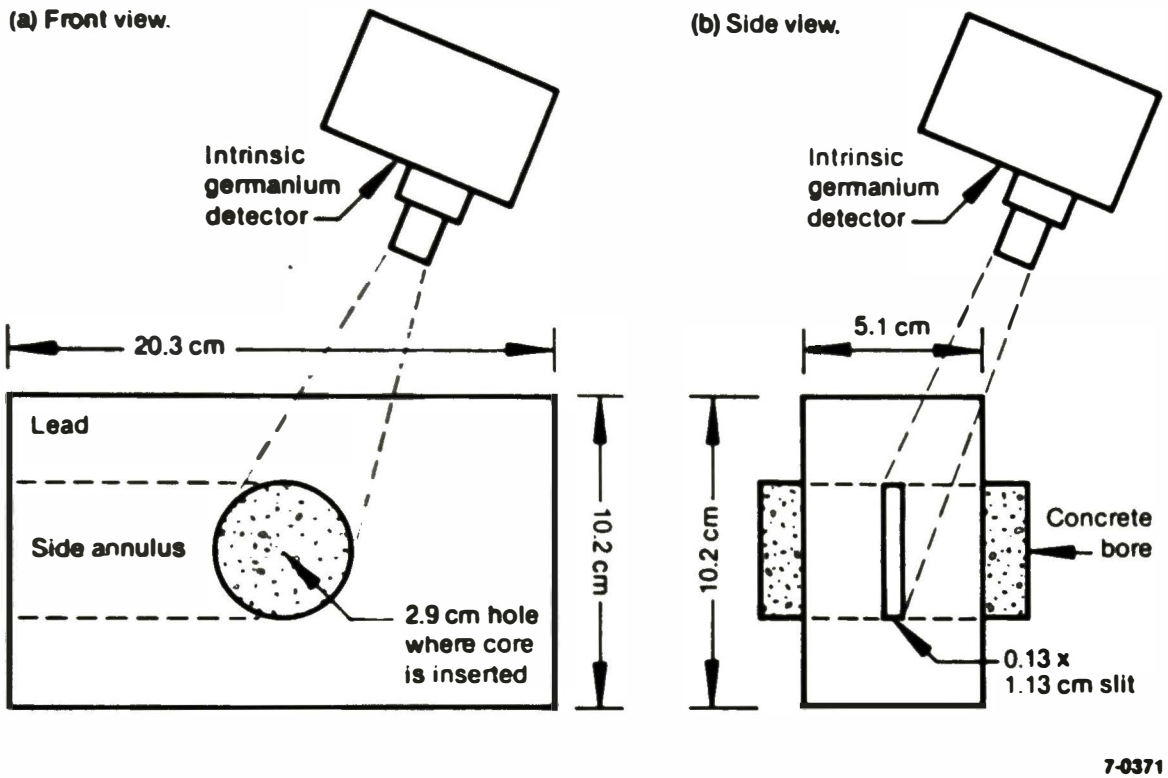


Figure 2. Method used to perform gamma spectroscopy analyses on the concrete bores.

National Corporation[6] and does not follow standard leaching procedures. Preparation of the concrete bores for the leaching study consisted of two parts. First, all surfaces of the bores were coated with paraffin except those faces which were to be leached (i.e., the front faces of A1 and B2 and both faces of Sub-2). This was done so that the radionuclide leaching would simulate the TMI-2 reactor building basement wall surfaces. Both front and back surfaces were left exposed on the concrete block sample (Sub-2), as the interior surface of the block was exposed to accident water present in the central annulus of the block. The second preparatory step performed just before the leaching study was to moisten the exposed sample surfaces by water misting to prevent rapid absorption of radionuclides into the interior of the sample material.

Each sample was leached in a four L container which contained 135 cm^3 of simulated reactor coolant per square centimeter of exposed surface area. This resulted in using 685 cm^3 of simulated coolant for samples A1 and B2 and 1370 cm^3 for sample Sub-2. The simulated reactor coolant specifications were provided by GPU and they are 5000-ppm boron and 1500-ppm sodium hydroxide, with an adjusted pH of 7.6. The leaching periods and the times when the coolant was replaced are listed in the examination results section as they were modified based on the measurement results.

The sampling procedure used when samples were obtained from the leaching solutions was to remove a 3-ml sample with a pipette. One milliliter was used for ^{90}Sr analysis, 1 ml was deposited on a filter paper and analyzed using the EG&G mobile laboratory gamma spectroscopy system,[7] and 1 ml was retained as an archive sample.

Bulk Sample Dissolution

Upon completion of the leaching portion of the study, each of the bores were dissolved and the total residual radionuclide content was measured. This was done because the initial radionuclide inventories used were estimates and were expected to be highly inaccurate. The destructive analysis was done in stages because of the large amount of material present

in each bore. First, each sample was crushed and placed in a platinum dish. Secondly, the crushed debris was pretreated with hydrofluoric acid and subjected to a potassium fluoride fusion. This fusion did not completely dissolve the debris, so the remaining material was subjected to a pyrosulfate fusion. The fused mass was then dissolved in 2M hydrochloric acid. It required between one and four liters of solution to prevent some components of the concrete bores from producing particulate material. Upon completion of the dissolution, samples were removed for ^{90}Sr and gamma ray emitter analysis.

EXAMINATION RESULTS

Examinations performed on the concrete bores included a photovisual examination, a gamma spectroscopy analysis of total activity and the penetration of radionuclides into the concrete, leaching of the radionuclide content from the bores, and a destructive dissolution of the bores to determine total radionuclide content. These examinations provided information that is valuable both in understanding the TMI-2 accident and in the decontamination effort now being performed by GPU.

Photovisual Examination

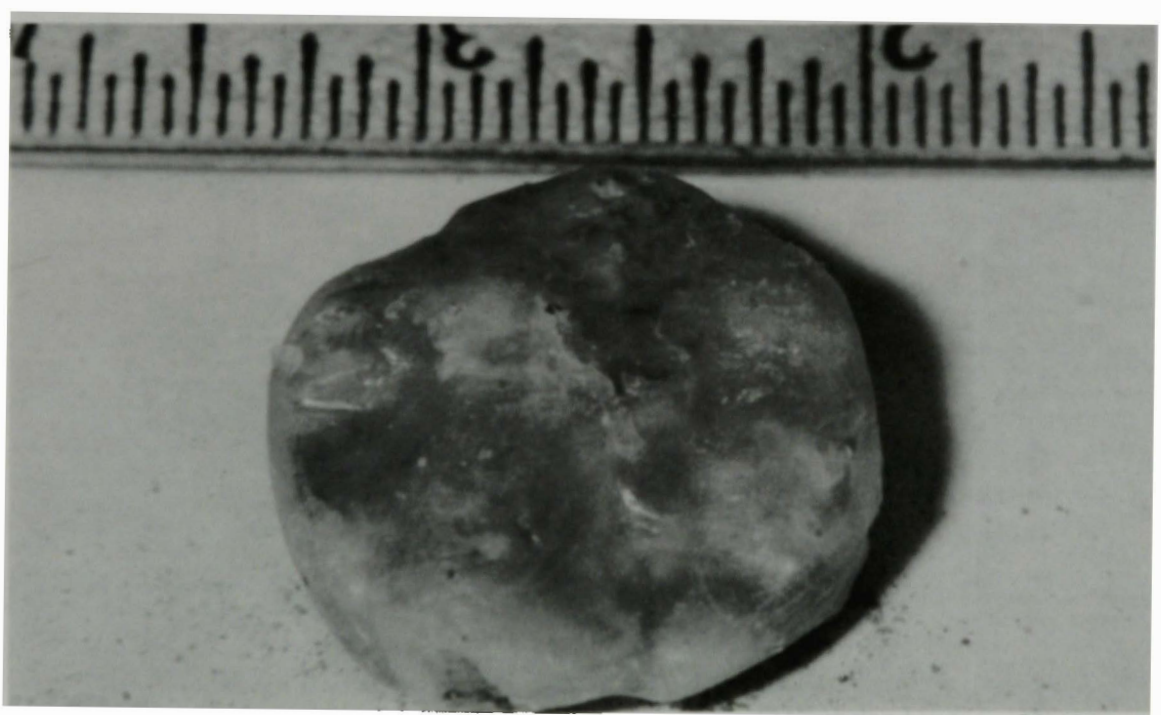
Photographs of the concrete bores were taken after they had been coated with paraffin on the surfaces that were not to be leached and after the initial 821-h leach. Figure 3 shows the front and back surfaces of sample A1. Figure 3a shows the unpainted surface of the 3000-psi concrete, and Figure 3b shows the back paraffin-coated surface of the sample. The majority of the surface (> 90 percent) is intact, which indicates that the concrete bore when leached is probably representative of the unpainted concrete surfaces in the reactor building basement where the sample was obtained. Figure 3b was included to provide a better perspective on the sample dimensions (2.5 cm diameter x 1.3 cm length).

