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UCID-18873

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HYDROTHERMAL INVESTIGATION OF SYNROC FORMULATIONS FROM
150° TO 610°C AT 100-MPa WATER PRESSURE

L. E. Page
C. Bazan
A. J. Piwinski
G. S. Smith
S. Wootton

December 1980

Lawrence
Livermore
Laboratory

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Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under Contract W-7405-Eng-48.

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ABSTRACT

The static leaching behavior of seven formulations of SYNROC and two preparations of hollandite have been investigated under hydrothermal conditions. Each formulation was tested at several times (1 to 60 days) and temperatures (150° to 610°C) at 100-MPa water pressure, using distilled water as the fluid. Both cored and powdered samples were employed in the hydrothermal experiments. Leach rates (g SYNROC/m²·day) were calculated on the basis of element concentrations observed in the leachate. Post-run SEM and XRD observations of some core specimens revealed crystalline precipitates occurring on core surfaces, which we interpreted to be metastable phases and/or precipitates that were formed during quenching. As a result, calculated leach rates based on some elements in the fluid phase are not true leach rates. The temperature dependence of apparent leach rate was erratic. The time dependence of apparent leach rate was consistent and well defined for all SYNROC formulations; it decreased as a function of time. Analysis of hydrothermal results suggests that runs of 30 to 60 days are required to approach, or to attain, steady-state apparent leach rates. Sample form appears to have a demonstrable effect on leaching behavior. For comparable run conditions, powders generally have lower apparent leach rates but have a higher percentage of material leached than cores. The mineral hollandite appears to be very resistant to hydrothermal leaching, with only titanium found in the leachate.

INTRODUCTION

The safe disposal of high-level nuclear wastes resulting from commercial and defense processes is, and will be, a major problem during the next 20 to 50 years. For the past two decades, borosilicate glass has been the medium advocated by some groups as the solid form to incorporate the wastes.

However, recent work by McCarthy et al. (1978) at Pennsylvania State University has shown that borosilicate glasses readily devitrify in the temperature interval 300° to 400°C under 30- to 100-MPa water pressure. An alternative scheme was initially proposed and discussed by Ringwood (1978) and Ringwood et al. (1979). In 1978, Ringwood proposed that radioactive waste could be immobilized as solid solutions in the crystal lattices of the following mineral assemblage: perovskite (CaTiO_3), barium feldspar ($\text{BaAl}_2\text{Si}_2\text{O}_8$), hollandite $[(\text{Ba}_{1/2}, \text{K})\text{AlTi}_3\text{O}_8]$, leucite (KAlSi_2O_6), and zirconia (ZrO_2) with radioactive waste comprising 10 to 20 wt% of the waste form. He called this synthetic rock (SYNROC). Recent work by Ringwood et al. (1979) and workers at the Lawrence Livermore National Laboratory (LLNL) has shown that SYNROC B is an effective formulation; this contains perovskite (CaTiO_3), Ba-hollandite ($\text{BaAl}_2\text{Ti}_6\text{O}_{16}$) and zirconolite ($\text{CaZrTi}_2\text{O}_7$). This assemblage closely resembles natural analogs that are known to have been stable throughout various geological environments for hundreds of millions of years. Cesium, strontium, and the actinide elements are among the most hazardous radioactive-waste elements. In SYNROC B, cesium fractionates into hollandite, and strontium is incorporated in perovskite (Ringwood et al., 1979). The long-lived actinides partition between zirconolite and perovskite.

A very important criterion in assessing the viability of any waste form is its resistance to attack by groundwater under temperatures and pressures simulating a putative underground geologic repository. The SYNROC development program commenced in June 1979 at LLNL; during the past 18 months, several variations on the SYNROC B composition have been produced. To assess the leaching characteristics of some of these products, we performed hydrothermal experiments at 100-MPa water pressure in the temperature interval 150° to 610°C. Analyses of the various SYNROC formulations by x-ray diffraction (XRD) before experimentation revealed the phases present in the starting mixtures. Subsequent post-run analyses indicated phases lost during high pressure-temperature (P-T) hydrothermal treatment. Post-run fluid-phase compositions were quantitatively analyzed to determine leaching characteristics of the various SYNROC formulations. The hydrothermal experiments described in this report were intended to be exploratory tests for SYNROC products fabricated during the early development of the waste form at LLNL. The P-T conditions of the static leach tests in this study equal or

exceed those conditions expected in a mined repository. The results of these experiments have been used to:

- Compare the behavior of different preparations of SYNROC.
- Determine if radioactive-waste elements were successfully incorporated into lattice sites.
- Obtain some quantitative measure of the leach rate of SYNROC ($\text{g SYNROC}/\text{m}^2 \cdot \text{day}$).

EXPERIMENTAL

SAMPLES

We employed nine SYNROC preparations in our experimental study; each differs from each other in composition and processing (Hoenig and Otto, 1980a; Hoenig et al., 1980b). All were preliminary products made during the first ten months of LLNL's development program. Some preparations contain accessory phases in addition to SYNROC B assemblage. All SYNROC formulations were fabricated and supplied to us by C. Hoenig, Chemistry and Materials Science Department. Complete details of the production procedures are discussed in detail by Hoenig et al. (1980b). The nine starting materials studied are listed in Table A-1 of Appendix A, along with metallographic sample numbers and data on preparation conditions, preleach phase composition, grain size, and sample form employed in the experiments.

Nominal compositions of the SYNROC starting materials are given in Table A-2 of Appendix A. The elements listed were added in a variety of forms (e.g., as oxides, hydroxides, and salts). These mixtures were then decomposed by heating; the compositions given are based on calculations, not on chemical analyses. The sum of a few compositions is not 100% because some Cs was lost during processing in early preparations. Cs analysis of preparations was done by x-ray fluorescence (XRF). Cesium weight percents were corrected in Table A-2, but compositions were not normalized.

The preparation codes (e.g., U11SA4A, MO6SA1A, and SO3HP1A) indicate the type of processes used in making the product. The preparation of these initial mixtures aimed for homogeneity and small particle size. The letter

"U" indicates the urea process (Hoenig and Otto, 1980a) in which salts of all of the elements were dissolved in urea. These mixtures were then heated in air at 150°C to decompose the urea. The product was then calcined at different temperatures for various times, in an attempt to complete decomposition with minimum increase in particle size. Use of the urea process was discontinued when it was observed that this method resulted in inferior products. The letter "M" indicates that the composition was prepared by mixing oxides in a mechanical mortar and pestle or ball mill. The letter "S" indicates spray drying (Hoenig and Otto, 1980a). These mixtures were prepared by dissolving oxides and salts in an acid solution. The solution was spray dried at less than 150°C. The resulting powders were calcined to complete decomposition of the salts. After the preparation of the powders by the urea, mixed oxide, or spray drying method, they were made into SYNROC by sintering in air (SA) or hot pressing (HP). Hot pressing was done in a resistance-heated-uniaxial hot press using graphite dies. Complete histories of fabrication are detailed by Hoenig et al. (1980b). The last two places in the seven-place preparation code refer to a specific sample. More complete descriptions of the production process can be found in Hoenig and Otto (1980a) and Hoenig et al. (1980b).

SYNROC of U12 and U11 composition has been the most extensively tested of all preparations included in this study. The U12 composition represents the original basic SYNROC B formulation without radioactive-waste components. Two preparations with the U12 composition have been tested: U12SA6A and U12HP3A.

Three SYNROC C compositions have been used: U11, U20, and S05. Two preparations of U11 (U11SA4A and U11HP2A) were tested. U11 is original SYNROC B plus a simulated radioactive-waste component consisting of uranium, strontium, cesium, and a few rare earths. U20 is essentially the same as U11, except that the percentage of SYNROC additives--especially alumina and titania--was reduced in an attempt to eliminate the formation of accessory phases such as corundum and rutile. S05 contains the modified SYNROC additives plus PW-4b-7, which is a simulated commercial-reactor waste consisting of 24 waste elements (Rusin, 1980).

U17 composition represents SYNROC D, which is being designed to contain U.S. defense wastes. U17 contains SYNROC additives plus a simulated radioactive-waste component that is equivalent in composition to Savannah River Plant composite sludge without aluminum removal and without zeolites added (Stone, 1979).

Two samples of hollandite were tested. MO6 is a basic SYNROC hollandite, $\text{BaAl}_2\text{Ti}_6\text{O}_{16}$. SO3 is hollandite plus 3.5% cesium as the simulated radioactive waste.

Both powders and cores of the SYNROC formulations were used in the hydrothermal experiments. Powders were prepared from all SYNROC preparations by crushing the SYNROC with a steel impactor and by grinding the SYNROC in a boron-carbide mortar and pestle. A magnet was subsequently passed over the sample to remove steel fragments. Powders were sieved by hand to separate size fractions <150 μm , and 150 to 300 μm for leaching. Powder surface areas used in leach rate calculations were measured using N_2 adsorption. Cores were prepared from U12SA6A, U12HP3A, U11SA4A, and U11HP2A.

Cores for leaching studies (0.3-mm diam by 4- to 7-mm long) were drilled with diamond-steel barrels. Cores of SYNROC preparations U11SA4A and U12SA6A were annealed at 1325°C in air for 3 hr before hydrothermal treatment in an attempt to remove the effects of drilling. Cores of preparations U11HP and U12HP were not annealed after drilling. The geometric surface area of cores was used in the calculation of leach rates. Nitrogen adsorption studies of cores show that nitrogen adsorption surface area is approximately 20 times greater than geometric surface area.

EXPERIMENTAL METHODS

All hydrothermal experiments were carried out in sealed platinum capsules placed in stellite, Tuttle cold-seal pressure vessels with outside diameters of 25.4 mm. Conventional air quenching was used. Measured amounts of SYNROC preparation and distilled water were placed into platinum capsules that had been washed in ultrapure nitric acid. The capsules were crimped shut, welded, and reweighed to assure that no water was lost. Sealed capsules were preheated at 100° to 120°C for 16 to 24 hr and then reweighed to check for leaks before being placed in a cold-seal pressure vessel. Samples showing losses were discarded.

Experiments were run at approximately 100 MPa. The pressure medium was argon. Pressures were read with bourdon-tube gauges, which were calibrated against a 700-MPa Heise bourdon-tube gauge with an accuracy of 0.1%. Pressures are believed to be accurate to $\pm 5\%$ of listed values.

Temperatures were measured by chromel-alumel thermocouples; voltages by multipoint DORIC recorder. A new thermocouple junction was prepared for each

run. All thermocouples were calibrated against melting points of the following salts at atmospheric pressure, following the procedure of Roberts, 1924:

- NaCl — 800.5°C
- KCl — 770.3°C
- NaCl — Na₂SO₄ — 627.0°C
(30.5%) (69.5%)
- K₂Cr₂O₇ — 397.5°C

Details of the calibrations are given in Appendix B. Temperatures are believed to be accurate to $\pm 5^{\circ}\text{C}$.

Experiments were run at nominal temperatures of 100°, 150°, 200°, 300°, 450°, and 600°C at the 100-MPa water pressure isobar. The temperatures given in Appendix C have been corrected. The fluid used in all experiments was distilled water obtained from a Barnstead still. All masses were measured on a Sartorius balance to ± 0.0001 g. Water to sample mass ratios ranged from 0.5 to 15. The ratio for core samples was generally between 0.5 and 2; the ratio for powders generally ranged between 5 and 11.

A list of experiments according to preparation type is provided in Appendix E. Specific information on each run (e.g., composition of preparation, sample form, sample mass, water-to-sample mass ratio, water volume to sample surface area ratio, nominal temperature, time, and results of fluid analysis) is given in Appendix E. Run data are arranged by preparation type, not by numerical sequence.

After each run was quenched, the capsules were centrifuged to separate any small particles from the fluid. The capsules were then opened using scissors and tweezers, and most of the fluid was recovered by pipette. Two fluid samples were taken from most capsules, one for inductively coupled plasma emission spectroscopy (ICP) and one for XRF analysis. The capsules and samples were dried in an oven at 100°C. The samples were then removed from the capsules. Most capsules were visually inspected. Some powder and core samples were submitted for x-ray diffraction analysis. Some core surfaces were observed after hydrothermal treatment by scanning electron microscope (SEM).

INDUCTIVELY COUPLED PLASMA EMISSION SPECTROMETRY ANALYSIS

Fluid analysis was done by ICP and by XRF spectroscopy. For all runs, ICP analysis was used to detect all elements except barium and cesium. XRF was used only on some runs for Ba and Cs analyses. As fluid was removed from a capsule, ICP samples were prepared by placing 150 to 300 μ l of the leachate in a precleaned plastic sample bottle, and diluting to 1 ml with ultrapure 0.1 M HNO_3 . These samples were processed manually because of their small volume. The ICP has standard channels for the analysis of most elements. A variable wavelength channel was used for lutecium analysis. The sample analyses were interspersed with check standards and blank (distilled H_2O) analyses.

A sample I.D. file was created on a floppy disk from punched-card decks that listed the samples along with descriptive remarks, which included sample weight, water weight, run conditions, and dilution factor. The ICP data were reduced by computer and stored as a file on a floppy disc. ICP data (micrograms/ml) were transferred to the leach rate analysis program on the OCTOPUS computer system--either directly by computer interconnections or by creating a printed record and retyping a file on the OCTOPUS system.

The detection limits for the ICP are presented in Appendix F. The lowest detectable leach rate based on a particular element differs for each experimental run, because the minimum detectable leach rate is a function of dilution factor and run time. For further details on the ICP system used for these analyses, see Peck et al. (1979).

X-RAY FLUORESCENCE ANALYSIS

The Cs and Ba measurements were done using x-ray fluorescence. Samples were prepared by pipetting 50 μ l of the leachate onto a 2.54-cm-diam, Whatman-41 filter paper. The wet filter paper was dried under a heat lamp and then counted for several hours. The x-ray fluorescence counting system consists of a Kevex Sili detector attached to a ND4410 minicomputer. The exciter source was ^{241}Am and the excited K-x-rays from Cs and Ba were resolved and calculated using two computer programs--PRANAL and GRPNL2. The results expressed in μ g of Cs and Ba per 50 μ l were transferred to the

OCTOPUS computer system for leach rate calculations by ND7600 computer. The calculational scheme for leach rates and percent leached is outlined in Appendix E.

X-RAY DIFFRACTION ANALYSIS

XRD analyses were carried out on a selected number of powders from the experiments. These diffraction patterns were then compared with those of the starting materials. The powder samples from the experiments were dusted onto the surface of glass microscope slides coated with a thin layer of grease on their surfaces. The diffraction scans were run on the LLNL automated system. Analyses of the scans were made by a computer program that allows data smoothing, background subtraction, and peak location.

RESULTS AND DISCUSSION

Leaching characteristics of the various SYNROC formulations fabricated during the first ten months of LLNL's development effort are illustrated in Figs. 1 to 8. Leach rates plotted would be independent of chemical species if dissolution of SYNROC preparations was homogeneous (i.e., congruent leaching) and if all dissolved material remained in solution. Leach rates based on different elements differ for the same preparation.

A few postrun samples, which were examined by the SEM, had noticeable precipitates on their surfaces. (See Appendix G for a detailed description of SEM analyses performed on some SYNROC formulations.) Considering the amount of water present in the runs, the texture, and the morphology of these precipitates, we have interpreted these precipitates as metastable phases and/or quench products, which are not stable at the pressure and temperature of the run. Thus, not all calculated leach rates based on solution analyses are true leach rates. For this reason, we characterize these solution results as apparent leach rates. Figures 1 through 8 present apparent leach rates based on elements yielding the highest leach rates. Leach rates based on several elements are often shown in the same figure. Apparent leach rates presented are expressed as $\text{g SYNROC/m}^2 \cdot \text{day}$, based on the concentration of a particular element in the leachate and its concentration in the original waste form. Appendix D lists a temperature-time matrix summarizing the

FIG. 1. Apparent leach rate of SYNROC B formulations as a function of time at 300°C and 100-MPa water pressure. Data for U12SA6A are given in Fig. 1a, and information on U12HP3A occurs in Fig. 1b. Open circles denote data points obtained on cores; closed circles indicate values determined on powders. All pertinent details on the starting materials are contained in Appendix A. Analytical data for the fluid-phase compositions are reported in Appendix D.

FIG. 2. Apparent leach rate of the SYNROC B, U12SA6A formulation as a function of temperature for various run times at 100-MPa water pressure. Open circles represent data points obtained on cores; closed circles denote values determined on powders. Relevant information on the starting material is provided in Appendix A. Fluid-phase compositions are given in Appendix D.

FIG. 3. Apparent leach rates of SYNROC B, U12HP3A powders as a function of temperature for a 1-day run at 100-MPa water pressure. Analytical data on fluid-phase compositions are reported in Appendix D.

FIG. 4. Apparent leach rate of SYNROC C formulations as a function of time at 300°C and 100-MPa water pressure. Data for U11SA4A are illustrated in Fig. 4a; information on U11HP2A is plotted in 4b. Open circles denote data points obtained on cores; closed circles indicate values determined on powders. All pertinent details on the starting materials are recorded in Appendix A. Fluid-phase compositions are contained in Appendix D.

FIG. 5. Apparent leach rate of SYNROC C, U11SA4A, cores as a function of temperature for 10-day runs at 100-MPa water pressure. Analytical data for fluid-phase compositions are stated in Appendix D.

FIG. 6. Apparent leach rate of SYNROC C, U11HP2A powder as a function of temperature for a 1-day run at 100-MPa water pressure. Fluid-phase compositions are given in Appendix D.

FIG. 7. Apparent leach rate of SYNROC C, U20HP3A powder as a function of time at 300°C and 100-MPa water pressure. Relevant information on the starting material is provided in Appendix A. Analytical data on the fluid-phase compositions are reported in Appendix D.

FIG. 8. Apparent leach rate of SYNROC C, U20HP3A as a function of temperature for 10-day runs at 100-MPa water pressure. Analytical data on the fluid phase compositions are given in Appendix D.

experiments completed for each preparation type. Appendix E presents data for all runs; these data include apparent leach rates based on all elements detected, as well as apparent leach rate expressed as g element/m²·day and the percentage of the element in leachate. Apparent leach rate datum points are sometimes labeled with a number that represents the percentage of the element leached during that run.

SYNROC B AND C

Two preparations of SYNROC B--U12SA6A and U12HP3A--have been tested at elevated temperature and pressure. Apparent leach rates determined for U12SA and U12HP as a function of time at 300°C are illustrated in Fig. 1. Calcium (Ca) was detected in the leachate for all SYNROC B (U12) samples, and Ca usually yielded the highest apparent leach rates for U12SA. Nickel (Ni) yielded the highest apparent leach rates for U12HP, and relatively low apparent leach rates for U12SA. Aluminum (Al) and titanium (Ti) were also detected in the leachate from some runs of U12SA and U12HP. In addition, zirconium (Zr) and barium (Ba) were detected in leachate from U12SA. Ba yields the highest leach rate only for the 450°C, 10-day experiment with U12SA powder; 16.3% of the Ba was in the leachate. Most U12SA samples were subjected to XRF analysis for Ba. Apparent leach rates for Ca in U12SA versus U12HP for similar run conditions are within one order of magnitude of each other. The ranking of elements ordered by apparent leach rate differs between the two preparations, with U12HP showing a markedly higher Ni leach rate. The apparent leaching rates are ranked in decreasing order for U12SA: (Ba) > Ca > Al > Ni > Ti(Zr), and for U12HP: Ni > Ca > Al > Ti.

The effect of run time on apparent leach rate at constant temperature shows a consistent trend in all SYNROC preparations. This trend of decreasing apparent leach rate with increasing run time is illustrated by the data for SYNROC B in Fig. 1. The rate of decrease of the apparent leach rate is often greater between 1- and 10-day runs than between the 10- and 30-day runs. This pattern of decreasing apparent leach rate is illustrated by data for the U12SA powder (Fig. 1a) and the U12HP cores (Fig. 1b). The data for U12SA cores show a more uniform decrease in apparent leach rate. Only 1- and 10-day runs were completed for U12HP powder. The corresponding percentage leached is listed next to the datum points. In some cases, the total percent leached increases with run time, but there appears to be no consistent run time effect on percentage leached.

Apparent leach rate as a function of temperature for various run times is presented for U12SA cores and powders in Fig. 2 and for U12HP powders in Fig. 3. For the U12SA cores and powders, the apparent Ca leach rate for the 1- and 10-day runs shows an increase from 150° to 300°C, and then a decrease from 300° to 450°C. Aluminum was only detected in the 300° and 450°C runs; it displays a sharply decreasing apparent leach rate with increasing temperature. For U12HP powders, both Ca and Ni apparent leach rates decrease with increasing temperature, which is opposite to the expected effect of temperature (i.e., apparent leach rate should ordinarily increase with temperature). Apparent leach rates for U12HP based on Al display the same maximum at 300°C as illustrated by Ca for U12SA formulations. In contrast, Ti apparent leach rates for U12HP reveal a minimum at 300°C.

For similar run conditions, sample form seems to affect apparent leaching rates. Cores generally yield higher apparent leach rates than powders, but powders show a greater percentage of element leached. SYNROC B data for both U12SA and U12HP illustrate the differences between sample forms (see Fig. 1). U12 cores yielded apparent leach rates higher than those from powders by one to two orders of magnitude. U12 powders show a percentage of element leached that is two to five times greater than for the cores. Powders provide a more sensitive indicator for detecting elements in solution--probably because of high surface-area-to mass factor. Also, powders were generally run with a higher water-to-sample mass ratio than cores, with typical ratios of 5 to 11 for powders, and 0.5 to 2 for cores.

The surface areas used in calculations are geometric for cores and nitrogen adsorption for powders. Nitrogen adsorption measurements on U11 cores indicate that the actual surface area is approximately 20 times greater than the geometric surface area; therefore, apparent leach rates for cores based on geometric surface areas may be inflated by a factor of 20 relative to apparent leach rates reported for powders. However, the two orders of magnitude difference between apparent leach rates calculated for cores and powders cannot be entirely explained by this surface area measurement discrepancy. For further discussion of surface area measurements and their application to leaching of SYNROC, see Coles and Bazan (1980).

Four preparations of SYNROC C--U11SA4A, U11HP2A, U20HP3A, and S05HP4A--have been run at elevated temperature and pressure. Both cores and

powders of U11 were used in the experiments. The differences between these preparations have previously been described. More complete details are contained in Hoenig et al. (1980b). Apparent leach rate data as a function of time at 300°C are presented for U11 formulations in Fig. 4 and for U20 in Fig. 7. Apparent leach rate information for 10-day runs on U11SA cores is plotted as a function of temperature in Fig. 5. One-day run apparent leach rate data for U11HP powders are plotted as a function of temperature in Fig. 6. We discuss, but do not plot, apparent leach rate data for S05HP because only a limited number of experiments were conducted on this preparation.

For U11 formulations, strontium (Sr) yielded the highest apparent leach rates for most samples, with Ca apparent leach rates approximately one to two orders of magnitude lower. U11SA powder is an exception; here Ca yields slightly higher apparent leach rates than Sr. Results for both Ca and Sr are shown in Figs. 4, 5, and 6. These plots illustrate the similar trends of apparent leach rates based on Ca and Sr with respect to time and temperature. Detection of aluminum was erratic for U11 samples, and apparent leach rates based on Al are generally low--from 10^{-3} to 10^{-7} g SYNROC/m²·day. Al was detected in fewer U11HP samples than U11SA samples. Apparent leach rates for the elements observed, ranked according to apparent leach rate at 300°C, are as follows:

- U11SA

Cores -- (Cs) > Sr > Ca > Ni > Lu > Ti

Powders -- (Cs) > Ca > Sr > Ba > Ce > Ni > Al, Ti

- U11HP

Cores -- Sr > Ca > Ce > Ti

Powders -- (Cs) > Sr > Ca > Ni > Ba > Ce > Al > Ti, Y, Zr, Lu

There were problems with cesium detection in U11. The weight of Cs in the original U11 samples is uncertain because of Cs losses during processing. (The amount of Cs in the U11 SYNROC C formulation is probably in the range of 0.1% to 0.01%.) Therefore, SYNROC leach rates and wt% leached could not be calculated based on Cs. However, Cs has been detected sporadically in

leachate from U11 preparations. The amount of Cs in the fluid is large compared with the estimates of Cs content in the formulations, yielding estimates of 4 to 80 wt% of Cs leached.

The effect of run time on apparent leach rate at 300°C for the U11 SYNROC C preparations follows the usual trend of decreasing apparent leach rate with increasing run time. Data for U11SA cores and U11HP powder are plotted for 1-, 10-, and 30-day runs (see Fig. 2a). Data for U11SA powder were collected for 10- and 30-day runs only. Data for U11HP cores are plotted for 10-, 30-, and 60-day runs. For each preparation and sample form (e.g., U11HP cores or U11HP powders), the apparent leach rate vs time curves for all the elements detected are parallel or subparallel to each other, indicating a similar trend in leaching behavior. For all U11 preparations, the rate of decrease in the apparent leach rate decreases with time. For U11HP cores, the apparent leach rate appears to reach a nearly steady-state condition between 30 and 60 days. Run time appears to have little or no correlation with percentage leached. For U11SA, the effect of temperature on apparent leach rate seems to be consistent for Sr, Ca, and Ni, with apparent leach rate decreasing as temperature increases (see Fig. 6). U11HP powders, on the other hand, show a more random temperature effect (see Fig. 7).

The effect of sample form on leach rate of U11 samples is consistent with the results for U12 samples. Apparent leach rates based on the same elements for similar runs are two to three orders of magnitude lower for powders than for cores for both U11SA and U11HP. The lower apparent leach rates for powders may be caused by solution saturation in the leachate. Powder samples had a water weight to sample surface area ratios approximately 20 times lower than for core samples. XRD data corroborate solution saturation for U11HP, but not for U11SA.

Apparent leach rates from comparable runs are generally higher for U11HP than for U11SA. Apparent leach rates for U11HP cores are higher than for U11SA cores by two orders of magnitude. The apparent leach rates for the powders of the two preparations are more nearly similar, with U11HP powders showing lower apparent leach rates for some conditions. Although water-to-sample weight ratios vary slightly from run to run, there is a general difference between the U11SA and U11HP series of experiments. U11HP runs generally had water-to-sample weight ratios of from one and a half to two times as high as U11SA runs, for both cores and powders.

For the U20HP3A SYNROC C formulation, γ powders were tested. The elements detected, ranked in order of apparent leach rate, are as follows:

$Cs > Sr \geq Ba > Ca > Ni > Ti, Ce.$

Ni shows an anomalously high apparent leach rate for 300°C, 1-day run, for which it exceeds all but the Cs leach rate (Fig. 7). Analysis for Cs was performed for only two U20 runs; thus, the trend of Cs data is tentative at best. Apparent leach rates based on Cs were the highest, at 5.9×10^{-1} g SYNROC/m²·day at 300°C, 1-day run (22.7%) and at 2.3×10^{-2} g SYNROC/m²·day at 300°C, 30-day run (26.65%). The percentage leached results for Cs are reasonable for U20; there is no reason to suspect problems with the Cs data for this composition.

The apparent leach rates determined for U20 in this investigation are very similar to Ca and Sr leach rates reported for the same U20 powder in a continuous-flow leaching study performed with distilled water at 25°C and 75°C at atmospheric pressure (Coles and Bazan, 1980). The continuous-flow tests show slightly higher leach rates based on Sr and Ca, and a drop in leach rates of approximately one order of magnitude between 1 and 10 days. These results are in agreement with our U20 data, which were collected at 300°C at 100-MPa water pressure.

The effect of run time on the apparent leach rate of U20HP is consistent with its effect on other preparations (Fig. 7). Apparent leach rate at the 300°C isotherm decreases with increasing run time. Ca and Cs data are presented in Fig. 7, although information was available for only the 1- and 30-day runs.

Ten-day apparent leach rate results for the U20HP SYNROC C preparation are plotted as a function of temperature in Fig. 8. Temperature appears to have a minor effect, but the results are somewhat erratic. Apparent leach rates for U20HP powders are slightly lower than leach rates for U11SA or U11HP powders for similar runs. The difference is generally less than one order of magnitude.

Only two runs were made on the S05HP4A SYNROC C powders: one was at 200°C, for 10 days, the other at 300°C for 10 days. Apparent leach rate data are reported in Appendix H. In general, the percent of elements leached

is low, with iron and cesium leading the list. Results from the S05HP4A powder indicate that the measured apparent leach rates are similar to results for U20HP, within the same order of magnitude for most elements. Continuous-flow leach tests (Coles and Bazan, 1980) performed at 25°C and 75°C at atmospheric pressure with S05HP powders of the same size range (150 to 300 μm) yielded leach rates similar within one order of magnitude to those reported in Appendix E.

Leach rates for similar run conditions differ slightly between the SYNROC B and C preparations investigated. Comparable runs for SYNROC B (U12) and SYNROC C (U11) yield leach rates that are similar, within approximately one order of magnitude. There is an approximately defined order of apparent leach rate magnitudes, with comparable leach rates ordered as follows:

$$\text{U11HP} \geq \text{U12HP} \geq \text{U12SA} \geq \text{U11SA} > \text{U20HP} \geq \text{S05HP}.$$

The ranking of elements by the apparent leach rates varies among the preparations. Ba and Cs or Ca and Sr generally lead the list, with Ni yielding the highest leach rates in some cases.

SYNROC D

Three runs were completed with powders of the SYNROC D preparation, U17HP1A. Apparent leach rate data based on all of the elements detected are presented in Appendix I. Apparent leach rates based on Ca for the 1- to 10-day runs at 300°C are low relative to Ca leach rates for other SYNROC powders. Cs was detected in the leachate from all three runs, and yielded the highest leach rate for the SYNROC D in all three cases. Cs detected in the leachate was 4.5% and 8.7% from the 300°C, 1- and 10-day runs, respectively. The leachate from the 450°C, 1-day run contained 37.6% of the Cs from the sample. The elements detected are ranked by order of apparent leach rate, g SYNROC/m² day, as follows:

- 300°C, 1 day: Cs > Al > Si > Ca > (Fe, Mn, Ni) > Ti
- 300°C, 10 days: Cs > Al > Si > Ca > Sr > (Mn, Ni)
- 450°C, 1 day: Cs > Na > Al > Si > (Ca, Fe, Mn) > Ti

The order of ranking is consistent, except that Na was detected only in the leachate from 450°C, 1-day run, and it ranks second after Cs for this run.

For the SYNROC D formulation U17HPLA, apparent leach rates based on most of the elements detected decrease with increasing time from 1 to 10 days at 300°C, and also decrease with increasing temperature from 300°C to 450°C (for 1-day runs). In general, the percent leached increases from the 1- to 10-day run at 300°C, and decreases with the rise in temperature from 300°C to 450°C. One exception to this pattern is Cs, which displays the highest apparent leach rate and also the highest percentage leached for the 1-day, 450°C run.

HOLLANDITE

Two preparations of hollandite, nominally $\text{BaAl}_2\text{Ti}_5\text{O}_{14}$, were run at elevated temperature and pressure. MO6SALA is a pure hollandite and SO3HP3A contained 3.5 wt% cesium. Four experiments were run with powders of each preparation.

The surface area of MO6 powder (particle size less than 44 μm) was estimated at $1 \text{ m}^2/\text{g}$. Apparent leach rates calculated on the basis of this estimate are not consistent with other apparent leach rates given in this report, because surface area analysis was not done by nitrogen adsorption. Three 1-day experiments at 150°C, 300°C, and 450°C, and one 10-day experiment at 300°C were run. Titanium was the only element detected in the leachate, and it appeared at very low levels, with the percentage of Ti leached on the order of 0.00001%. X-ray diffraction data from the MO6 powder show a good hollandite pattern before and after leaching, with no alteration in lattice constants and no new peaks forming. MO6SALA hollandite thus appears to be very resistant to high-temperature hydrothermal solutions based on our fluid analyses.