Figure 4 shows the painted 5000-psi concrete sample (B2). Again, the surface of this sample appears to be intact, with most of the concrete remaining on the sample. This sample was longer than the A1 sample and had dimensions of 2.5 cm diameter with a length of 2.2 cm.

Figure 5 shows the exterior and interior surfaces of the concrete black sample (Sub-2). The exterior surface shown in Figure 5a is discolored, probably due to the presence of particulate material deposited on the surface during the formation of the "bathtub" ring.[7] The interior surface was not discolored, probably because the accident water to which this surface was exposed had to leak into the interior of the block before

(a) Exposed surface. 86-478-1-4

a. Exposed surface.



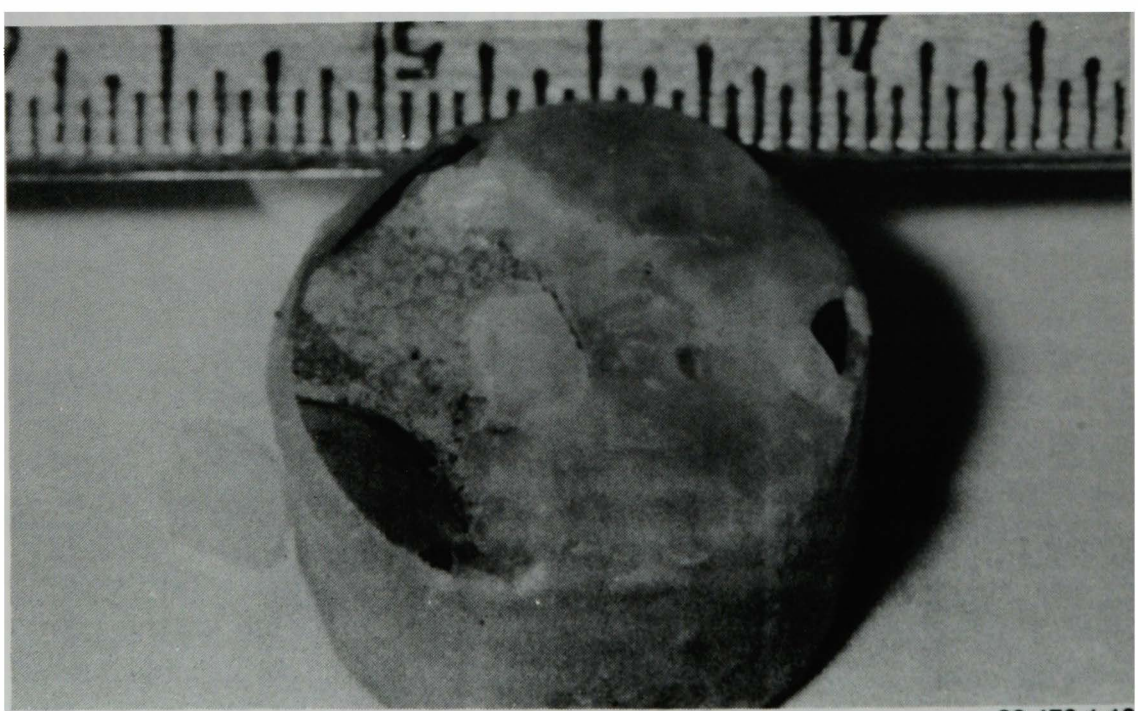
(b) Paraffin-coated back surface. 86-478-1-6

b. Paraffin-coated back surface.

Figure 3. Unpainted 3000-psi concrete (A1).

(a) Painted surface. 86-478-1-11

a. Painted surface.



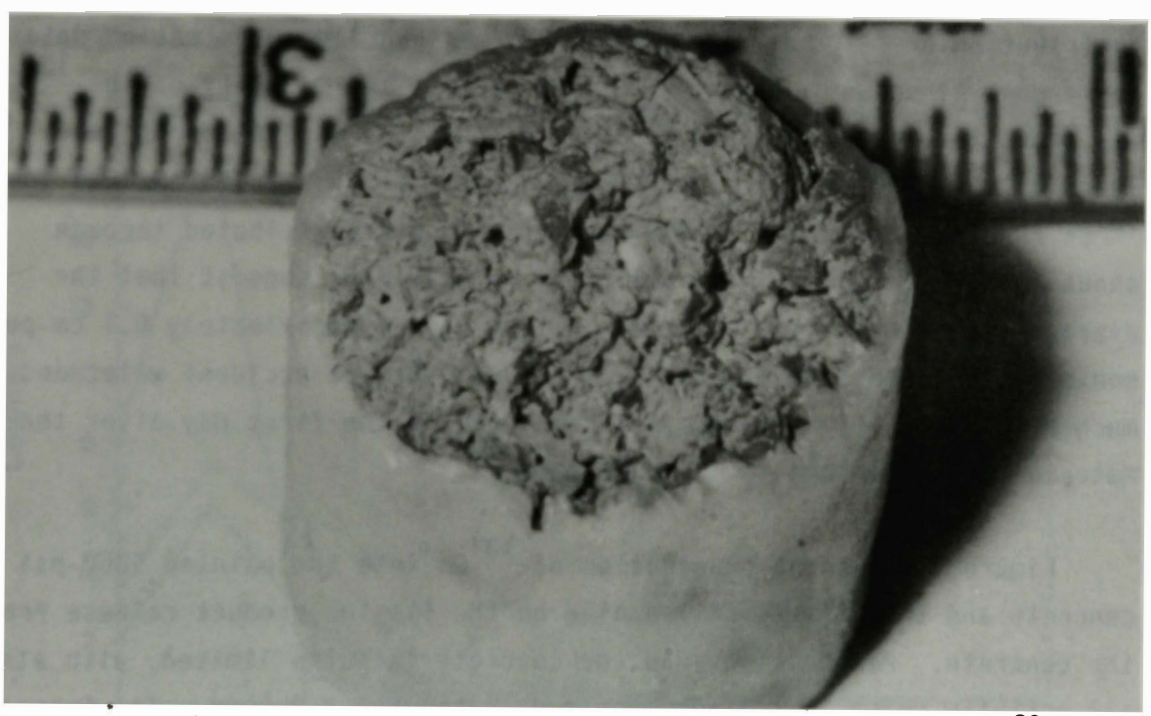
(b) Paraffin-coated back surface. 86-478-1-13

b. Paraffin-coated back surface.

Figure 4. Painted 5000-psi concrete (B2).

(a) Exterior surface exposed to the basement. 86-478-1-7

a. Exterior surface exposed to the basement.