SO3HP3A was treated at 200°C for 1, 10, and 30 days, and at 300°C for 10 days. Cs analysis by XRF was completed for three of the four runs. The elements detected in order of apparent leach rate are $\text{Cs} > \text{Al} > \text{Ti}$. The percentage of Cs in the leachate falls between 2% and 4% for all runs, and Cs yielded leach rates between 9.9×10^{-3} and $4.5 \times 10^{-1} \text{ g SYNROC/m}^2\text{-day}$.

Leach rates based on Al and Ti are significantly lower--in the range of 10^{-4} to 10^{-5} for Al, 10^{-5} to 10^{-6} for Ti. For further details, consult Appendix E. Continuous-flow leach tests performed on the same materials at 25°C and 75°C at one atmosphere pressure by Coles and Bazan (1980) yield Cs leach rates that are a factor of five lower than our leach results from 200°C. The decrease in the leach rate with time between 1 and 30 days was greater for the continuous-flow tests than for the 200°C static tests.

SUMMARY AND CONCLUSIONS

Static leaching behavior has been investigated for two preparations of SYNROC B, four preparations of SYNROC C, one preparation of SYNROC D, and two preparations of hollandite. Each preparation was tested at several times and temperatures using Pt capsules in cold seal pressure vessels at 100-MPa water pressure. Distilled water was the fluid. Both cored and powdered samples were employed in the hydrothermal experiments.

Leach rates ($\text{g SYNROC}/\text{m}^2\cdot\text{day}$) were calculated on the basis of element concentrations observed in the leachate. Fluids coexisting with the various SYNROC formulations were analyzed by XRF and ICP techniques. Post-run SEM observation of some core specimens reveals crystalline precipitates occurring on the core surfaces, which we interpret to be metastable phases and/or quench products, which were formed during cooling from high temperature. XRD analyses have identified new post-run phases in some samples. The presence of metastable phases and/or quench growth thus indicates that the calculated leach rates based on some elements in the fluid phase are not true leach rates, but minimum values. Because of this, we use the term "apparent leach rate" to refer to the calculated leach rates presented in this paper.

Apparent leach rates based on Ca or Sr were the highest for most SYNROC preparations. Analyses for Ba and Cs were done only for some runs. As discussed earlier, we encountered problems with Cs analysis for some preparations. Hence, trends for Ba and Cs leaching are not well defined by our investigation. However, in some cases, Ba and/or Cs yield leach rates that exceed Ca and Sr leach rates. In some instances, Ni yields the highest leach rate.

Calcium is a component of two SYNROC phases, perovskite, and zirconolite. The radioactive-waste element, strontium, enters perovskite preferentially substituting for calcium. For the various SYNROC formulations that contain strontium, Ca and Sr display similar leaching behavior, with Sr generally yielding higher apparent leach rates by up to approximately one order of magnitude. The similar apparent leach rate patterns illustrated by Ca and Sr suggest that perovskite is the main source for these elements. Apparent leach rates based on Zr are usually several orders of magnitude lower than for Ca and Sr, and none of the quench phases examined by the energy dispersive system using the SEM were high in Zr. It is thus unlikely that zirconolite is the major source of the ubiquitous Ca in the leachate. This was also observed for preparation S05 (SYNROC C) by Coles and Bazan (1980).

Hollandite is the only SYNROC phase containing Ba and Cs; therefore, dissolution of hollandite is a likely source for these elements. However, it is suspected that high Cs leach rates may reflect the easy release of Cs from grain boundaries or from extremely soluble non-SYNROC phases containing Cs. Unpublished results of R. Lim (1980) indicate that Cs has been washed from some early SYNROC preparations at ambient temperature and pressure during overnight experiments. Ni is present in SYNROC formulations as NiO and metallic Ni. Both act to control the oxidation state, and are not radioactive-waste hosts.

The order of apparent leach rates for SYNROC B (U12) based on the elements detected is: (Ba) > Ca > Al > Ni > Ti, Zr for the sintered samples, and Ni > Ca > Al > Ti for the hot-pressed samples. Barium was only detected in the 450°C, 10-day U12SA run. The more complex SYNROC C formulation (U11, U20, S05), which contains mock radioactive-waste elements, displays variations in the order of apparent leach rates based on the different elements. In general, the order is:

$$(Cs) \geq Sr \geq Ca > (Ba) > Ni \geq Ce > Al, Ti, Zr, Lu, Y.$$

The relatively higher leach rates of Cs, Ba, Sr, and Ca are clearly indicated.

The SYNROC D formulation differs significantly in bulk composition from the SYNROC B and C preparations. For example, SYNROC D contains Si and Na; as a result, nepheline is formed. The general order of apparent leach rates, as determined by the elements detected in the leachate from SYNROC D, is as follows:

Cs > (Na) > Al > Si > Ca, Sr, Mn, Ni, Fe > Ti. (Na was detected for the 450°C, 1-day run only.)

For hollandite preparation, MO6, only Ti was detected in the leachate. The order of apparent leach rates in the Cs-bearing hollandite, SO3, is

Cs > Al > Ti.

The difference between apparent leach rates based on different elements for identical formulations suggests incongruent dissolution of SYNROC. Although the formation of metastable and/or quench phases introduced uncertainty into the leach rate relationships discussed above, it is doubtful that this alone can account for all the discrepancies in the apparent leach rates.

The temperature dependence of apparent leach rate is erratic. In many cases, apparent leach rates decrease with increasing temperature, which is opposite to what is expected (i.e., increasing apparent leach rate with temperature). Examination of all the results suggests that runs of 1 to 10 days in duration may not be sufficient to approach, or to attain, stable equilibrium. Leaching behavior for most SYNROC formulations does not appear to be strongly temperature dependent, with changes in the apparent leach rate from 150°C to 450°C of approximately one order of magnitude or less. Coles and Bazan (1980) reported similar results for continuous-flow leaching tests performed at 25°C and 75°C at atmospheric pressure. In general, more elements appeared in the fluid phase at detectable levels for high-temperature runs than for low-temperature runs.

The time dependence of apparent leach rates is consistent and well defined by the results obtained on all SYNROC formulations. Apparent leach rates were found to decrease as a function of time. This may be a solution saturation effect; however, Coles and Bazan (1980) reported similar results using a continuous-flow leaching technique where solution saturation problems are not encountered. The rate of decrease in apparent leach rate is generally greater between 1 and 10 days, than between 10 and 30 days or 30 to 60 days. Analysis of these new results suggests that hydrothermal runs of 30 to 60 days are required to approach or to attain steady-state apparent leach rates using our methods.

Based on SEM examination of the core surfaces of SYNROC formulations U12SA and U11HP, the amount of metastable phases, and/or quench growth increases isothermally with run duration. The greater the amount of precipitates, the greater the difference between the apparent and true leach rates. XRD analyses of U11HP showing the development of new phases during leaching support this idea. XRD analyses of U11SA powders, however, show that no new postrun phases have developed during our longest hydrothermal experiment. This suggests that apparent leach rates determined from fluid analyses in long-term runs on U11SA may approximate true leach rates for this SYNROC formulation.

Sample form of various SYNROC preparations employed in the hydrothermal experiments appears to have a demonstrable effect on leaching behavior. Both powders and cores were tested for preparations U12 (SYNROC B) and U11 (SYNROC C). For comparable run conditions, powders generally yield lower apparent leach rates, but a higher percentage of material leached for any one element. Apparent leach rates obtained from powders are generally one to three orders of magnitude lower than those obtained for cores. Because surface area factors employed in the apparent leach rate calculations are geometric for cores and nitrogen adsorption for powders, the experimental results are not easily comparable. However, in the case of some annealed cores, gas adsorption surface area data have been found to be approximately 20 times greater than their geometric surface area. Thus, core and powder apparent leach rates can be compared in an approximate manner if core data are divided by a factor of 20. However, performing this operation still does not resolve some of the large differences occurring between core and powder leach rates.

The apparent leach rates derived from these hydrothermal investigations are not directly comparable to leach rates measured for other waste forms under various temperatures, and pressures using different methods. In general, comparable leach rates (similar run conditions, same element) for all SYNROC B and C formulations tested lie within two orders of magnitude. The approximately defined order of apparent leach rates for SYNROC preparations is as follows:

$$U11HP > U12HP > U12SA > U11SA > U20HP > S05HP.$$

The most detailed work was carried out on the SYNROC C formulation, UllHP. Some precipitates occurring on both powders and surfaces of cores were identified by EDS and XRD as predominantly boehmite. This suggests that for UllHP the true leach rate for aluminum is definitely higher than the apparent leach rate. XRD analyses of UllHP powders before and after hydrothermal treatment show that an accessory phase, Al_2TiO_5 , breaks down at elevated temperature to form boehmite and anatase. The major SYNROC phases remain essentially unaltered at the level of sensitivity of XRD. UllHP (SYNROC C) displays the greatest amount of quench growth on the core surface, and also highest apparent leach rates for SYNROC elements.

Hollandite, MO6, appeared to be most resistant to leaching, with only Ti found in the fluid phase. Evidence obtained from XRD studies revealed that postrun hollandite was essentially unaltered.

ACKNOWLEDGMENTS

We thank C. Hoenig for preparing all SYNROC and hollandite starting materials, A. Langhorst for ICP-OES analyses, C. Slettevold for gas adsorption surface area analyses, and J. Rego for writing and running the data analyses program. The manuscript was critically reviewed by J. Akella, D. Coles, R. Ryerson, J. Tewhey, and H. Weed. W. Pebler typed the final-draft manuscript.

APPENDIX A

SYNROC Formulations Used in the Experimental Investigation

TABLE A-1. Starting materials used in the experimental study.

Preparation code	Met sample No.	Preparation conditions $T(^{\circ}\text{C})$ /time/pressure	Median grain size (μm)	Phase ^a composition		Sample form	Surface area factor m^2/g
				XRD	SEM		
SYNROC B U12SA6A	2207	1325 $^{\circ}\text{C}$ /3 h	—	—	—	Core (an)	
						Powder (1)	0.429 ^d
						Powder (2)	0.183 ^d
U12HP3A	2240	1200 $^{\circ}\text{C}$ /1 h/3000 psi	—	H,P,Z,C	—	Core	
						Powder (1)	0.432
						Powder (2)	0.155
SYNROC C U11BA4A	2209	1324 $^{\circ}\text{C}$ /3 h	5	H,P,Z,R	—	Core (an)	
						Powder (1)	0.429 ^d
						Powder (2)	0.155
U11HP2a	2239	1300 $^{\circ}\text{C}$ /1 h/3000 psi	3	H,P,Z,R ATO	H,P,Z ATO	Core	
						Powder (1)	0.426
						Powder (2)	0.211
U20HP3A	2261	1250 $^{\circ}\text{C}$ /1 h/3000 psi	1				
SO5HP4A	2291	1200 $^{\circ}\text{C}$ /1 h/4000 psi	1	H,P,Z ^e	—	Powder (2)	0.246
SYNROC D U17HP1A	2242	1200 $^{\circ}\text{C}$ /7/4000 psi	1	—	—	Powder (1)	0.551
Hollandite MO6SA1A	2263	1400 $^{\circ}\text{C}$ /3 h	—	H	H	Powder (3)	1.00 ^f
SO3HP3A	2290	1200 $^{\circ}\text{C}$ /1 h	—	H,C	—	Powder (2)	0.080

See footnotes next page.

^aXRD = x-ray diffraction, SEM = scanning electron microscopy, H = hollandite, Z = zirconolite, P = perovskite, R = rutile, C = corundum, ATO = Al_2TiO_5 .

^bFirst letter indicates method of powder preparation: U = coprecipitation from urea solution, S = spray dried from nitrate solution, M = mixed oxides, carbonates, or hydroxides. Next two numbers indicate the preparation number of this method. The next two letters indicate processing method: SA = sintered in air, HP = hot pressed. Next number indicates the fabrication number of this sample. The last letter indicates piece from specimen.

^c1 = <150 μm , 2 = 150 to 300 μm , 3 = <44 μm ; an = cores annealed at 1325°C for 3 hours.

^dSurface area factor not measured by nitrogen adsorption; instead, an average of nitrogen adsorption values for other SYNROC powders of similar size range has been used.

^eOther minor phases.

^fSurface area estimate.

TABLE A-2. Calculated nominal compositions of SYNROC formulations.

		S05		U11		U20		U12	
		Oxide wt%	Element wt%	Oxide wt%	Element wt%	Oxide wt%	Element wt%	Oxide wt%	Element wt%
TiO ₂	(Ti)	51.54	30.90	56.4	33.8	54.3	32.6	60.4	36.2
CaO	(Ca)	12.72	9.09	12.9	9.2	12.4	8.8	13.9	9.9
Al ₂ O ₃	(Al)	7.80	4.13	10.3	5.5	10.1	5.4	11.0	5.8
ZrO ₂	(Zr)	10.33	7.65	9.2	6.8	8.8	6.5	9.9	7.3
BaO	(Ba)	6.15	5.51	3.9	3.5	7.6	6.8	4.2	3.8
NiO	(Ni)	--	3.00	0.5	0.4	0.5	0.4	<u>0.6</u>	0.5
UO ₂	(U)	0.50	0.44	2.7	2.4	2.7	2.4	100%	
SrO	(Sr)	0.26	0.22	0.7	0.6	0.7	0.6		
Cs ₂ O	(Cs)	0.71	0.67	(?)	(?)	0.09	0.08		
CeO ₂	(Ce)	0.82	0.67	0.7	0.6	0.7	0.6		
Gd ₂ O ₃	(Gd)	0.03	0.03	0.7	0.6	<u>0.7</u>	0.6		
Lu	(Lu)	--	--	0.7	0.6	98.6%			
Y ₂ O ₃	(Y)	0.15	0.12	<u>0.7</u>	0.6				
Cr ₂ O ₃	(Cr)	0.09	0.06	99.4%					
Fe ₂ O ₃	(Fe)	0.37	0.26						
CoO	(Co)	0.02	0.02						
NiO	(Ni)	0.03	0.02						
P ₂ O ₅	(P)	0.17	0.07						
Rb ₂ O	(Rb)	0.09	0.08						
La ₂ O ₃	(La)	0.37	0.32						
Pr ₆ O ₁₁	(Pr)	0.37	0.31						
Nd ₂ O ₃	(Nd)	1.18	1.01						
Pm ₂ O ₃	(Pm)	0.03	0.03						
Sm ₂ O ₃	(Sm)	0.23	0.20						
Eu ₂ O ₃	(Eu)	0.05	0.04						
MoO ₃	(Mo)	1.57	1.04						
RuO ₂	(Ru)	0.73	0.55						
Rh ₂ O ₃	(Rh)	0.12	0.10						
PdO	(Pd)	0.36	0.31						
Ag ₂ O	(Ag)	0.02	0.02						
TcO ₂	(Tc)	<u>0.19</u>	0.15						
		100.00%							

TABLE A-3. Calculated nominal compositions of SYNROC formulations and hollandite.

Oxide	Element	Hollandite		Hollandite		SYNROC D	
		MO6		SO3		U17	
		Oxide	Element	Oxide	Element	Oxide	Element
		wt%	wt%	wt%	wt%	wt%	wt%
TiO ₂	(Ti)	61.00	36.6	63.95	38.33	15.1	9.0
Al ₂ O ₃	(Al)	15.57	8.3	13.70	7.25	21.5	11.0
BaO	(Ba)	23.43	21.1	18.60	16.66	--	--
CaO	(Ca)	--	--	--	--	6.9	4.9
ZrO ₂	(Zr)	--	--	--	--	4.0	3.0
Ce ₂ O ₃	(Ce)	--	--	3.75	3.54	0.7	0.6
NiO	(Ni)	--	--	--	--	3.4	2.7
UO ₂	(U)	--	--	--	--	2.3	2.0
SrO	(Sr)	--	--	--	--	0.7	0.6
CeO ₂	(Ce)	--	--	--	--	0.7	0.6
Gd ₂ O ₃	(Gd)	--	--	--	--	0.7	0.6
SiO ₂	(Si)	--	--	--	--	8.1	4.5
MnO	(Mn)	--	--	--	--	6.2	4.7
Na ₂ O	(Na)	--	--	--	--	3.8	2.8
Fe ₃ O ₄	(Fe)	--	--	--	--	25.8	18.5
		100%		100%		99.9%	

APPENDIX B

Corrected Run Temperatures

TABLE B-1. Corrected temperatures.

Run No.	T(°C)	Run No.	T(°C)	Run No.	T(°C)
5	154	49	452	74	450
8	309	50	302	75	152
10	306	51	305	76	450
12	607	52	152	78	305
13	157	53	303	79	296
14	304	54	302	81	450
18	303	55	451	83	302
22	159	57	155	84	152
23	306	58	152	85	296
25	302	59	452	86	302
26	451	60	305	87	206
27	302	62	309	88	302
29	305	63	306	89	204
31	454	64	155	90	199
35	305	65	152	91	296
36	305	66	307	92	451
38	456	67	153	94	301
39	302	68	296	95	454
41	303	69	452	96	302
42	305	70	306	97	450
43	452	71	308	98	158
44	304	72	156	99	296
46	153	73	301	101	105
48	153				

APPENDIX C

List of Runs Performed According to Preparation Type

A temperature-time matrix of runs is listed for each formulation, with run numbers. More complete information about each run is given in Appendix D.

TABLE C-1. U12SA6A SYNROC B run numbers.

Sample form	T°C	Run numbers		
		Time (days)		
		1	10	30
Cores	150	5	13	--
	300	8	10 (9 days)	36
		--	35	--
	450	12 (600°C)	31 (13 days)	--
Powders	150	46	57	--
<150 μ m	300	14 ^a	39	41
	450	55	74	--

NOTE: Two postrun cores have been observed using an SEM. See Appendix D for further details.

^a Powder size is 150 to 500 μ m.

TABLE C-2. U12HP3A SYNROC B run numbers.

Sample form	T°C	Run number			
		Time (days)			
		1	10	30	60
Cores	150	64	--	--	--
	300	63	62	85	86
Powders	150	98	65	--	--
<150 μ m	300	96	66	--	--
	450	97	--	--	--

NOTE: One postrun core has been examined using SEM. See Appendix G for further details.

TABLE C-3. U11SA4A SYNROC C run numbers.

Sample form	T°C	Run number		
		Time (days)		
		1	10	30
Cores	150	52, 58	75	--
	300	18	25	51
	450	76	59 (11 d)	--
Powder	150	48	22	--
<150 μ m	300	23 ^a	25 ^a , 50	29
	450	49	26 ^a , 38 (9 d)	--

^a Powder size 150 to 300 μ m.

TABLE C-4. U11HP2A SYNROC C run numbers.

Sample form	T°C	Run numbers			
		Time (days)			
		1	10	30	60
Cores	300	--	60	78	79
Powder	150	84	--	--	--
<150 μ m	300	83	54	53	--
	450	81	--	--	--

NOTE: Three postrun cores have been examined using SEM. See Appendix G for further details.

TABLE C-5. U20HP3A SYNROC C run numbers.

T°C	Run numbers		
	Time (days)		
	1	10	30
150	72	99	--
300	73	71	94
450	92	95	--

NOTE: All samples are powder < 150 μ m.

TABLE C-6. S05HP4A SYNROC C run numbers.

T°C	Run numbers	
	time	
	10 days	
200	90	
300	91	

NOTE: Both samples are powders 150 to 300 μ m.

TABLE C-7. U17HP1A SYNROC D run numbers.

T°C	Run numbers	
	Time (days)	
	1	10
300	42	44
450	43	--

NOTE: All samples are powders <150 μ m.

TABLE C-8. MO6SA1A hollandite
run numbers.

T °C	Run numbers	
	Time (days)	
	1	10
150	67	--
300	68	70
450	69	--

NOTE: All samples are powders
<44 μ m.

TABLE C-9. SO3HP3A (hollandite with cesium) run
numbers.

T °C	Run numbers		
	Time (days)		
	1	10	30
200	89	87	101
300	--	88	--

NOTE: All samples are powders 150 to 300 μ m.

APPENDIX D

Data Summaries for Hydrothermal Runs

DATA SUMMARIES FOR HYDROTHERMAL RUNS

Appendix D presents a summary of data obtained for all hydrothermal runs. The results are grouped according to formulation type as ordered in Appendix C, not in numerical sequence according to run number. Formulation, sample composition, sample form, run number, run condition, nominal temperature and water pressure, run time, sample mass, water mass, water to sample mass ratio, sample surface area and water volume to sample surface area ratio are listed. Other quantities reported are the following:

- Dilution factor = $\frac{\text{fluid volume in capsule}}{\text{ICP fluid-sample volume}}$.

The remainder of the fluid is used in XRF analysis.

- $\mu\text{g in fluid}$ = total weight of an element in the fluid after hydrothermal treatment.

$$= [g(d) \cdot g(b)] \times D$$

where $g(d)$ = grams of element detected in the 1-ml diluted ICP fluid sample.

$g(b)$ = grams of element detected in a 1-ml water blank sample.

D = dilution factor.

- Percent total in fluid = percent of an element in the original solid sample that is later detected in fluid

$$= \frac{\mu\text{g (element) in fluid}}{\mu\text{g (element) in SYNROC sample}} \times 100 .$$

- $g \text{ (element)}/\text{m}^2 \cdot \text{day}$ = leach rate for the element

$$= \frac{(g \text{ of element in fluid} \times 10^{-6})}{\text{sample surface area (m}^2\text{)} \times \text{length of run (days)}} .$$

• $g \text{ (SYNROC)}/m^2 \cdot \text{day} = \text{leach rate for the waste form assuming homogeneous dissolution} =$

$$\frac{g \text{ (element)}}{m^2 \cdot \text{day}} \times \frac{100}{\text{wt\% of element in SYNROC}} .$$

These calculated leach rates must be characterized as apparent leach rates for reasons explained in the text. The calculated leach rates present a minimum leach rate based on any element. Elements yielding the highest calculated leach rates probably present a reasonable estimate of the static leach rate for the waste form.

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12SAGA RUN NO. 5

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 1.5400E-04 M2

CONDITIONS TEMP=150. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 0.58 DF(DILUTION FACTOR)= 2.39

V/SA (VOL RATIO)= 1.5519E+03

SAMPLE WT.= 4.24E-01 GRAMS WATER WT.= 2.39E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	3.2743E+00	7.7931E-03	2.1292E-02	2.1476E-01
SI	2.9900E+00	0.	0.	0.
		SUM	2.13E-02	AVE 2.15E-01

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12SA6A RUN NO. 13

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 6.8000E-05 M2

CONDITIONS TEMP=150. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.28 DF(DILUTION FACTOR)= 1.31

V/SA (VOL RATIO)= 2.8824E+03

SAMPLE WT.= 1.53E-01 GRAMS WATER WT.= 1.08E-01 GRAMS

ELEMENT	MO IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	1.9285E+00	1.2817E-02	2.8512E-03	2.8800E-02
FE	1.5720E-02	0.	0.	0.
SUM			2.85E-03	2.88E-02

PREP. COMPOSITION (WT. PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12SASA RUN NO. 8

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 7.4000E-05 M2

CONDITIONS TEMP=300. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.20 DF(DILUTION FACTOR)= 2.19

V/SA (VOL RATIO)= 2.9595E+03

SAMPLE WT.= 1.83E-01 GRAMS WATER WT.= 2.19E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	3.9845E+00	1.8737E-02	4.5872E-02	4.5335E-01
SI	2.4090E+00	0.	0.	0.
			SUM 4.58E-02	AVE 0. 4.63E-01

PREP COMPOSITION (WT.PCT)

AL 5.80E+00

CA 9.90E+00

NI 9.00E-01

TI 3.62E+01

ZR 7.30E+00

BA 3.80E+00

COMMENTS.

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U128A6A RUN NO. 10

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 6.6000E-05 M2

CONDITIONS TEMP=300. DEG. C 9. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.37 DF(DILUTION FACTOR)= 1.51

V/SA (VOL RATIO)= 3.4242E+03

SAMPLE WT.= 1.85E-01 GRAMS WATER WT.= 2.28E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	3.4428E-01	3.8040E-03	3.7980E-04	3.9930E-03
CA	3.3418E+00	2.0494E-02	5.6256E-03	6.8825E-02
FE	9.0600E-03	0.	0.	0.
MN	3.0200E-03	0.	0.	0.
NA	2.5066E-01	0.	0.	0.
		SUM	6.21E-03	AVE 3.34E-02

PREP. COMPOSITION (WT.PCT)

AL	5.60E+00
CA	9.90E+00
NI	8.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12SAGA RUN NO. 35

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 7.1000E-05 M2

CONDITIONS TEMP=300. DEG. C 10, DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.80 DF(DILUTION FACTOR)= 2.12

V/SA (VOL RATIO)= 4.4789E+03

SAMPLE WT.= 1.77E-01 GRAMS WATER WT.= 3.18E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	2.1770E+01	1.2424E-01	3.4069E-02	3.10E-0
FE	< 1.0600E-02	0.	0.	0.
MN	1.0600E-02	0.	0.	0.
NA	3.1500E-02	0.	0.	0.
		SUM	3.41E-02	AVE 3.44E-01

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U128A6A RUN NO. 36

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 7.8000E-05 M2

CONDITIONS TENP=300. DEG. C 30. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.65 OF(DILUTION FACTOR)= 1.28

V/SA (VOL RATIO)= 4.0897E+03

SAMPLE WT.= 1.93E-01 GRAMS WATER WT.= 3.19E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	1.6640E-02	1.4837E-04	7.1111E-06	1.2261E-04
CA	2.7611E-01	1.4449E-01	1.1800E-02	1.1919E-01
FE	3.7120E-02	0.	0.	0.
MN	3.8400E-03	0.	0.	0.
NA	7.7952E-01	0.	0.	0.
NI	7.6800E-03	7.9844E-04	3.2821E-06	6.5641E-04
SI	2.8752E-03	0.	0.	0.
SR	4.0960E-02	0.	0.	0.
TI	7.9360E-02	1.1353E-04	3.3915E-05	9.3687E-05
LU	< 1.2800E-03	0.	0.	0.
			SUM 1.18E-02	AVE 3.00E-02

PREP. COMPOSITION (WT,PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12SA6A RUN NO. 12

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 5.7000E-03 M2

CONDITIONS TEMP=600. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.18 DF(DILUTION FACTOR)= 3.01

V/SA (VOL RATIO)= 2.6316E+03

SAMPLE WT.= 1.26E-01 GRAMS WATER WT.= 1.50E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	1.1137E-01	1.5048E-03	1.8539E-03	3.3697E-02
CA	4.8053E-01	3.6456E-03	8.0795E-03	8.1611E-02
SI	3.3952E+00	0.	0.	0.
ZR	1.1799E-01	1.2603E-03	2.0595E-03	2.8212E-02
			SUM 1.21E-02	AVE 4.78E-02

PREP. COMPOSITION (WT.PCT)

AL 5.80E+00
CA 9.90E+00
NI 5.00E-01
TI 3.62E+01
ZR 7.30E+00
BA 3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12SA6A RUN NO. 31

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 8.0000E-05 M2

CONDITIONS TEMP=450. DEG. C 13. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.38 DF(DILUTION FACTOR)= 5.44

V/SA (VOL RATIO)= 3.4000E+03

SAMPLE WT.= 1.97E-01 GRAMS WATER WT.= 2.72E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	2.1780E-02	1.9035E-04	2.0923E-05	3.6074E-04
CA	8.6499E-01	4.4328E-03	8.3169E-04	8.4009E-03
CE	4.3620E-02	0.	0.	0.
NA	1.6701E+00	0.	0.	0.
SUM			8.53E-04	AVE 4.38E-03

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12SASA RUN NO. 46

SAMPLE FORM POWDER SIZE RANGE P=150 U SURFACE AREA 8.9661E-03 M2

CONDITIONS TEMP=150. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 17.75 DF(DILUTION FACTOR)= 1.86

V/SA (VOL RATIO)= 4.1376E+01

SAMPLE WT.= 2.09E-02 GRAMS WATER WT.= 3.71E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELEMENT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	8.8448E+00	3.9081E-01	7.8341E-04	7.7112E-03
FE	3.4298E+00	0.	0.	0.
MN	2.4180E-02	0.	0.	0.
NA	4.8732E-01	0.	0.	0.
NI	6.5100E-02	6.2297E-02	7.2607E-06	1.4521E-03
SI	4.1106E+00	0.	0.	0.
SR	2.7900E-02	0.	0.	0.
TI	1.4860E-02	1.9667E-04	1.6596E-06	4.5845E-06
U	1.6800E-02	0.	0.	0.
			SUM 7.72E-04	AVE 3.06E-03

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12SA6A RUN NO. 57

SAMPLE FORM POWDER SIZE RANGE P<150 U SURFACE AREA 2.8185E-02 M2

CONDITIONS TEMP=150. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 7.31 DF(DILUTION FACTOR)= 2.40

V/SA (VOL RATIO)= 1.7090E+01

SAMPLE WT.= 6.57E-02 GRAMS WATER WT.= 4.80E-01 GRAMS

ELEMENT	UQ IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	1.9778E+01	3.0405E-01	7.0184E-05	7.0873E-04
FE	2.3089E+01	0.	0.	0.
MN	1.2800E-01	0.	0.	0.
NA	1.4084E+00	0.	0.	0.
NI	6.7200E-02	2.0457E-02	3.842E-07	7.884E-05
SI	1.0464E+01	0.	0.	0.
SR	1.1520E-01	0.	0.	0.
TI	2.6400E-02	1.1100E-04	3.666E-08	2.5875E-07
U	9.6000E-02	0.	0.	0.
			SUM 7.03E-05	AVE 2.92E-01

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.82E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U123A6A RUN NO. 14

SAMPLE FORM POWDER SIZE RANGE P=150- 300U SURFACE AREA 6.4416E-03 M2

CONDITIONS TEMP=300. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 4.74 DF(DILUTION FACTOR)= 3.34

V/SA (VOL RATIO)= 2.5925E+01

SAMPLE WT.= 3.52E-02 GRAMS WATER WT.= 1.67E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELEMENT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	3.3400E-03	1.8360E-04	5.1850E-07	8.9397E-06
CA	8.8032E+00	1.8949E-01	1.0261E-03	1.0354E-02
SI	4.5695E+00	0.	0.	0.
LU	5.0100E-02	0.	0.	0.
		SUM	1.03E-03	AVE 5.18E-03

PREP. COMPOSITION (WT. PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12SA8A RUN NO. 39

SAMPLE FORM POWDER SIZE RANGE P<150 U SURFACE AREA 1.5107E-02 M2

CONDITIONS TEMP=300. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.42 DF(DILUTION FACTOR)= 1.95

V/SA (VOL RATIO)= 2.4298E+01

SAMPLE WT.= 9.54E-02 GRAMS WATER WT.= 9.69E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	2.7300E-01	1.3295E-02	1.7976E-06	3.0994E-05
CA	3.6426E+01	1.0394E+00	2.3986E-04	2.4228E-03
FE	1.0686E+00	0.	0.	0.
MN	3.0000E-03	0.	0.	0.
NA	1.9149E+00	0.	0.	0.
NI	2.8350E-02	1.4322E-02	1.6692E-07	3.3385E-05
SI	1.6163E+00	0.	0.	0.
SR	1.6573E-01	0.	0.	0.
			SUM 2.42E-04	AVE 8.29E-04

PREP. COMPOSITION (WT.PCT)