(b) Interior surface. 86-478-1-9

b. Interior surface.

Figure 5. Concrete Block (Sub-2).

depositing on the surface and either the surface contaminants were leached out or there was adequate time for particulate material to settle out on surfaces lower in the block wall.

Concrete Bore Gamma Scans

Gamma scans were performed at three different times during the leaching analysis; before the leaching analysis was begun, after 821 h, and after 3006 h of total leaching. As previously discussed, measurements were made of radionuclide penetration into the concrete by taking collimated gamma ray spectra at 0.16-cm increments from the front face of the bore. The full length of each bore was scanned. Measurements of the front and back faces of the samples were also performed to determine if significant amounts of the total activity had been released by the leaching process. The measurements of radionuclide penetration into the concrete bores are tabulated in Appendix B, Tables B-1 through B-3.

Figures 6 through 8 show the ^{137}Cs penetration into concrete bores A1, B2, and Sub-2, respectively, and the leaching effects on the distribution of ^{137}Cs in the bores. The radionuclide penetration data for sample A1 shown in Figure 6 indicates that the majority of the ^{137}Cs was deposited in the front 0.32 to 0.48 cm of the unpainted concrete. The leaching data indicates a significant release of this activity, but some ^{137}Cs remained deposited in the concrete and was distributed through about the first 1.0 cm of the concrete. These data suggest that the average penetration into the concrete was slow (approximately 0.1 cm per month) during the approximately 9-month exposure to accident water and that much of the activity was probably deposited in the first day after the material was submerged in accident water.[9]

Figure 7 shows the penetration of ^{137}Cs into the painted 5000-psi concrete and the effects of leaching on the fission product release from the concrete. Penetration into the concrete is quite limited, with almost all activity being initially deposited in the front 0.5 cm. The subsequent measurements, after 821 and 3006 h, indicate that the peak activity near

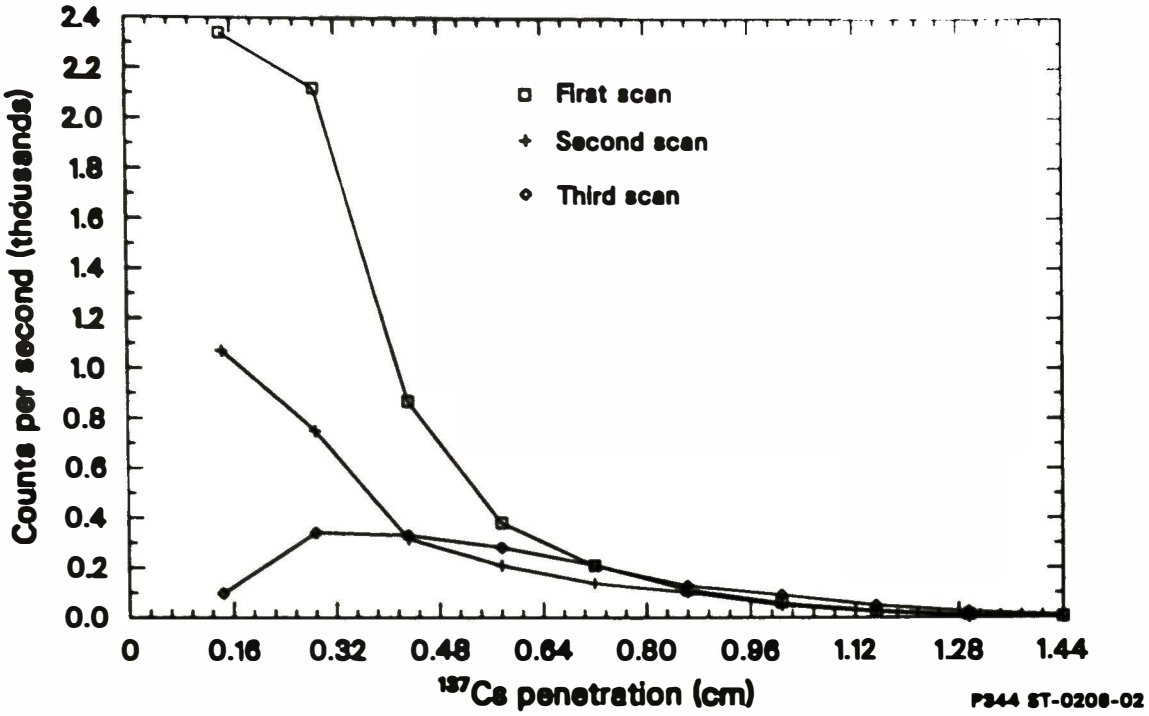


Figure 6. ^{137}Cs penetration in the 3000-psi concrete (A1).

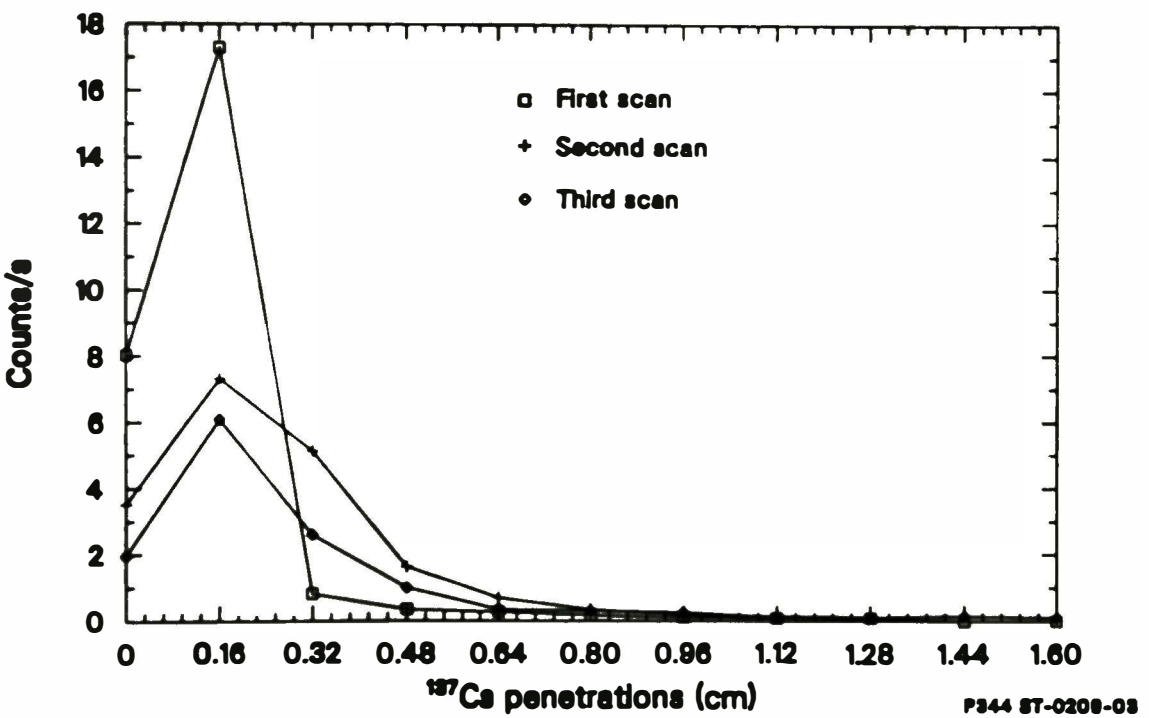


Figure 7. ^{137}Cs penetration in the 5000-psi painted concrete (B2).