AL	5.60E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12SA6A RUN NO. 41

SAMPLE FORM POWDER SIZE RANGE P<150 U SURFACE AREA 1.5187E-02 M2

CONDITIONS TEMP=300. DEG. C 30. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.42 DF(DILUTION FACTOR)= 1.85

V/SA (VOL RATIO)= 2.4298E+01

SAMPLE WT.= 3.54E-02 GRAMS WATER WT.= 3.69E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	3.4558E+01	9.8608E-01	7.5852E-05	7.6618E-04
FE	8.1605E-01	0.	0.	0.
MIN	7.8500E-03	0.	0.	0.
NA	1.1137E+00	0.	0.	0.
NI	2.5900E-02	1.4633E-02	5.6848E-08	1.1370E-05
SI	1.6280E+00	0.	0.	0.
SR	2.0165E-01	0.	0.	0.
		SUM	7.59E-05	AVE 3.69E-04

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12SA6A RUN NO. 55

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 1.3471E-02 M2

CONDITIONS TEMP=450. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 11.15 DF(DILUTION FACTOR)= 1.76

V/SA (VOL RATIO)= 2.6557E+01

SAMPLE WT.= 3.14E-02 GRAMS WATER WT.= 3.51E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELNNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	7.5680E-02	4.1955E-03	5.6182E-06	9.6863E-05
CA	7.6205E+00	2.4615E-01	5.6574E-04	5.7145E-03
FE	1.4837E+00	0.	0.	0.
MN	1.7500E-03	0.	0.	0.
NA	1.0205E+00	0.	0.	0.
NI	< 3.9200E-02	2.2420E-02	2.6131E-06	5.2262E-04
SI	4.3624E+00	0.	0.	0.
SR	< 1.7600E-02	0.	0.	0.
TI	4.4000E-02	3.6708E-04	3.2864E-06	9.0231E-06
Y	< 1.7600E-03	0.	0.	0.
			SUM 5.77E-04	AVE 1.59E-03

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U123A9A RUN NO. 74

SAMPLE FORM POWDER SIZE RANGE P=150 U SURFACE AREA 6.6495E-03 M2

CONDITIONS TEMP=450. DEG. C 10. DAYS PRESSURE= 1KB, M20

W/S (WT RATIO)= 12.00 DF(DILUTION FACTOR)= 1.23

V/SA (VOL RATIO)= 2.7972E+01

SAMPLE WT.= 1.55E-02 GRAMS WATER WT.= 1.66E-01 GRAMS

ELEMENT	QS IN FLUID	PCT TOTAL IN FLUID	G(ELEMENT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	9.6400E-03	1.0945E-03	1.4790E-07	2.5514E-06
CA	4.3050E+00	2.8055E-01	6.4742E-05	6.5395E-04
FE	1.6421E+00	0.	0.	0.
MN	1.7205E-02	0.	0.	0.
NA	7.3052E-01	0.	0.	0.
SI	1.4120E+00	0.	0.	0.
TI	7.1800E-03	1.3139E-04	1.1096E-07	3.0559E-07
ZR	6.3640E-02	7.3920E-03	1.2578E-06	1.7231E-05
BA	9.5940E+01	1.6269E+01	1.4428E-03	3.7968E-02
OS	1.0701E+02	0.	0.	0.
SUN			1.51E-03	7.73E-03

PREP. COMPOSITION (WT.PCT)

AL	1.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12HP3A RUN NO. 84

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 7.3000E-05 M2

CONDITIONS TEMP=150. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 2.22 DF(DILUTION FACTOR)= 1.98

V/SA (VOL RATIO)= 5.4110E+03

SAMPLE WT.= 1.78E-01 GRAMS WATER WT.= 3.95E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELEMENT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	2.8888E+00	1.6430E-02	3.9579E-02	3.9979E-01
NA	1.2731E+00	0.	0.	0.
NI	5.0549E+00	5.6925E-01	6.9245E-02	1.3849E+01
SI	8.1182E-01	0.	0.	0.
SR	3.9600E-03	0.	0.	0.
TI	3.9600E-03	6.1599E-05	5.4247E-05	1.4963E-04
			SUM 1.09E-01	AVE 4.75E+00

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

REMARKS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12NP3A RUN NO. 63

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 7.2000E-05 M2

CONDITIONS TEMP=300. DEG. C 1. DAYS PRESSURE= 1KB. H2O

W/S (WT RATIO)= 2.07 DF(DILUTION FACTOR)= 1.79

V/SA (VOL RATIO)= 4.9583E+03

SAMPLE WT.= 1.73E-01 GRAMS WATER WT.= 3.57E-01 GRAMS

ELEMENT	US IN FLUID	PCT TOTAL IN FLUID	G(ELUENT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	1.0004E+01	5.8582E-02	1.3895E-01	1.4035E+00
NA	1.9890E-01	0.	0.	0.
NI	6.7662E-01	7.8449E-02	9.3975E-03	1.8795E+00
SI	4.8682E-01	0.	0.	0.
SR	2.6850E-02	0.	0.	0.
TI	3.5800E-03	5.7330E-06	4.9722E-05	1.3735E-04
			SUM 1.48E-01	AVE 1.09E+00

PREP. COMPOSITION (WT.PCT)

AL	5.60E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.90E+00
BA	3.60E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12HP3A RUN NO. 62

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 7.3000E-05 M2

CONDITIONS TEMP=300. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 2.04 DF(DILUTION FACTOR)= 1.46

V/SA (VOL RATIO)= 4.9863E+03

SAMPLE WT.= 1.78E-01 GRAMS WATER WT.= 3.64E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROD)/ M2-DAY
AL	3.2120E-02	3.1050E-04	4.4000E-05	7.5862E-04
CA	1.3184E-01	7.4689E-02	1.8060E-02	1.8242E-01
NA	2.6134E-01	0.	0.	0.
NI	8.7800E-02	9.8261E-03	1.2000E-04	2.4000E-02
SI	1.4195E+00	0.	0.	0.
SR	3.9420E-02	0.	0.	0.
			SUM 1.82E-02	AVE 5.91E-02

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12HP3A RUN NO. 85

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 7.2000E-05 M2

CONDITIONS TEMP=300. DEG. C 30. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.95 DF(DILUTION FACTOR)= 2.32

V/SA (VOL RATIO)= 4.6472E+03

SAMPLE WT.= 1.76E-01 GRAMS WATER WT.= 0.49E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	9.9902E-01	2.0599E-01	1.6636E-02	1.6803E-01
MA	6.8600E-03	0.	0.	0.
NA	2.9464E-01	0.	0.	0.
NI	1.8488E-01	2.2120E-02	9.0222E-05	1.8044E-02
SI	1.0672E+00	0.	0.	0.
SR	7.6580E-02	0.	0.	0.
			SUM 1.67E-02	AVE 9.30E-02

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.60E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12HP3A RUN NO. 86

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 7.2000E-05 M2

CONDITIONS TEMP=300. DEG. C 60. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.94 DF(DILUTION FACTOR)= 1.63

V/SA (VOL RATIO)= 4.5276E+03

SAMPLE WT.= 1.68E-01 GRAMS WATER WT.= 3.26E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	1.3040E-02	1.3359E-04	3.0185E-06	5.2043E-05
CA	1.3581E+01	9.3615E-02	3.6068E-03	3.6432E-02
MN	6.3200E-03	0.	0.	0.
NA	5.6235E-01	0.	0.	0.
NI	7.9870E-02	3.4914E-03	1.8488E-05	3.6977E-03
SI	1.0644E+00	0.	0.	0.
SR	1.0921E-01	0.	0.	0.
BA	8.5200E+00	1.0195E-01	1.5093E-03	3.9715E-02
			SUM 5.14E-03	AVE 2.00E-02

PREP. COMPOSITION (WT.PCT)

AL 5.80E+00

CA 9.90E+00

NI 5.00E-01

TI 3.62E+01

ZR 7.30E+00

BA 3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12HP3A RUN NO. 98

SAMPLE FORM POWDER SIZE RANGE P<150 U SURFACE AREA 1.6716E-02 M2

CONDITIONS TEMP=150. DEG. C 1. DAY3 PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.00 DF(DILUTION FACTOR)= 2.58

V/SA (VOL RATIO)= 2.3148E+01

SAMPLE WT.= 3.67E-02 GRAMS WATER WT.= 3.67E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELEMENT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	4.1280E-02	1.8391E-03	2.4691E-06	4.2371E-05
CA	7.9570E+00	2.0795E-01	4.7654E-04	4.6136E-03
NA	2.1672E-01	0.	0.	0.
NI	7.2163E+00	3.7293E+00	4.3184E-04	8.6327E-02
SI	1.5274E+00	0.	0.	0.
SR	2.0640E-02	0.	0.	0.
TI	3.0120E-02	2.6763E-04	2.1605E-06	5.9682E-06
		SUM	9.13E-04	AVE 2.29E-02

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	6.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12HP3A RUN NO. 65

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 3.4474E-02 M2

CONDITIONS TEMP=150. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 4.91 DF(DILUTION FACTOR)= 1.98

V/SA (VOL RATIO)= 1.1971E+01

SAMPLE WT.= 7.98E-02 GRAMS WATER WT.= 3.92E-01 GRAMS

ELEMENT	WG IN FLUID	PCT TOTAL IN FLUID	G(ELEMENT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	8.8200E+00	1.1164E-01	2.5585E-05	2.5843E-04
FE	1.9600E-02	0.	0.	0.
NA	7.8204E-01	0.	0.	0.
NI	1.2936E-01	3.2421E-02	3.7524E-07	7.5049E-05
SJ	2.7636E-01	0.	0.	0.
SR	1.3720E-01	0.	0.	0.
TI	1.9600E-02	6.7849E-05	6.6855E-08	1.5706E-07
			SUM 2.60E-05	AVE 1.11E-04

E.P. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12HP2A RUN NO. 56

SAMPLE FORM POWDER SIZE RANGE P=150 U SURFACE AREA 1.5552E-02 M2

CONDITIONS TEMP=300. DEG. C 1. DAYS PRESSURE= 1KB. H2O

W/S (WT RATIO)= 10.39 DF(DILUTION FACTOR)= 2.49

V/SA (VOL RATIO)= 2.4048E+01

SAMPLE WT.= 3.60E-02 GRAMS WATER WT.= 3.74E-01 GRAMS

ELEMENT	US IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	8.5776E-01	2.8713E-02	3.5964E-05	5.1655E-04
CA	8.7469E+00	1.6126E-01	3.6953E-04	3.7326E-03
FE	1.7430E-02	0.	0.	0.
NA	3.6856E-01	0.	0.	0.
NI	1.3670E+00	7.5945E-01	8.7899E-05	1.7590E-02
SI	7.4948E-01	0.	0.	0.
SR	5.4789E-02	0.	0.	0.
TI	8.9800E-03	7.6427E-05	8.4043E-07	1.7891E-06
		SUM	4.94E-04	AVE 5.48E-03

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.90E+00
BA	3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12HP3A RUN NO. 66

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 2.6438E-02 M2

CONDITIONS TEMP=300. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 5.75 DF(DILUTION FACTOR)= 1.76

V/SA (VOL RATIO)= 1.3314E+01

SAMPLE WT.= 6.12E-02 GRAMS WATER WT.= 3.52E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	2.5029E+01	4.2960E-01	9.8450E-05	9.9445E-04
NA	1.0877E+00	0.	0.	0.
NI	2.0532E-01	6.7294E-02	7.7887E-07	1.5577E-04
SI	4.9280E-02	0.	0.	0.
SR	3.5365E-01	0.	0.	0.
TI	1.4060E-02	6.3554E-03	5.3256E-08	1.4712E-07
		SUM	9.93E-05	3.83E-04
		AVE		

PREP. COMPOSITION (WT. PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.90E+00
BA	3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U12HP3A RUN NO. 97

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 1.3651E-02 M2

CONDITIONS TEMP=150, DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.16 DF(DILUTION FACTOR)= 3.21

V/SA (VOL RATIO)= 2.3514E+01

SAMPLE WT.= 3.16E-02 GRAMS WATER WT.= 3.21E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	5.1360E-02	2.8023E-03	3.7623E-06	5.4887E-05
CA	3.0174E-02	9.6402E-02	2.2104E-04	2.2327E-03
FE	1.5097E-01	0.	0.	0.
MN	1.2840E-02	0.	0.	0.
NA	2.0052E-01	0.	0.	0.
NI	2.1779E-01	2.0113E-01	2.3279E-05	4.6559E-03
SI	1.2872E-02	0.	0.	0.
SR	1.0050E-02	0.	0.	0.
TI	1.8939E-01	1.6556E-03	1.3074E-05	3.8325E-05
		SUM	2.62E-04	AVE 1.75E-03

PREP. COMPOSITION (WT.PCT)

AL	5.80E+00
CA	9.90E+00
NI	5.00E-01
TI	3.62E+01
ZR	7.30E+00
BA	3.80E+00

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 52

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 7.9000E-05 M2

CONDITIONS TEMP=150. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.79 DF(DILUTION FACTOR)= 1.80

V/SA (VOL RATIO)= 4.6570E+03

SAMPLE WT.= 2.01E-01 GRAMS WATER WT.= 3.60E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	Q(ELMNT)/ M2-DAY	Q(SYNROC)/ M2-DAY
CA	4.266E-01	2.3047E-03	5.4000E-03	5.8696E-02
NA	1.1520E-01	0.	0.	0.
NI	5.2200E-02	6.4861E-03	6.6076E-04	1.6519E-01
SI	6.1680E-01	0.	0.	0.
SR	6.1000E-02	6.7097E-03	1.0253E-03	1.7089E-01
TI	7.2000E-03	1.0667E-05	9.1139E-05	2.6964E-04
			SUM 7.18E-03	AVE 9.88E-02

PREP. COMPOSITION (WT.PCT)

AL 5.50E+00
 CA 9.20E+00
 CE 6.00E-01
 NI 4.00E-01
 SR 6.00E-01
 TI 3.38E+01
 U 2.40E+00
 Y 6.00E-01
 ZR 6.80E+00
 LV 6.00E-01
 BA 3.50E+00
 CS 1.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U113A4A RUN NO. 58

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 8.0000E-05 M2

CONDITIONS TEMP=150, DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 2.26 DF(DILUTION FACTOR)= 1.56

V/SA (VOL RATIO)= 5.8375E+03

SAMPLE WT.= 2.07E-01 GRAMS WATER WT.= 4.67E-01 GRAMS

ELEMENT	UP IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	1.2480E-02	1.0962E-04	1.5600E-04	2.8364E-03
CA	1.0920E+00	5.7941E-03	1.3650E-02	1.4837E-01
FE	5.3960E-02	0.	0.	0.
NA	1.7004E-01	0.	0.	0.
NI	1.6720E-02	2.2609E-03	2.3400E-04	5.8500E-02
SI	3.4820E-01	0.	0.	0.
SR	2.6208E-01	2.1101E-02	3.2760E-03	5.4600E-01
SUM			1.73E-02	AVE 1.89E-01

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 75

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 8.8000E-05 M2

CONDITIONS TEMP=150. DEG. C 10. DAYS PRESSURE= 1KB, M26

W/S (WT RATIO)= 1.90 DF(DILUTION FACTOR)= 1.47

V/SA (VOL RATIO)= 5.1023E+03

SAMPLE WT.= 2.97E-01 GRAMS WATER WT.= 4.49E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNRSC)/ M2-DAY
AL	8.8200E-03	6.7750E-05	1.0023E-05	1.8223E-04
CA	3.8220E+00	1.7851E-02	4.3432E-03	4.7209E-02
NA	3.8653E-01	0.	0.	0.
NI	3.8880E-02	4.1920E-03	4.5102E-03	1.1278E-02
SI	2.7754E+00	0.	0.	0.
SR	9.8931E-01	8.9860E-02	1.1242E-03	1.8727E-01
ZR	8.8200E-03	6.4798E-05	1.0023E-05	1.4799E-04
SUM			5.53E-03	4.92E-02
AVE				

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	8.00E-01
BA	3.50E+00
CS	1.00E-02

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 18

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 9.2000E-05 M2

CONDITIONS TEMP=300. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 0.82 DF(DILUTION FACTOR)= 1.95

V/SA (VOL RATIO)= 2.1196E+03

SAMPLE WT.= 2.38E-01 GRAMS WATER WT.= 1.95E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	1.0296E+00	4.7062E-03	1.1191E-02	1.2164E-01
NN	1.8770E-01	0.	0.	0.
NA	1.3650E-02	0.	0.	0.
		SUM	1.12E-02	AVE 1.22E-01

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.60E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U118A4A RUN NO. 27

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 8.0000E-05 M2

CONDITIONS TEMP=300. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.02 DF(DILUTION FACTOR)= 2.12

V/SA (VOL RATIO)= 2.6500E+03

SAMPLE WT.= 2.08E-01 GRAMS WATER WT.= 2.12E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	1.1864E+00	8.0488E-03	1.4442E-03	1.5698E-02
FE	3.4556E-01	0.	0.	0.
NI	1.2720E-02	1.8311E-03	1.5900E-05	3.9750E-03
SR	2.5228E-01	2.0244E-02	3.1895E-04	5.2555E-02
LU	2.3320E-02	1.8713E-03	2.9150E-05	4.8833E-03
			SUM 1.80E-03	AVE 1.93E-02

PREP. COMPOSITION (WT.PCT)

AL	3.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.00E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 51

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 8.5000E-05 M2

CONDITIONS TEMP=300. DEG. C 30. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.64 DF(DILUTION FACTOR)= 2.49

V/SA (VOL RATIO)= 4.2824E+03

SAMPLE WT. = 2.22E-01 GRAMS WATER WT. = 3.64E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	2.8407E+00	1.3921E-02	1.1140E-03	1.2109E-02
NA	1.7253E-01	0.	0.	0.
NI	3.1550E-02	3.5806E-03	1.2368E-05	3.0971E-03
SI	1.5649E+00	0.	0.	0.
SR	6.4152E-01	4.8206E-02	2.5156E-04	4.1929E-02
TI	< 4.6600E-03	6.4827E-06	1.0059E-06	5.6387E-06
			SUM 1.38E-03	AVE 1.43E-02

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E+02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 76

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 7.9000E-03 M2

CONDITIONS TEMP=450. DEG. C 1. DAYS PRESSURE= 1XB, H2O

W/S (WT RATIO)= 1.96 DF(DILUTION FACTOR)= 1.35

V/SA (VOL RATIO)= 5.1392E+03

SAMPLE WT.= 2.07E-01 GRAMS WATER WT.= 4.06E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNRCO)/ M2-DAY
CA	1.6200E+00	8.5066E-03	2.0506E-02	2.2289E-01
FE	1.4850E-02	0.	0.	0.
NA	9.5239E-01	0.	0.	0.
SI	1.5308E+00	0.	0.	0.
SR	4.5495E-01	9.6630E-02	5.7589E-03	9.5981E-01
CS	6.1000E+00	3.9130E+01	1.0253E-01	1.0253E+03
			SUM 1.29E-01	AVE 3.42E+02

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	5.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 59

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 8.0000E-05 M2

CONDITIONS TEMP=450. DEG. C 11. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.87 DF(DILUTION FACTOR)= 1.94

V/SA (VOL RATIO)= 4.8500E+03

SAMPLE WT.= 2.08E-01 GRAMS WATER WT.= 3.88E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	5.2380E-01	2.7425E-03	8.9523E-04	8.4699E-03
NA	1.0476E-01	0.	0.	0.
NI	5.8200E-03	7.0087E-04	6.8136E-06	1.6534E-03
SI	1.0263E+00	0.	0.	0.
SR	1.9192E-01	1.0591E-02	1.4991E-04	2.4985E-02
			SUM 7.52E-04	AVE 1.10E-02

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 48

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 2.8443E-02 M2

CONDITIONS TEMP=160, DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 6.86 DF(DILUTION FACTOR)= 2.28

V/SA (VOL RATIO)= 1.5887E+01

SAMPLE WT.= 6.63E-02 GRAMS WATER WT.= 4.56E-01 GRAMS

ELEMENT	UB	1: FLUID	PC7	TOTAL IN FLUID	G(ELNNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	<	2.736E-02		7.5031E-04	9.6193E-07	1.7490E-05
CA		3.0278E+01		4.8640E-01	1.0645E-03	1.1571E-02
FE		9.3799E+00		0.	0.	0.
NN		2.5080E-02		0.	0.	0.
NA		1.7328E+00		0.	0.	0.
NI		3.1920E-02		1.2036E-02	1.1223E-06	2.8056E-04
SI		1.2556E+01		0.	0.	0.
SR		1.9220E+00		4.8317E-01	6.7576E-05	1.1263E-02
TI		3.1920E-02		1.4244E-04	1.1223E-06	3.0203E-06
U		4.5600E-02		2.8658E-03	1.6032E-06	6.6801E-05
				SUM	1.14E-03	AVE 3.87E-03

PREP. COMPOSITION (WT.PCT)

	5.50E+00
CA	20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 22

SAMPLE FORM POWDER SIZE RANGE P=150- 300U SURFACE AREA 4.7946E-03 M2

CONDITIONS TEMP=150. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 5.53 OF(DILUTION FACTOR)= 2.90

V/SA (VOL RATIO)= 3.0242E+01

SAMPLE WT.= 2.64E-02 GRAMS WATER WT.= 1.46E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	2.1750E+01	3.0234E-01	4.5364E-04	4.9309E-03
FE	5.8000E-02	0.	0.	0.
SR	3.0400E-01	5.7557E-01	1.6871E-05	3.1452E-03
TI	< 2.9000E-03	3.2749E-05	6.0485E-08	1.7895E-07
			SUM 4.73E-04	AVE 2.69E-03

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	5.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

COMMENTS:

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 23

SAMPLE FORM POWDER SIZE RANGE P=150- 300U SURFACE AREA 4.8678E-03 M2

CONDITIONS TEMP=900. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 5.78 DF(DILUTION FACTOR)= 3.08

V/SA (VOL RATIO)= 3.1836E+01

SAMPLE WT.= 2.86E-02 GRAMS WATER WT.= 1.54E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	3.5090E+01	1.4339E+00	7.2087E-03	7.8355E-02
HN	8.1928E-01	0.	0.	0.
NA	4.8664E-01	0.	0.	0.
			SUM 7.21E-03	AVE 7.84E-02

PREP COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 25

SAMPLE FORM POWDER SIZE RANGE P=150- 300U SURFACE AREA 1.5793E-02 M2

CONDITIONS: TEMP=300. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 2.19 OF(DILUTION FACTOR)= 3.78

V/SA (VOL RATIO)= 1.1987E+01

SAMPLE WT.= 8.63E-02 GRAMS WATER WT.= 1.89E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROD)/ M2-DAY
CA	1.1151E+02	1.4045E+00	7.0608E-04	7.6747E-03
FE	5.8700E-01	0.	0.	0.
NI	3.7800E-03	1.0950E-03	2.3935E-08	5.9837E-06
SR	4.7250E+00	9.1251E-01	2.9919E-05	4.9854E-03
BA	3.7800E+00	1.2514E-01	2.3935E-05	6.8365E-04
CS	3.7800E+00	4.3601E-01	2.3935E-05	2.6900E-01
			SUM 7.84E-04	AVE 5.05E-02

PREP COMPOSITION (WT.PCT)

AL 5.50E+00
 CA 9.20E+00
 CE 6.00E-01
 NI 4.00E-01
 SR 6.00E-01
 TI 3.38E+01
 U 2.40E+00
 Y 6.00E-01
 ZR 6.80E+00
 LU 6.00E-01
 BA 3.50E+00
 CS 1.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U118A4A RUN NO. 50

SAMPLE FORM POWDER SIZE RANGE P=150 U SURFACE AREA 1.3728E-02 M2

CONDITIONS TEMP=300. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 13.06 DF(DILUTION FACTOR)= 2.09

V/SA (VOL RATIO)= 3.0449E+01

SAMPLE WT.= 3.20E-02 GRAMS WATER WT.= 4.18E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	2.0900E-03	1.1875E-04	1.8224E-06	2.7681E-07
CA	1.2912E+02	4.3859E+00	9.4056E-04	1.0223E-02
CE	3.0096E-01	1.5675E-01	2.1923E-06	3.6538E-04
FE	2.6000E+00	0.	0.	0.
HN	1.6720E-02	0.	0.	0.
NA	1.6072E+00	0.	0.	0.
NI	1.4630E-02	1.1430E-02	1.0857E-07	2.6643E-05
SI	2.2217E+01	0.	0.	0.
SR	4.3681E+00	2.2751E+00	9.1819E-05	3.3032E-03
SUM			9.75E-04	3.18E-03

PREP. COMPOSITION (WT.PCT)

AL	3.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

ACCELERATED LEACH DATA SUMMARY

PREP NAME U118A4A RUN NO. 29

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 3.8524E-02 M2

CONDITIONS TEMP=300. DEG. C 30. DAYS PRESSURE= 1KB. H2O

W/S (WT RATIO)= 4.54 DF(DILUTION FACTOR)= 2.72

V/SA (VOL RATIO)2 1.0891E+01

SAMPLE WT.= 8.98E-02 GRAMS WATER WT.= 4.08E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	1.6320E-02	3.3043E-04	1.4121E-08	2.5675E-07
CA	2.7192E+02	3.2914E+00	2.3529E-04	2.5672E-03
CE	5.7856E-01	1.6306E-01	7.6018E-07	1.2670E-04
FE	5.1136E-01	0.	0.	0.
MM	8.2000E-05	0.	0.	0.
NI	2.4480E-02	6.8151E-03	2.1181E-08	5.2954E-06
SI	1.8456E-01	0.	0.	0.
SR	1.8456E-01	9.0542E+00	1.4239E-05	2.3731E-03
TI	1.0890E-02	3.5648E-05	9.4140E-09	2.7852E-08
LU	2.7200E-03	5.0488E-04	2.3535E-09	3.2455E-07
BA	1.0056E-01	4.1540E-01	1.1297E-05	2.2772E-04
CS	5.4400E+00	6.0579E+01	4.7070E-06	4.7070E-02
SUM			2.66E-04	5.83E-03
AVE				

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 49

SAMPLE FORM POWDER SIZE RANGE P<150 U SURFACE AREA 1.6087E-02 M2

CONDITIONS TEMP=490. DEG. C 1. DAYS PRESSURE= 1KB, M20

W/S (WT RATIO)= 10.13 DF(DILUTION FACTOR)= 1.90

V/SA (VOL RATIO)= 2.3621E+01

SAMPLE WT.= 3.75E-02 GRAMS WATER WT.= 3.80E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	3.2680E-01	1.5845E-02	2.0314E-05	3.6934E-04
CA	1.2156E+02	3.5235E+00	7.5963E-03	6.2134E-02
CE	4.1800E-01	1.8578E-01	2.5963E-05	4.3305E-03
FE	9.8420E-01	0.	0.	0.
NN	7.8000E-02	0.	0.	0.
NA	1.9988E+00	0.	0.	0.
NI	3.9900E-02	2.6600E-02	2.4802E-06	6.2005E-04
SI	1.2445E+01	0.	0.	0.
SR	7.2010E+00	3.2004E+00	4.4781E-04	7.4602E-02
TI	2.0900E-02	1.6489E-04	1.2991E-05	3.8436E-03
Y	3.8000E-03	1.6889E-03	2.3621E-07	3.9368E-05
LU	3.8000E-03	1.6889E-03	2.3621E-07	3.9368E-05
BA	6.0297E+01	4.5833E+00	3.7474E-03	1.0707E-01
SUM			1.18E-02	2.99E-02
AVE				

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 26

SAMPLE FORM POWDER SIZE RANGE P=150- 300U SURFACE AREA 9.3147E-03 M2

CONDITIONS TEMP=450. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 3.69 DF(DILUTION FACTOR)= 3.76

V/\$A (VOL RATIO)= 2.0183E+01

SAMPLE WT. = 5.09E-02 GRAMS WATER WT. = 1.88E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNRGCC)/ M2-DAY
AL	2.256E-02	5.358E-04	2.422E-07	4.503E-08
CA	6.429E+01	1.373E+00	6.302E-04	7.502E-03
FE	9.400E-02	0.	0.	0.
NI	3.760E-03	1.846E-03	4.036E-08	1.009E-05
SR	6.354E+00	2.080E+00	6.921E-03	1.137E-02
TI	3.780E-03	2.185E-05	4.036E-08	1.194E-07
BA	6.769E+01	3.799E+00	7.269E-04	2.076E-02
CS	4.185E+00	8.125E+01	4.440E-05	4.440E-01
		SUM	1.53E-03	AVE 6.91E-02

PREP. COMPOSITION (WT. PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	5.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11SA4A RUN NO. 38

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 2.9644E-02 M2

CONDITIONS TEMP=150. DEG. C 9. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 4.15 DF(DILUTION FACTOR)= 5.74

V/SA (VOL RATIO)= 9.6816E+00

SAMPLE WT.= 6.91E-02 GRAMS WATER WT.= 2.87E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	1.6513E+02	2.5975E+00	6.1395E-04	6.7278E-03
CE	5.1086E-01	1.2322E-01	1.9148E-06	3.1913E-04
FE	4.5920E-02	0.	0.	0.
MN	1.8827E-01	0.	0.	0.
NA	5.7400E-03	0.	0.	0.
		SUM	6.21E-04	AVE 3.52E-03

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.60E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11HP2A RUN NO. 50

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 6.6000E-05 M2

CONDITIONS TEMP=300. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 1.98 DF(DILUTION FACTOR)= 1.44

V/SA (VOL RATIO)= 4.5000E+03

SAMPLE WT.= 1.50E-01 GRAMS WATER WT.= 2.97E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	5.007E-01	4.2670E-01	0.3190E-02	3.0349E-01
CE	6.685E-01	7.3134E-02	9.8827E-04	1.6655E-01
PN	8.647E-03	0.	0.	0.
NA	8.412E+00	0.	0.	0.
NI	4.7684E-01	7.9281E-02	7.2218E-04	1.6055E-01
SI	2.7360E-02	0.	0.	0.
SR	2.7848E-01	3.0659E-00	4.1891E-02	.9818E+00
BA	1.6655E+02	3.1680E+00	2.5250E-01	7.2143E+00
CS	1.2086E+02	8.0479E+02	1.8327E-01	1.8327E+03
			SUM 5.69E-01	AVE 3.08E+02

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11HP2A RUN NO. 78

SAMPLE FORM C.S.R. SIZE RANGE

SURFACE AREA 5.8000E-05 M2

CONDITIONS TEMP=300. DEG. C 30. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 2.01 DF(DILUTION FACTOR)= 2.08

V/SA (VOL RATIO)= 4.6029E+03

SAMPLE WT.= 1.56E-01 GRAMS WATER WT.= 9.13E-01 GRAMS

ELEMENT	UG (IN FLU)	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	5.1143E+01	3.5728E-01	2.3070E-02	2.7250E-01
CE	3.2655E+01	3.4979E-02	1.6006E-04	2.6650E-02
FE	1.0400E+02	0.	0.	0.
MN	2.2880E+02	0.	0.	0.
NA	3.5544E+00	0.	0.	0.
NI	2.4960E+01	4.0103E-02	1.2235E-04	3.0588E-02
SI	7.2800E+02	0.	0.	0.
SR	1.4834E+01	1.5997E+00	7.3208E-03	1.2201E+00
TI	1.0400E-02	1.9775E-05	5.0980E-06	1.5083E-05
SUM			9.27E-02	3.10E-01

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	8.50E-01
NI	4.50E-01
SR	6.50E-01
TI	3.58E+01
U	2.40E+00
Y	6.50E-01
ZR	6.50E+00
LV	6.50E-01
BA	3.50E+00
CS	1.00E-02