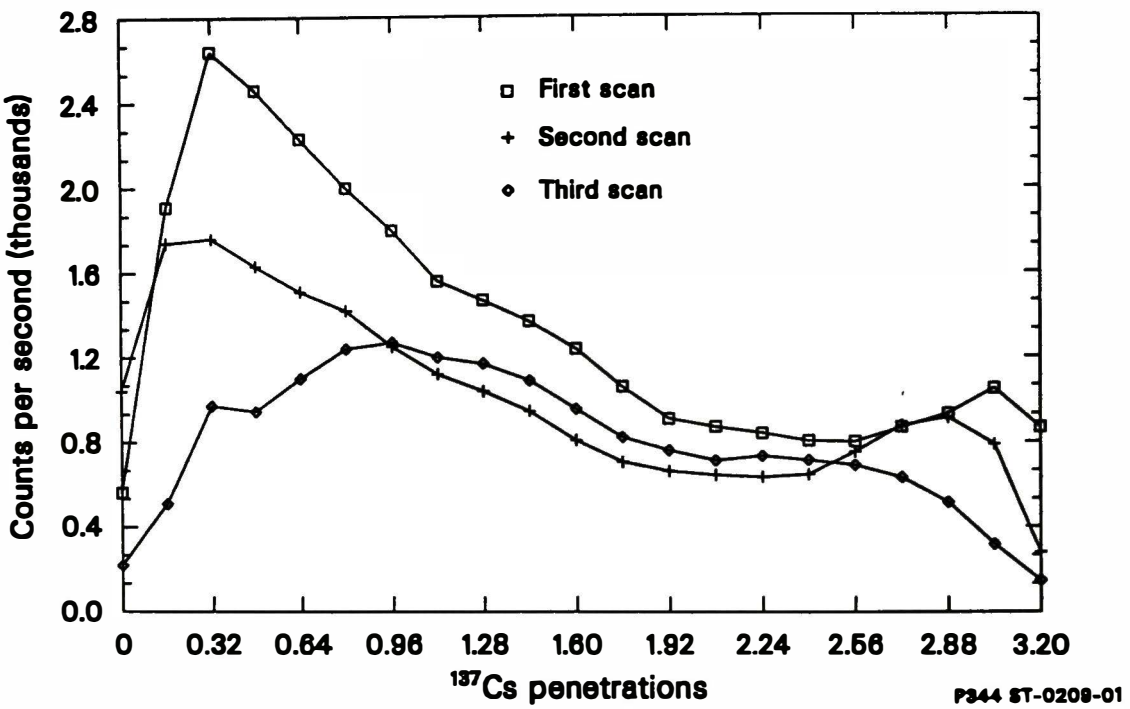


Figure 8. ^{137}Cs penetration in the concrete block (Sub-2).

the surface of the concrete is substantially reduced and that there is migration into the interior of the concrete as a function of time. This sample was exposed to the accident water for a period of 30 months; and the penetration rate, if averaged over the period the sample was submerged, is 0.017 cm/month. In fact, the migration is probably not linear; but these data give an indication of the low porosity of the painted 5000-psi concrete and its reduced potential for radionuclide absorption.

Figure B shows the penetration of ^{137}Cs into the concrete block wall sample and the effects of leaching on the ^{137}Cs release from the block material. A greater number of scans were taken on this sample to characterize the ^{137}Cs content through the entire block. The concrete block is considerably more porous than the other samples, and significant amounts of ^{137}Cs were transported through the block. This is fairly important, as the block was only submerged in coolant for a period of approximately 10 months. However, capillary action in the concrete would tend to carry water into the concrete some distance above the surface of the free standing water level.[9] The leaching effects on the ^{137}Cs in the concrete block indicate a gradient behavior, with the highest concentrations being reduced to an approximately average distribution across the block.

In addition to characterization of the ^{137}Cs migration in the concrete block, scans were taken of the front and back surfaces of the samples to determine if significant reductions or migration of the activity in the block were occurring during the leaching tests . Table B-4 (Appendix B) lists the measurement results. These data indicate reductions in the total measurable activity that are consistent with the distribution of radionuclides listed in Tables B-1 through B-3 and with sample dissolution results which are to be presented.

Radionuclide Leaching Analysis Results

The radionuclide leaching evaluations on the concrete bores were performed to determine the effects of long-term leaching and of replacing the leach solution on the behavior of fission products deposited in the

reactor building basement. Table 2 lists the leach periods intervals between samples, solution changes, and when gamma spectrometry were measurements made. The leaching analysis was begun on March 26, 1986. The ^{137}Cs and ^{90}Sr leaching data for the concrete bores are listed in Appendix C. These data are listed in microcuries per milliliter of solution, which is then multiplied by the volume of the leach solution and divided by the total inventory of the fission product deposited in the concrete core, i.e.,

$$\text{Release Fraction} = \frac{\text{Concentration (Ci/ml) x Volume of solution (ml)}}{\text{Inventory (Ci)}} \qquad (1)$$

The total inventories of fission products present in the concrete bores and their uncertainties are discussed in the following section. Plots of the cumulative release fractions for samples A1, B2, and Sub-2 for cesium and strontium are shown in Figures 9 and 10, respectively. The release fraction data are plotted versus the square root of the cumulative leach period. The cesium release fraction data plotted in Figure 9 indicate relatively linear leaching with some exceptions. These exceptions generally occur in the period after the leaching solution has been replaced and indicate a sudden increase in the leach rate. The most likely cause of the change in release rate is the establishment of a new concentration gradient between the surface of the concrete and the uncontaminated solution. Figures C-1 through C-3 (Appendix C) show the comparisons between the ^{137}Cs and ^{90}Sr behavior for each sample.

An analytical evaluation of the transport of the cesium and strontium was performed by Oak Ridge National Laboratory (ORNL) personnel.[10] These data indicate that the observed fission product leaching behavior exhibited by sample A1 is consistent with one-dimensional diffusion from a slab or surface into a solution. The B2 sample data, however, suggest a more complex mechanism (e.g., linear surface transfer through a film) which would tend to slow the migration of fission products into the concrete.

The strontium data shown in Figure 10 follow the same general leaching behavior as that exhibited by cesium for each sample. The concentrations,

TABLE 2. LEACHING ANALYSIS SAMPLE SCHEDULE

Sample Number	Total Leach Time (h)	Leach Period/Sample for Each (h)	Comments
	0	0	Gamma scan each core
1	4	4	
2	8	8	
3	24	24	
4	48	48	
5	168	168	
6	336	336	
7	672	672	
8	821	821	Gamma scan samples
	--	0	Replaced solution
9	1181	360	
10	1493	672	
11	1661	840	
		0	Replaced solution
12	2023	362	
13	2331	670	
		0	Replaced solution
14	2671	340	
15	3006	675	Gamma scan samples