ACCELERATED LEADH DATA SUMMARY

PREP NAME U11HP2A RUN NO. 79

SAMPLE FORM CORE SIZE RANGE

SURFACE AREA 6.6000E-05 M2

CONDITIONS TEMP=900. DEG. C 60. DAYS PRESSURE= 1KB, H2O

W/SA (WT RATIO)= 2.00 DF(DILUTION FACTOR)= 1.60

V/SA (VOL RATIO)= 4.6912E+03

SAMPLE WT.= 1.60E-01 GRAMS WATER WT.= 3.19E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	8.1742E+01	5.5601E-01	2.0035E-02	2.1777E-01
CE	3.4000E-01	2.1200E-02	2.0035E-02	2.1777E-01
FE	1.5400E+00	0.	0.	0.
MN	4.9500E-02	0.	0.	0.
NA	9.2624E+00	0.	0.	0.
NI	5.6480E-01	8.8360E-02	1.3843E-04	3.4608E-02
SI	1.6000E-03	0.	0.	0.
SR	3.5040E+01	3.6540E+00	3.5562E-03	1.4314E+00
TI	1.6000E-03	2.9623E-06	3.9216E-07	1.1502E-06
SUM			2.90E-02	3.44E-01

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11HP2A RUN NO. B4

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 1.6614E-02 M2

CONDITIONS TEMP=150. DEG. C 1. DAYS PRESSURE= 1KB. H2O

W/S (WT RATIO)= 10.08 DF(DILUTION FACTOR)= 1.96

V/SA (VOL RATIO)= 2.3655E+01

SAMPLE WT.= 3.90E-02 GRAMS WATER WT.= 3.93E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	1.2152E-01	5.6653E-03	7.3143E-06	1.3299E-04
CA	1.9757E-01	5.5064E-01	1.1892E-03	1.2928E-02
CE	2.9400E-02	1.2564E-02	1.7696E-06	2.9493E-04
FE	4.5768E+00	0.	0.	0.
MN	1.9500E-03	0.	0.	0.
NA	1.6768E+00	0.	0.	0.
NI	1.8150E+00	1.0353E+00	9.7210E-05	2.4302E-02
SI	3.5437E+00	0.	0.	0.
SR	5.0764E+00	2.1694E+00	3.0555E-04	5.0925E-02
TI	2.5872E-01	1.9627E-03	1.5572E-05	4.6072E-05
Y	1.8800E-03	8.3781E-04	1.1787E-07	1.8882E-05
ZR	6.8600E-02	2.5867E-03	4.1290E-06	6.0721E-05
LU	3.9200E-03	1.6762E-03	2.3595E-07	3.9324E-05
BA	4.7040E-01	3.4462E+00	2.8313E-03	6.0896E-02
CS	1.5680E+01	4.0205E+02	9.4378E-04	5.4378E+00
SUM			5.40E-03	8.79E-01
Ave				

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	8.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	8.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11HP2A RUN NO. 83

SAMPLE FORM POWDER SIZE RANGE P<150 U SURFACE AREA 1.5702E-02 M2

CONDITIONS TEMP=300. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.05 DF(DILUTION FACTOR)= 2.46

V/SA (VOL RATIO)= 2.3601E+01

SAMPLE WT.= 3.70E-02 GRAMS WATER WT.= 3.72E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G/SYNROC/ M2-DAY
CA	2.1868E+01	6.4535E-01	1.3937E-03	1.5149E-02
CE	0.3640E-02	3.7676E-02	5.3064E-06	8.8441E-04
FE	1.3288E+00	0.	0.	0.
NA	1.1306E+00	0.	0.	0.
NI	5.9778E-01	4.0391E-01	3.7925E-05	9.4813E-03
SI	2.4797E+00	0.	0.	0.
SR	4.4772E+00	2.0166E+00	2.8408E-04	4.7342E-02
BA	1.4760E+01	1.1398E+00	9.3643E-04	2.6755E-02
CS	1.4760E+01	3.9892E-02	9.3643E-04	9.3643E+00
SUM			3.59E-03	1.58E+00
AVE				

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11HF2A RUN NO. 54

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 1.5506E-02 M2

CONDITIONS TEMP=300. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 12.09 DF(DILUTION FACTOR)= 2.20

V/SA (VOL RATIO)= 2.8375E+01

SAMPLE WT.= 3.64E-02 GRAMS WATER WT.= 4.40E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	3.3000E-02	1.6484E-03	2.1282E-07	3.8694E-06
CA	3.5816E+01	1.0695E+00	2.3098E-04	2.5106E-03
CE	2.3300E-01	1.1584E-01	1.6318E-06	2.7193E-04
FE	9.0200E-02	0.	0.	0.
MN	1.3200E-02	0.	0.	0.
NA	1.8854E+00	0.	0.	0.
NI	9.5700E-01	8.5728E-01	6.1716E-06	1.5429E-03
SR	1.2650E+01	5.7921E+00	8.1579E-05	1.3597E-02
TI	7.7000E-02	6.2585E-04	4.9657E-07	1.4691E-06
BA	1.7006E+01	1.3349E+00	1.0967E-04	3.1335E-03
CS	1.7800E+01	4.8352E+02	1.1350E-04	1.1350E+00
		SUM	5.44E-04	AVE 1.45E-01

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11HP2A RUN NO. 53

SAMPLE FORM POWDER SIZE RANGE P<150 U SURFACE AREA 2.7733E-02 M2

CONDITIONS TEMP=300. DEG. C 30. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 5.99 DF(DILUTION FACTOR)= 1.95

V/SA (VOL RATIO)= 1.4063E+01

SAMPLE WT.= 6.51E-02 GRAMS WATER WT.= 3.90E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	3.0030E+01	5.0140E-01	3.6035E-05	3.9233E-04
CE	4.7970E-01	1.2281E-01	5.7866E-07	8.6036E-06
FE	2.3200E-02	0.	0.	0.
MG	5.6500E-03	0.	0.	0.
NA	6.4935E-01	0.	0.	0.
NI	4.1145E-01	1.5801E-01	4.9454E-07	1.2364E-04
SR	1.9227E+01	4.9224E+00	2.3110E-05	3.6617E-03
TI	9.7500E-03	4.4311E-05	1.1719E-08	3.4872E-08
			SUM 6.03E-05	AVE 8.93E-04

PREP. COMPOSITION (WT.PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

ACCELERATED LEACH DATA SUMMARY

PREP NAME U11HP2A RUN NO. 61

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 1.5379E-02 M2

CONDITIONS TEMP=450. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.14 DP(DILUTION FACTOR)= 3.61

V/SA (VOL RATIO)= 2.3799E+01

SAMPLE WT.= 3.61E-02 GRAMS WATER WT.= 3.66E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	3.6100E-02	1.8182E-03	2.3474E-06	4.2680E-05
CA	1.3357E+01	4.0217E-01	8.6654E-04	9.4407E-03
FE	1.6678E+00	0.	0.	0.
MN	1.4440E-02	0.	0.	0.
NA	1.2816E+00	0.	0.	0.
NI	2.0360E+00	1.4100E+00	1.3239E-04	3.3099E-02
SI	2.6126E+00	0.	0.	0.
SR	4.4764E+00	2.0667E+00	2.9108E-04	4.8513E-02
TI	1.8050E-02	1.4793E-04	1.1737E-06	3.4725E-06
CS	1.4440E+01	4.0000E+02	9.3897E-04	9.3897E+00
SUM			2.23E-03	AVE 1.58E+00

PREP. COMPOSITION (WT. PCT)

AL	5.50E+00
CA	9.20E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.38E+01
U	2.40E+00
Y	6.00E-01
ZR	6.80E+00
LU	6.00E-01
BA	3.50E+00
CS	1.00E-02

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ACCELERATED LEACH DATA SUMMARY

PREP NAME U20HP3A RUN NO. 72

SAMPLE FORM POWDER SIZE RANGE P=150 U SURFACE AREA 2.6856E-02 M2

CONDITIONS TEMP=150. DEG. C 1. DAYS PRESSURE= 1KB. M20

W/S (WT RATIO)= 8.70 DF(DILUTION FACTOR)= 2.30

V/SA (VOL RATIO)= 1.7257E+01

SAMPLE WT.= 8.87E-02 GRAMS WATER WT.= 4.80E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELEMENT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	1.0118E+01	1.6738E-01	3.7837E-04	4.3133E-03
FE	8.8949E+00	0.	0.	0.
MN	3.4500E-02	0.	0.	0.
NA	8.7170E-01	0.	0.	0.
NI	1.4900E-01	8.4403E-02	5.6086E-06	1.4021E-03
SI	9.2820E-01	0.	0.	0.
SR	2.5200E+00	5.1079E-01	9.4914E-05	1.8819E-02
TI	3.4500E-02	1.6404E-04	1.2843E-06	3.9702E-05
SUM			4.81E-04	5.58E-04

PREP. COMPOSITION (WT.PCT)

AL	5.40E+00
CA	8.80E+00
CE	6.00E-01
NI	4.00E-01
SR	8.00E-01
TI	3.28E+01
U	2.40E+00
ZR	6.50E+00
BA	5.80E+00
CS	8.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U20HP3A RUN NO. 99

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 1.3425E-02 M2

CONDITIONS TEMP=150. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 14.88 DF(DILUTION FACTOR)= 2.58

V/SA (VOL RATIO)= 3.8362E+01

SAMPLE WT.= 3.46E-02 GRAMS WATER WT.= 5.15E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	8(ELMNT)/ M2-DAY	8(SYNROC)/ M2-DAY
AL	1.9221E+00	1.0297E-01	1.4910E-05	2.6514E-04
CA	4.9758E+00	1.6345E-01	3.7072E-05	4.2127E-04
HN	7.7400E-03	0.	0.	0.
NA	3.2508E-01	0.	0.	0.
NI	1.2800E-02	9.3208E-03	9.6091E-08	2.4020E-05
SI	2.5800E-03	0.	0.	0.
SR	1.2390E+00	5.0547E-01	9.8785E-06	1.5891E-03
BA	3.0580E+01	1.0159E+01	2.3062E-04	3.9914E-03
SUM			2.91E-04	1.13E-03

PREP. COMPOSITION (WT.PCT)

AL	5.40E+00
CA	8.80E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.26E+01
U	2.40E+00
ZR	6.50E+00
BA	6.80E+00
CS	8.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME UO2H-3A RUN NO. 73

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 2.2970E-02 M2

CONDITIONS TEMP=300, DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 7.28 DF(DILUTION FACTOR)= 2.15

V/SA (VOL RATIO)= 1.8720E+01

SAMPLE WT.= 5.92E-02 GRAMS WATER WT.= 4.30E-01 GRAMS

ELEMENT	UO IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	4.6225E-01	1.4400E-02	2.0124E-05	3.7267E-04
CA	8.9360E+00	1.3371E-01	3.0327E-04	3.4463E-03
CE	2.7890E-02	7.8899E-03	1.2166E-06	2.0280E-04
FE	1.8966E-01	0.	0.	0.
MN	5.5900E-02	0.	0.	0.
NI	8.4178E+00	2.7102E+00	2.7940E-04	6.9850E-02
SI	8.9365E-01	0.	0.	0.
SR	2.2360E+00	6.2950E-01	9.7348E-05	1.6224E-02
TI	0.3110E-01	1.7186E-03	1.4415E-05	4.4217E-05
ZR	2.1500E-02	5.5873E-04	9.3602E-07	1.4400E-05
BA	4.8750E+01	1.0612E+00	1.8599E-03	2.7511E-02
CS	1.0750E+01	2.2699E+01	4.6601E-04	5.6501E-01
		SUM	5.04E-03	AVE 7.61E-02

PREP. COMPOSITION (WT.PCT)

AL	5.40E+00
CA	8.80E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.26E+01
U	2.40E+00
ZR	8.50E+00
BA	6.80E+00
CS	8.00E-02

ACCELERATED LEACH DATA SUMMARY

PREP NAME U20HP3A RUN NO. 71

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 1.6934E-02 M2

CONDITIONS TEMP=300. DEG. C 10, DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 8.65 DF(DILUTION FACTOR)= 2.11

V/SA (VOL RATIO)= 2.2267E+01

SAMPLE WT.= 4.00E-01 GRAMS WATER WT.= 4.22E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	3.9457E+00	9.1860E-02	2.0839E-05	2.3880E-04
FE	3.3780E-02	0.	0.	0.
BA	7.0895E-01	0.	0.	0.
NI	3.3780E-02	1.7293E-02	1.7830E-07	4.4579E-05
SR	2.2155E+00	7.6666E-01	1.1701E-05	1.9502E-03
TI	1.8990E-02	1.1937E-04	1.0029E-07	3.0769E-07
			SUM 3.28E-05	AVE 8.56E-04

PREP. COMPOSITION (WT.PCT)

AL	5.40E+00
CA	8.80E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.26E+01
U	2.40E+00
ZR	6.50E+00
BA	6.80E+00
CS	8.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U20HP3A RUN NO. 94

SAMPLE FORM POWDER SIZE RANGE P=150 U SURFACE AREA 1.4744E-02 M2

CONDITIONS TEMP=300. DEG. C 30. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.61 DF(DILUTION FACTOR)= 2.02

V/SA (VOL RATIO)= 2.7333E+01

SAMPLE WT.= 3.80E-02 GRAMS WATER WT.= 4.03E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	0(ELMNT)/ M2-DAY	0(SYNROC)/ M2-DAY
AL	8.080E-03	3.9376E-04	1.6267E-06	3.3828E-07
CA	9.4132E-01	2.8150E-02	2.1281E-06	2.4183E-05
MN	9.8980E-02	0.	0.	0.
NA	8.8980E-01	0.	0.	0.
NI	6.2820E-02	4.1197E-02	1.4157E-07	3.5393E-05
SI	2.2220E-02	0.	0.	0.
SR	3.1108E+00	1.3644E+00	7.0329E-06	1.1722E-03
TI	1.2120E-02	9.7927E-05	2.7401E-08	8.4052E-08
BA	3.2820E+01	1.2506E+00	7.3069E-05	1.0745E-03
CS	8.0800E+00	2.6579E+01	1.8267E-05	2.2894E-02
			SUM 1.01E-04	AVE 3.59E-03

PREP. COMPOSITION (WT.PCT)

AL	5.40E+00
CA	8.80E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.26E+01
U	2.40E+00
ZR	6.50E+00
BA	6.80E+00
CS	8.00E-02

COMMENTS:

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ACCELERATED LEACH DATA SUMMARY

PREP NAME U20HP3A RUN NO. 92

SAMPLE FORM POWDER SIZE RANGE P<150 U SURFACE AREA 1.5404E-02 M2

CONDITIONS TEMP= 460 DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.30 DF(DILUTION FACTOR)= 2.05

V/SA (VOL RATIO)= 2.6552E+01

SAMPLE WT. = 3.97E-02 GRAMS WATER WT. = 4.09E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	3.8950E-02	1.8169E-03	2.5286E-06	4.6826E-06
CA	2.7960E+00	7.9744E-02	1.0066E-04	2.0553E-03
FE	6.4060E-02	0.	0.	0.
MN	8.2000E-03	0.	0.	0.
NA	5.4530E-01	0.	0.	0.
NI	4.3050E-02	2.7110E-02	2.7948E-06	6.9870E-04
SI	4.1815E-01	0.	0.	0.
SR	1.6314E+00	6.4288E-01	9.9413E-05	1.6569E-02
TI	1.4965E-01	1.1563E-03	9.7183E-06	2.9601E-06
		SUM	2.95E-04	AVE 3.08E-03

PREP. COMPOSITION (WT.PCT)

AL	5.40E+00
CA	8.80E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.26E+01
U	2.40E+00
ZR	6.50E+00
BA	6.80E+00
CS	6.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME U20HP3A RUN NO. 95