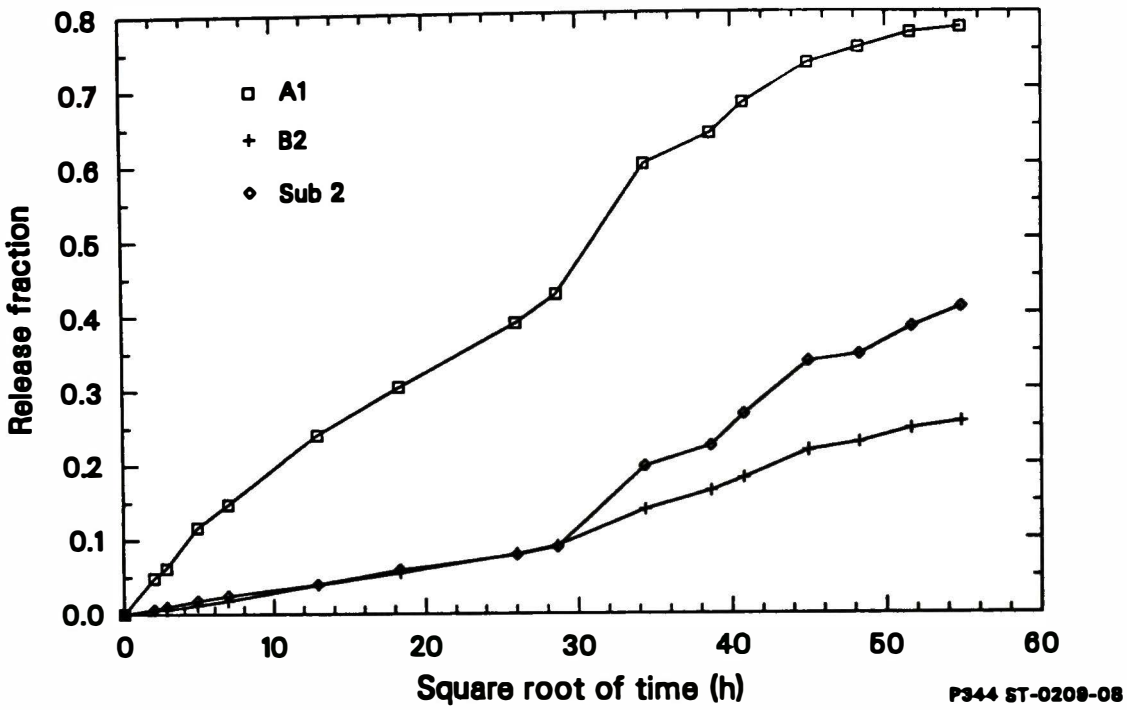


Figure 9. Cumulative ^{137}Cs release fractions relative to leaching time.

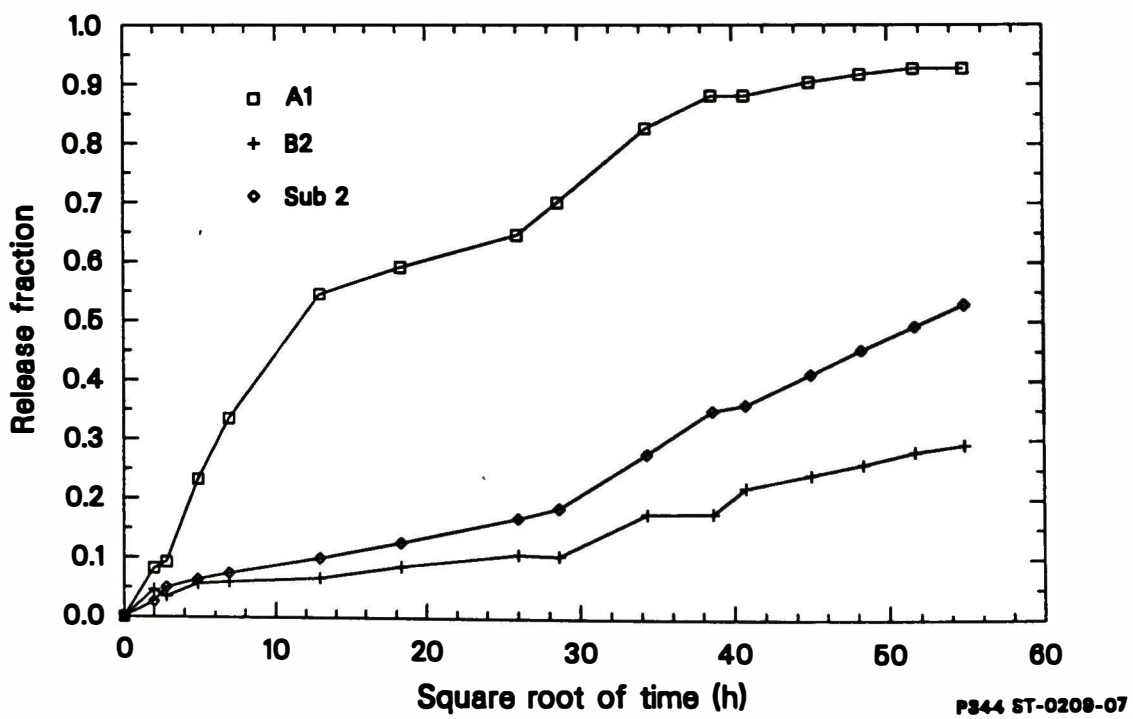


Figure 10. Cumulative ^{90}Sr release fractions relative to leaching time.

although not similar, follow the same general pattern. For both strontium and cesium, the concrete block exhibited the greatest leachability, followed by the unpainted concrete and the painted concrete.

Bulk Dissolution and Total Releases

Upon completion of the leaching study (3006 h), the concrete bores were gamma-scanned and dissolved to determine the actual content of fission products (i.e., cesium and strontium) present. The quantity of cesium and strontium originally present in the bores was determined by measuring the retained radionuclides present in the bores after leaching and adding this quantity to the quantity of material leached into solution. Table 3 lists the total quantity of fission products present in each bore and the total percentages leached into solution during the 4-month study.

These data indicate that a substantial percentage of the fission product inventories of the concrete bores can be removed by leaching and that the 3000-psi concrete (A1) is most susceptible to leaching in that almost 80% of the ^{137}Cs inventory and >90% of the strontium inventory were removed during the leaching process. The probable reasons for the lesser reduction in activity for sample 82 are that the fission product inventories were substantially lower (factors of 229 and 18 for cesium and strontium, respectively) and that reactions with the painted surface may have caused irreversible plateout on this surface. The lesser reduction in activity for Sub-2, the concrete block sample, may be surmised from the redistribution of activity which occurred during the leaching period. The later scans indicated that the concentrations in the interior of the block increased with the amount of time the block was submerged. These data suggest that the capillary action of the water to the inner portions of the block carried some of the deposited radionuclides further into the concrete rather than outward into the leaching solution.

TABLE 3. RADIONUCLIDE INVENTORIES AND TOTAL RELEASES CAUSED BY LEACHING FROM THE CONCRETE BORES

Concrete Core	^{137}Cs Inventory[a]	^{137}Cs Total Release (%)[b]	^{90}Sr Inventory[a]	^{90}Sr Total Release (%)[b]
A1	3.79 E+3	77.9	7.46 E+1	92.7
B2	1.36 E+1	25.5	4.21 E0	29.3
Sub-2	1.45 E+4	40.8	3.36 E+2	53.0

a. Inventory is listed in microcuries per sample and represents the total quantity of the listed fission products in the sample.

b. Total percentage of inventory leached into solution during the 4 month study.

CONTRIBUTIONS TO REACTOR DECONTAMINATION

The principal contribution that the concrete bore data makes to reactor decontamination is that the concrete data suggest that leaching may be an alternative to mechanical removal of surface deposited and/or absorbed radionuclides from concrete surfaces which have been submerged in reactor coolant for periods of time. A second contribution is that differential absorption of cesium and strontium occurs in the concrete in the reactor building. Previous estimates have assumed that the absorptions of cesium and strontium at TMI-2 were similar and that the total quantities absorbed were similar. The concrete data suggests, however, that absorption is affected by the type of concrete in which the absorption occurs and that cesium and strontion absorptions differ.

The cesium-to-strontium inventory ratios for A1, B2 and Sub-2 are 50.8, 3.2, and 43.2 respectively. The bare concrete surfaces indicate Cs to Sr ratios of approximately 50, whereas the painted surface ratio is substantially different (3.2). The conclusion that may be drawn is that the paint substantially affects cesium absorption as the painted surface has significantly lower surface concentrations.

The quantity of ^{137}Cs present in the basement (water) has been estimated at 310,000 Ci, whereas the ^{90}Sr inventory was estimated at 11,000 Ci.[11] These data produce an atom ratio of approximately 29 which is less than the observed maximum absorption ratios in the concrete by a factor of 1.8. This data again suggests selective absorption of ^{137}Cs. However, it should be noted that the concentrations in the basement water to which the samples may have been exposed may be substantially different from this ratio, because samples A1 and Sub-2 were exposed to accident water only for a relatively short time (10 months) during 1982 which may not have ^{137}Cs and ^{90}Sr concentrations similar to the average concentrations of both radionuclides. Also of interest is the fact that quantities of ^{90}Sr remained in solution 20 months after the accident and were available for deposition on concrete approximately 2.5 m from the basement floor (i.e., A1 and Sub-2).

CONCLUSIONS

The principal observations and conclusions that can be made from the concrete core leaching studies that relate to the reactor decontamination effort being performed by GPU Nuclear are:

- The quantity of radionuclides that can be deposited in the reactor building concrete is affected by the type and density of the concrete.

- Coatings (e.g., paint) appear to significantly restrict the absorption of radionuclides into the surface.

- Leaching of cesium and strontium from reactor building surfaces is significant, as up to 93% of the strontium and up to 77.9% of the cesium can be removed by leaching.

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APPENDIX A
SAMPLE PACKAGING AND HANDLING

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SAMPLE PACKAGING AND HANDLING

All three samples (A1, B2 and Sub-2) were transported to the INEL in a small lead shielded container sealed loose in plastic bags or in a plastic tube. The samples had only small amounts of surface contamination, which was mostly removed with Kimwipes.

APPENDIX B
RESULTS OF GAMMA SPECTROSCOPY ANALYSIS

APPENDIX B
RESULTS OF GAMMA SPECTROSCOPY ANALYSIS

The results from gamma-scanning Samples A1, B2, Sub-2, and the concrete bore faces for all three samples are given in Tables B-1 through B-4. All results have been decay-corrected to March 26, 1986, for comparison purposes.

TABLE B-1. SAMPLE A1 ^{137}Cs GAMMA SCAN RESULTS (counts/s)

Position[a]	First Scan	Second Scan	Third Scan
1	2.34 E03 ± 5.86 E01	1.07 E03 ± 2.58 E01	9.67 E01 ± 1.81 E00
2	2.12 E03 ± 4.88 E01	7.49 E02 ± 1.35 E01	3.40 E02 ± 6.12 E00
3	8.68 E02 ± 1.56 E01	3.15 E02 ± 4.41 E00	3.29 E02 ± 6.12 E00
4	3.80 E02 ± 1.10 E01	2.09 E02 ± 3.14 E00	2.81 E02 ± 5.31 E00
5	2.09 E02 ± 5.86 E00	1.37 E02 ± 3.02 E00	2.10 E02 ± 6.62 E00
6	1.12 E02 ± 3.03 E00	1.01 E02 ± 2.84 E00	1.29 E02 ± 1.74 E00
7	5.95 E01 ± 1.55 E00	4.74 E01 ± 1.42 E00	9.06 E01 ± 1.91 E00
8	2.89 E01 ± 9.24 E-01	2.26 E01 ± 5.19 E-01	4.96 E01 ± 1.46 E00
9	1.28 E01 ± 3.97 E-01	2.50 E00 ± 8.00 E-02	2.43 E01 ± 4.13 E-01
10	3.27 E00 ± 9.81 E-02	5.20 E-01 ± 4.89 E-02	1.11 E01 ± 3.94 E-01

a. Sample was scanned at 1/16-in. intervals.

TABLE B-2. SAMPLE 82 ^{137}Cs GAMMA SCAN RESULTS (counts/s)

Position[a]	First Scan	Second Scan	Third Scan
1	8.03 E+00 ± 1.53 E-01	3.52 E+00 ± 5.28 E-02	1.97 E+01 ± 2.14 E-02
2	1.73 E+01 ± 4.15 E-01	7.32 E+00 ± 1.32 E-01	2.60 E+00 ± 6.14 E-02
3	8.20 E-01 ± 1.80 E-02	5.13 E+00 ± 9.75 E-02	6.09 E+00 ± 1.28 E-01
4	3.50 E-01 ± 1.23 E-02	1.63 E+00 ± 5.54 E-02	3.06 E+00 ± 8.14 E-02
5	2.70 E-01 ± 1.57 E-02	6.90 E-01 ± 1.52 E-02	8.58 E-01 ± 2.73 E-02
6	1.70 E-01 ± 7.82 E-03	3.50 E-01 ± 1.05 E-02	3.64 E-01 ± 1.22 E-02
7[b]	1.10 E-01 ± 6.60 E-03	1.90 E-01 ± 7.98 E-03	2.62 E-01 ± 1.39 E-02
8[b]	9.00 E-02 ± 6.48 E-03	1.50 E-01 ± 7.35 E-03	1.15 E-01 ± 2.59 E-02
9[b]	8.00 E-02 ± 5.84 E-03	1.20 E-01 ± 1.07 E-02	1.20 E-01 ± 2.43 E-02
10[b]	0.00 E+00 ± 0	1.30 E-01 ± 7.02 E-03	1.49 E-01 ± 2.00 E-02
11[b]	0.00 E+00 ± 0	1.20 E-01 ± 7.20 E-03	1.03 E-01 ± 4.23 E-02

a. Sample scanned at 1/16-in. intervals unless otherwise noted.

b. Sample scanned at 2/16-in. intervals.

TABLE B-3. SAMPLE SUB-2 ^{137}Cs GAMMA SCAN RESULTS (counts/s)

Position[a]	First Scan	Second Scan	Third Scan
1	8.66 E02 ± 2.77 E01	2.79 E02 ± 5.02 E00	2.18 E02 ± 4.62 E00
2	1.05 E03 ± 3.38 E01	7.86 E02 ± 1.49 E01	5.09 E02 ± 1.22 E01
3	9.32 E02 ± 2.80 E01	9.13 E02 ± 1.83 E01	9.71 E02 ± 2.39 E01
4	8.68 E02 ± 2.52 E01	8.77 E02 ± 1.75 E01	9.44 E02 ± 2.26 E01
5	8.00 E02 ± 2.24 E01	7.51 E02 ± 1.50 E01	1.10 E03 ± 2.72 E01
6	8.04 E02 ± 2.73 E01	6.44 E02 ± 1.29 E01	1.24 E03 ± 3.24 E01
7	8.40 E02 ± 2.77 E01	6.33 E02 ± 1.20 E01	1.27 E03 ± 3.30 E01
8	8.70 E02 ± 2.78 E01	6.43 E02 ± 1.22 E01	1.20 E03 ± 3.11 E01
9	9.09 E02 ± 2.82 E01	6.61 E02 ± 1.26 E01	1.17 E03 ± 2.97 E01
10	1.06 E03 ± 2.97 E01	7.05 E02 ± 1.27 E01	1.09 E03 ± 2.56 E01
11	1.24 E03 ± 4.20 E01	8.08 E02 ± 1.62 E01	9.55 E02 ± 2.19 E01
12	1.37 E03 ± 4.26 E01	9.45 E02 ± 1.99 E01	8.21 E02 ± 1.95 E01
13	1.47 E03 ± 4.57 E01	1.04 E03 ± 2.28 E01	7.59 E02 ± 1.72 E01
14	1.56 E03 ± 4.82 E01	1.12 E03 ± 2.57 E01	7.11 E02 ± 1.61 E01
15	1.80 E03 ± 5.92 E01	1.25 E03 ± 2.88 E01	7.32 E02 ± 1.64 E01
16	2.00 E03 ± 6.60 E01	1.42 E03 ± 3.42 E01	7.12 E02 ± 1.56 E01
17	2.23 E03 ± 6.90 E01	1.51 E03 ± 3.46 E01	6.88 E02 ± 1.49 E01
18	2.46 E03 ± 7.61 E01	1.63 E03 ± 4.08 E01	6.31 E02 ± 1.36 E01
19	2.64 E03 ± 7.13 E01	1.76 E03 ± 4.57 E01	5.13 E02 ± 9.95 E00
20	1.91 E03 ± 4.96 E01	1.74 E03 ± 4.54 E01	3.16 E02 ± 5.97 E00
21	5.60 E02 ± 1.40 E01	1.04 E03 ± 2.19 E01	1.46 E02 ± 2.10 E00

a. Sample scanned at 1/16 in. intervals.

TABLE B-4. CONCRETE BORE FACE ^{137}Cs GAMMA SCAN RESULTS (μCi)[a]

Sample	First Scan[b]	Second Scan	Third Scan
A1			
Inside[c]	2.49 E03 ± 8.52 E01	8.46 E02 ± 3.00 E01	6.42 E02 ± 1.68 E01
Outside	3.01 E03 ± 1.04 E02	1.73 E03 ± 6.33 E01	6.99 E02 ± 2.03 E01
B2			
Inside	5.17 E00 ± 2.15 E-01	4.52 E00 ± 1.25 E-01	4.00 E00 ± 1.13 E-01
Outside (Painted)	9.37 E00 ± 3.78 E-01	8.52 E00 ± 3.03 E-01	7.09 E00 ± 2.14 E-01
Sub-2			
Inside	1.08 E04 ± 3.49 E02	1.01 E04 ± 3.03 E02	7.32 E03 ± 2.28 E02
Outside	1.23 E04 ± 4.42 E02	1.11 E04 ± 3.72 E02	7.71 E03 ± 2.41 E02

a. All data has been corrected for background and adjusted using RML standards.

b. First scan was performed before any leaching was done.

c. Inside face is in the wall.

APPENDIX C
RESULTS OF CONCRETE BORE LEACHING ANALYSIS

APPENDIX C

RESULTS OF CONCRETE BORE LEACHING ANALYSIS

The results of the leaching analysis on Samples A1, B2, and Sub-2 are given in Tables C-1 through C-3 and Figures C-1 through C-3. All results have been decay-corrected to March 26, 1986, for comparison purposes.

TABLE C-1. SAMPLE A1 ALIQUOT RESULTS (μCi/mL)

Hours	^{137}Cs	^{90}Sr
4	2.66 E-01 ± 3.19 E-03	8.91 E-03 ± 1.34 E-03
8	3.41 E-01 ± 4.90 E-03	1.01 E-02 ± 1.52 E-03
24	6.41 E-01 ± 1.41 E-02	2.53 E-02 ± 3.80 E-03
48	8.11 E-01 ± 5.56 E-03	3.65 E-02 ± 5.48 E-03
168	1.33 E00 ± 1.63 E-02	5.93 E-02 ± 8.90 E-03
336	1.68 E00 ± 2.69 E-02	6.44 E-02 ± 9.66 E-03
667	2.15 E00 ± 2.20 E-02	7.04 E-02 ± 1.06 E-03
821	2.36 E00 ± 4.13 E-02	7.63 E-02 ± 1.14 E-03
--[a]		
360	9.60 E-01 ± 1.48 E-02	1.37 E-02 ± 2.06 E-03
672	1.18 E00 ± 1.65 E-02	1.90 E-02 ± 2.85 E-03
840	1.40 E00 ± 9.91 E-03	1.96 E-02 ± 2.94 E-03
--[a]		
362	2.88 E-01 ± 9.44 E-03	2.58 E-03 ± 3.87 E-04
670	4.01 E-01 ± 8.34 E-03	3.88 E-03 ± 5.82 E-04
--[a]		
340	1.13 E-01 ± 1.83 E-03	8.36 E-04 ± 1.25 E-04
675	1.48 E-01 ± 3.52 E-03	1.31 E-03 ± 1.96 E-04

a. Complete leachant change out.

TABLE C-2. SAMPLE B2 ALIQUOT RESULTS (μCi/mL)

Hours	^{137}Cs	^{90}Sr
4	1.05 E-04 ± 5.16 E-06	2.83 E-04 ± 5.66 E-05
8	1.16 E-04 ± 5.98 E-06	2.16 E-04 ± 4.32 E-05
24	2.31 E-04 ± 8.66 E-06	3.46 E-04 ± 6.92 E-05
48	3.47 E-04 ± 1.30 E-05	3.67 E-04 ± 7.34 E-05
168	7.69 E-04 ± 2.37 E-05	4.08 E-04 ± 8.16 E-05
336	1.09 E-03 ± 1.64 E-05	5.29 E-04 ± 1.06 E-04
677	1.58 E-03 ± 4.24 E-05	6.58 E-04 ± 1.32 E-04
821	1.80 E-03 ± 3.11 E-05	6.45 E-04 ± 1.29 E-04
--[a]		
360	9.68 E-04 ± 2.81 E-05	4.36 E-04 ± 8.72 E-05
672	1.45 E-03 ± 4.40 E-05	4.45 E-04 ± 8.90 E-05
840	1.80 E-03 ± 3.23 E-05	7.08 E-04 ± 1.42 E-04
--[a]		
362	7.12 E-04 ± 2.72 E-05	1.43 E-04 ± 2.86 E-05
670	9.34 E-04 ± 2.25 E-05	2.49 E-04 ± 4.98 E-05
--[a]		
340	3.45 E-04 ± 2.82 E-05	1.30 E-04 ± 2.60 E-05
675	5.33 E-04 ± 4.09 E-05	1.96 E-04 ± 3.92 E-05

a. Complete leachant change out.

TABLE C-3. SAMPLE SUB-2 ALIQUOT RESULTS (μCi/mL)

Hours	^{137}Cs	^{90}Sr
4	7.20 E-02 ± 1.66 E-03	6.29 E-03 ± 9.44 E-04
8	1.09 E-01 ± 1.54 E-03	1.22 E-02 ± 1.83 E-03
24	1.88 E-01 ± 3.00 E-03	1.56 E-02 ± 2.34 E-03
48	2.58 E-01 ± 5.79 E-03	1.82 E-02 ± 2.73 E-03
168	4.19 E-01 ± 7.03 E-03	2.44 E-02 ± 3.66 E-03
336	6.23 E-01 ± 7.16 E-03	3.09 E-02 ± 4.64 E-03
677	8.31 E-01 ± 1.21 E-02	4.12 E-02 ± 6.18 E-03
821	9.41 E-01 ± 1.83 E-02	4.53 E-02 ± 6.80 E-03
--[a]		
360	1.15 E00 ± 1.72 E-02	2.27 E-02 ± 3.41 E-03
672	1.43 E00 ± 1.96 E-02	4.05 E-02 ± 6.08 E-03
840	1.87 E00 ± 9.77 E-02	4.30 E-02 ± 6.45 E-03
--[a]		
362	7.53 E-01 ± 1.29 E-02	1.28 E-02 ± 1.92 E-03
670	8.37 E-01 ± 6.90 E-02	2.22 E-02 ± 3.33 E-03
--[a]		
340	3.89 E-01 ± 4.07 E-02	9.89 E-03 ± 1.48 E-03
675	6.72 E-01 ± 1.39 E-02	1.88 E-02 ± 2.82 E-03

a. Complete leachant change out.

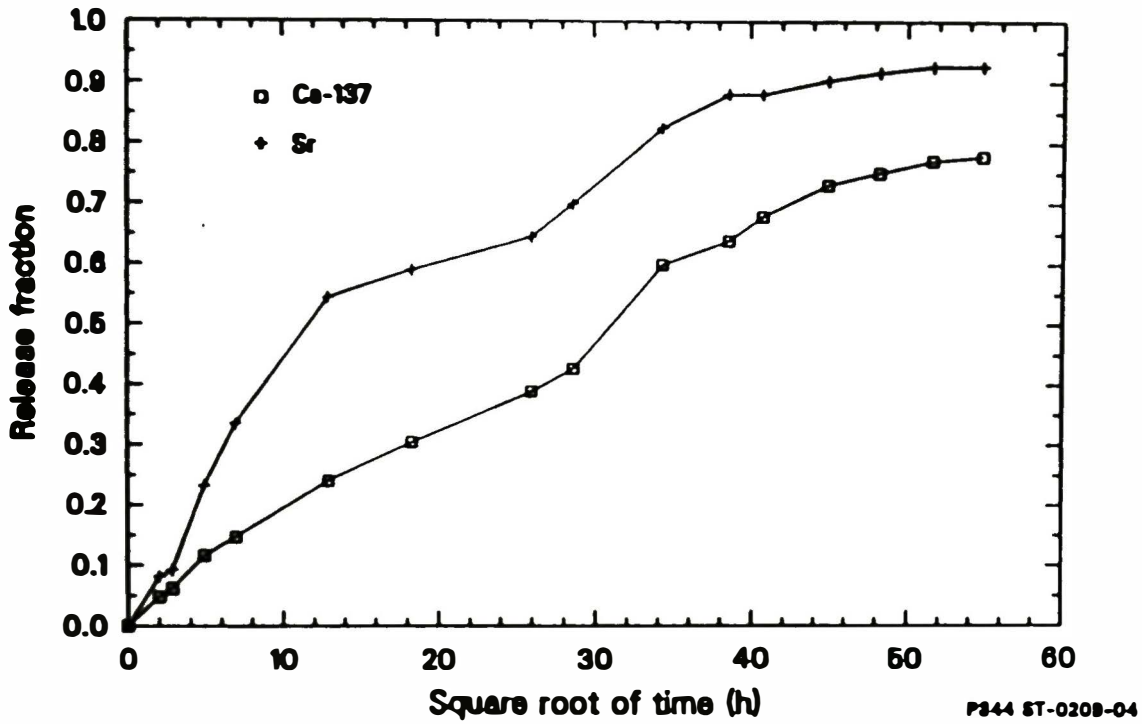

Figure C-1. Comparison between ^{90}Sr and ^{137}Cs leaching release fractions for Sample A1.

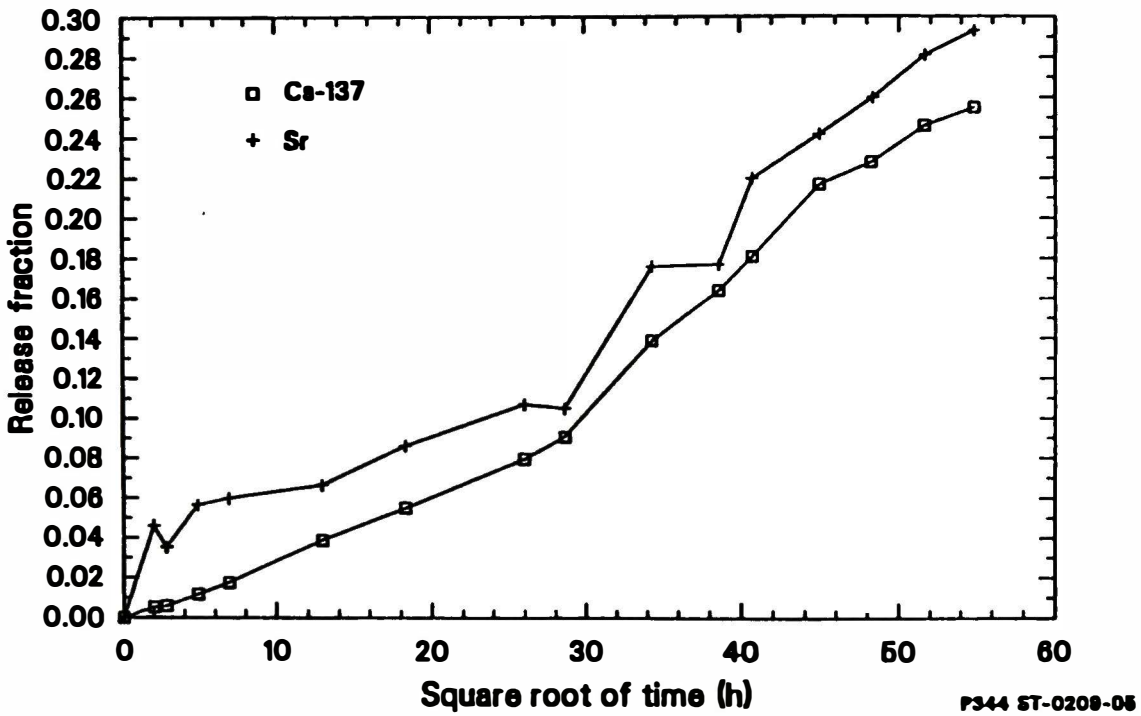

Figure C-2. Comparison between ^{90}Sr and ^{137}Cs leaching release fractions for Sample B2.

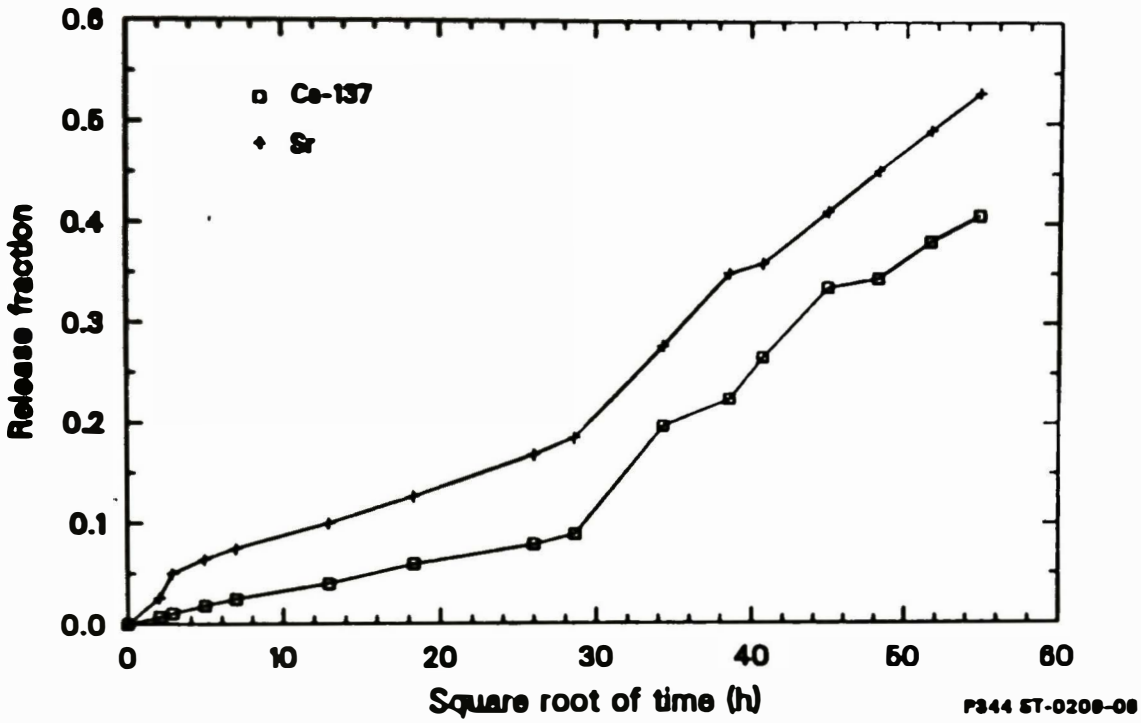

Figure C-3. Comparison between ^{90}Sr and ^{137}Cs leaching release fractions for Sample Sub-2.