SAMPLE FORM POWDER SIZE RANGE P<150 U SURFACE AREA 1.1834E-02 M2

CONDITIONS TEMP=450. DEG. C 10. DAYS PRESSURE= 1KB, M20

W/S (WT RATIO)= 10.43 DF(DILUTION FACTOR)= 2.12

V/SA (VOL RATIO)= 2.6672E+01

SAMPLE WT.= 3.05E-02 GRAMS WATER WT.= 3.18E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROG)/ M2-DAY
CA	2.7533E+00	1.0260E-01	2.3271E-05	2.6444E-04
NA	3.4132E-01	0.	0.	0.
NI	5.3000E-02	4.3443E-02	4.4786E-07	1.1197E-04
SI	2.9296E-01	0.	0.	0.
SR	1.1786E+00	6.4295E-01	9.9425E-06	1.6571E-03
TI	2.3320E-02	2.3494E-04	1.9706E-07	6.0449E-07
BA	3.1800E+01	1.5399E+00	2.6872E-04	3.9517E-03
		SUM	3.03E-04	AVE 1.20E-03

PREP COMPOSITION (WT.PCT)

AL	5.40E+00
CA	9.80E+00
CE	6.00E-01
NI	4.00E-01
SR	6.00E-01
TI	3.26E+01
U	2.40E+00
ZR	8.50E+00
BA	6.80E+00
CS	8.00E-02

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME S05HP4A RUN NO. 90

SAMPLE FORM POWDER SIZE RANGE P=150- 300U SURFACE AREA 7.7736E-03 M2

CONDITIONS TEMP=200. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.82 DF(DILUTION FACTOR)= 2.27

V/SA (VOL RATIO)= 4.3995E+01

SAMPLE WT.= 0.16E-02 GRAMS WATER WT.= 3.42E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	2.4970E-02	1.9133E-03	3.2122E-07	7.7776E-06
CA	4.5562E+00	1.5889E-01	5.8636E-05	6.4507E-04
FE	4.2956E+00	5.2164E+00	9.5132E-05	2.1205E-02
MN	2.0430E-01	0.	0.	0.
NA	1.7888E+01	0.	0.	0.
NI	9.7383E-01	1.0194E-01	1.2527E-05	4.1440E-04
SI	1.3168E-01	0.	0.	0.
SR	4.4719E-01	6.4325E-01	5.7527E-06	2.6149E-03
TI	2.4970E-02	2.5572E-04	3.2122E-07	1.0395E-06
			SUM 1.33E-04	AVE 4.15E-03

PREP. COMPOSITION (WT.PCT)

AL	4.13E+00
CA	9.09E+00
CE	6.70E-01
FE	2.60E-01
NI	3.02E+00
SR	2.20E-01
TI	3.08E+01
U	4.40E-01
Y	1.20E-01
ZR	7.83E+00
BA	5.51E+00
CS	6.70E-01

ACCELERATED LEACH DATA SUMMARY

PREP NAME S05HP4A RUN NO. 91

SAMPLE FORM POWDER SIZE RANGE P=150- 300U SURFACE AREA 8.0688E-03 M2

CONDITIONS TEMP=300, DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.46 DF(DILUTION FACTOR)= 1.71

V/SA (VOL RATIO)= 4.2509E+01

SAMPLE WT.= 3.28E-02 GRAMS WATER WT.= 3.43E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	1.8810E-02	1.3886E-03	2.3212E-07	5.6446E-06
CA	1.3047E+00	4.3761E-02	1.6170E-05	1.7789E-04
FE	1.4022E-01	1.6442E-01	1.7378E-06	6.6839E-04
HN	1.0174E+00	0.	0.	0.
NA	1.8596E+01	0.	0.	0.
NI	3.1122E-01	3.1387E-02	3.6571E-06	1.2759E-04
SI	3.6765E-01	0.	0.	0.
SR	1.1970E+01	1.6586E-01	1.4835E-06	6.7431E-04
BA	1.0680E+01	7.5694E-01	1.6954E-04	3.0770E-03
CS	2.0520E+01	9.3378E+00	2.5431E-04	3.7957E-02
			SUM 4.47E-04	AVE 6.10E-03

PREP. COMPOSITION (WT.PCT)

AL	4.13E+00
CA	9.09E+00
CE	6.70E-01
FE	2.60E-01
NI	3.02E+00
SR	2.20E-01
TI	3.09E-01
U	4.40E-01
Y	1.20E-01
ZR	7.65E+00
BA	5.51E+00
CS	6.70E-01

ACCELERATED LEACH DATA SUMMARY

PREP NAME U17HP1A RUN NO. 42

SAMPLE FORM POWDER SIZE RANGE P=<150 U SURFACE AREA 4.8615E-02 M2

CONDITIONS TEMP=300. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 5.82 DF(DILUTION FACTOR)= 1.97

V/SA (VOL RATIO)= 1.0555E+01

SAMPLE WT.= 8.48E-02 GRAMS WATER WT.= 4.92E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	1.6977E+02	1.7918E+00	3.642E-03	3.2518E-02
CA	3.0338E-01	7.3185E-03	6.6083E-06	1.3282E-04
FE	2.8959E-01	1.8503E-03	6.2124E-06	3.3581E-05
MN	6.3040E-02	1.8854E-03	1.3524E-06	2.8774E-05
NI	1.3780E-02	6.0371E-04	2.9583E-07	1.0937E-05
SI	3.0752E+01	6.0777E-01	6.8970E-04	1.4660E-02
Ti	2.7682E-02	3.6223E-04	5.9166E-07	6.5740E-06
Y	2.3840E-02	0.	0.	0.
CS	2.2653E+01	4.4632E+00	4.8601E-04	6.1001E-02
			SUM 4.80E-03	AVE 1.60E-02

PREP. COMPOSITION (WT.PCT)

AL	1.12E+01
CA	4.90E+00
CE	6.00E-01
FE	1.85E+01
MN	4.70E+00
NA	2.80E+00
NI	2.70E+00
SI	4.50E+00
SR	6.00E-01
Ti	9.00E+00
U	2.00E+00
ZR	3.00E+00
CS	8.00E-01

ACCELERATED LEACH DATA SUMMARY

PREP NAME U17NP1A RUN NO. 44

SAMPLE FORM POWDER SIZE RANGE P<150 U SURFACE AREA 2.4685E-02 M2

CONDITIONS TEMP=300. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 8.66 DF(DILUTION FACTOR)= 2.59

V/SA (VOL RATIO)= 1.8718E+01

SAMPLE WT.= 4.48E-02 GRAMS WATER WT.= 3.88E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	1.9168E+02	3.8198E+00	7.7643E-04	6.9324E-03
CA	2.6158E-01	1.1916E-02	1.0597E-06	2.1627E-05
MN	7.7700E-03	3.6902E-04	3.1477E-08	6.6972E-07
NI	5.1800E-03	4.2624E-04	2.0985E-08	7.7721E-07
SI	6.7888E+00	3.3660E-01	2.7490E-05	6.1088E-04
SR	1.2950E-02	4.8177E-03	5.2481E-08	8.7436E-06
Y	2.5900E-03	0.	0.	0.
CS	2.3310E+01	8.6719E+00	9.4431E-05	1.5738E-02
			SUM 9.00E-04	AVE 3.35E-03

PREP. COMPOSITION (WT.PCT)

AL	1.12E+01
CA	4.90E+00
CE	6.00E-01
FE	1.85E+01
MN	4.70E+00
NA	2.80E+00
NI	2.70E+00
SI	4.50E+00
SR	6.00E-01
TJ	9.00E+00
U	2.00E+00
ZR	3.00E+00
CS	6.00E-01

ACCELERATED LEACH DATA SUMMARY

PREP NAME U17HP1A RUN NO. 43

SAMPLE FORM POWDER SIZE RANGE P=160 U SURFACE AREA 2.7109E-02 M2

CONDITIONS TEMP=450. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 7.05 DF(DILUTION FACTOR)= 3.47

V/SA (VOL RATIO)= 1.2800E+01

SAMPLE WT.= 4.92E-02 GRAMS WATER WT.= 3.47E-01 GRAMS

ELEMENT	UB IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	1.7867E-01	3.242E-01	6.590E-04	5.884E-03
CA	1.2145E-01	5.0377E-03	4.480E-06	9.142E-05
FE	1.3188E-01	1.4487E-03	4.8640E-06	2.629E-05
MN	1.3890E-02	5.004E-04	5.120E-07	1.089E-05
NA	2.8447E-02	2.0649E-01	1.0493E-02	3.747E-01
SI	1.0826E+00	4.8900E-02	3.993E-05	8.6747E-04
TJ	3.4700E-03	7.8365E-05	1.2800E-07	1.4222E-06
Y	1.7350E-02	0.	0.	0.
CS	1.1104E-02	3.7615E-01	4.0980E-03	6.8267E-01
			SUM 1.53E-02	AVE 1.93E-01

PREP. COMPOSITION (WT.PCT)

AL	1.12E+01
CA	4.90E+00
CE	6.00E-01
FE	1.85E+01
MN	4.70E+00
NA	2.80E+00
NI	2.70E+00
SI	4.80E+00
SR	6.00E-01
TI	9.00E+00
U	2.00E+00
ZR	3.00E+00
CS	6.00E-01

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME MOSSA1A RUN NO. 67

SAMPLE FORM POWDER SIZE RANGE P= 44 U SURFACE AREA 6.0700E-02 M2

CONDITIONS TEMP=150. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 6.84 DF(DILUTION FACTOR)= 1.99

V/SA (VOL RATIO)= 6.5404E+00

SAMPLE WT.= 6.07E-02 GRAMS WATER WT.= 3.97E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	4.8591E+00	0.	0.	0.
NA	1.0581E+00	0.	0.	0.
N1	1.1940E+02	0.	0.	0.
SI	1.3531E+00	0.	0.	0.
SR	2.1890E+00	0.	0.	0.
TI	1.7910E-02	6.0617E-05	2.9506E-07	8.0617E-07
			SUM 2.95E-07	AVE 8.06E-07

PREP. COMPOSITION (WT.PCT)

AL 8.30E+00

TI 3.66E+01

BA 2.11E+01

COMMENTS: SA NOT ACCURATE FOR POWDER SIZE 44U

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME NOSSA1A RUN NO. 68

SAMPLE FORM POWDER SIZE RANGE P= <44 U SURFACE AREA 8.0600E-02 M2

CONDITIONS TEMP=300. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 4.96 DF(DILUTION FACTOR)= 2.00

V/SA (VOL RATIO)= 4.9628E+00

SAMPLE WT. = 8.06E-02 GRAMS WATER WT. = 4.00E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL	IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	3.5580E+00	0.	0.	0.	0.
FE	2.1050E+00	0.	0.	0.	0.
MN	4.6000E-02	0.	0.	0.	0.
NA	2.370E+00	0.	0.	0.	0.
NI	2.4000E-02	0.	0.	0.	0.
SI	5.4200E+01	0.	0.	0.	0.
SR	2.3800E+00	0.	0.	0.	0.
TI	1.2000E-02	4.0679E-05		1.4888E-07	4.0679E-07
			SUM	1.48E-07	AVE 4.07E-07

PREP. COMPOSITION (WT.PCT)

AL 8.30E+00

TI 3.66E+01

BA 2.11E+01

COMMENTS: SA NOT ACCURATE FOR POWDER SIZE 44U

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME H06SA1A RUN NO. 70

SAMPLE FORM POWDER SIZE RANGE P= <44 U SURFACE AREA: 6.7700E-02 M2

CONDITIONS TEMP=300. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 5.60 DF(DILUTION FACTOR)= 1.91

V/SA (VOL RATIO)= 5.5962E+00

SAMPLE WT.= 6.77E-02 GRAMS WATER WT.= 3.79E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
CA	3.7417E+00	0.	0.	0.
HA	4.2020E-02	0.	0.	0.
NA	2.4162E+00	0.	0.	0.
NI	1.3575E-02	0.	0.	0.
SI	4.2575E-01	0.	0.	0.
SR	2.1563E+00	0.	0.	0.
TI	9.8500E-03	3.8542E-05	1.4106E-08	9.8542E-08
LU	< 1.9100E-03	0.	0.	0.
		SUM	1.41E-08	AVE 3.88E-08

PREP. COMPOSITION (WT.PCT)

AL 5.30E+00

TI 3.68E+01

BA 2.11E+01

COMMENTS: SA NOT ACCURATE FOR POWDER SIZE 44U

101

1

ACCELERATED LEACH DATA SUMMARY

PREP NAME N06SA1A RUN NO. 89

SAMPLE FORM POWDER SIZE RANGE P# 44 U SURFACE AREA 6.0800E-02 M2

CONDITIONS TEMP=450. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 6.30 DF(DILUTION FACTOR)= 1.92

V/SA (VOL RATIO)= 6.2993E+00

SAMPLE WT.= 6.08E-02 GRAMS WATER WT.= 3.84E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELNMNT)/ M2-DAY	G(SYNRGCC)/ M2-DAY
CA	2.20E+00	0.	0.	0.
MN	1.25E-03	0.	0.	0.
NA	2.35E+00	0.	0.	0.
NI	1.90E-03	0.	0.	0.
SI	4.74E-01	0.	0.	0.
SR	2.07E+00	0.	0.	0.
TI	1.14E-02	0.1769E-05	1.8947E-57	5.1789E-07
			SUM 1.89E-07	AVE 5.18E-07

PREP. COMPOSITION (WT PCT)

AL 8.30E+00

TI 3.66E+01

BA 2.11E+01

COMMENTS: 3A NOT ACCURATE FOR POWDER SIZE 44U

ACCELERATED LEACH DATA SUMMARY

PREP NAME S03HP3A RUN NO. 89

SAMPLE FORM POWDER SIZE RANGE P=150- 3000 SURFACE AREA 2.9520E-03 M2

CONDITIONS TEMP=200. DEG. C 1. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.88 DF(DILUTION FACTOR)= 1.97

V/SA (VOL RATIO)= 1.3313E+02

SAMPLE WT. = 3.69E-02 GRAMS WATER WT. = 3.99E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	< 2.3640E-02	6.8388E-04	8.0081E-06	1.1046E-04
CA	2.6988E-01	0.	0.	0.
FE	2.8161E+01	0.	0.	0.
HA	2.9944E-01	0.	0.	0.
SI	1.6646E+00	0.	0.	0.
TI	5.9100E-03	4.1785E-05	2.0020E-06	5.2231E-08
LU	< 1.9700E-03	0.	0.	0.
CS	4.7280E+01	3.6195E+00	1.6018E-02	4.5244E-01
			SUM 1.60E-02	AVE 1.51E-01

PREP. COMPOSITION (WT.PCT)

AL 7.29E+00

TI 3.83E+01

SA 1.67E+01

CS 3.54E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME S03HP3A RUN NO. 87

SAMPLE FORM POWDER SIZE RANGE P=150- 300U SURFACE AREA 2.8080E-03 M2

CONDITIONS TEMP=200. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 9.83 OF(DILUTION FACTOR)= 1.72

V/SA (VOL RATIO)= 1.2286E+02

SAMPLE WT.= 3.51E-02 GRAMS WATER WT.= 3.45E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	8.1404E-01	2.4130E-02	2.1868E-05	3.0162E-04
CA	8.9784E-01	0.	0.	0.
FE	9.1666E+00	0.	0.	0.
NA	3.9732E-01	0.	0.	0.
NI	2.6120E-02	0.	0.	0.
SI	6.4369E+00	0.	0.	0.
SR	2.2360E-02	0.	0.	0.
TI	2.4252E-01	1.8026E-03	8.6368E-06	2.2533E-05
			SUM 3.05E-05	AVE 1.62E-04

PREP. COMPOSITION (WT.PCT)

AL	7.25E+00
TI	3.83E+01
SA	1.67E+01
CS	3.54E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME S03HP3A RUN NO.101

SAMPLE FORM POWDER SIZE RANGE P=150- 300U SURFACE AREA 2.4880E-03 M2

CONDITIONS TEMP=200. DEG. C 30. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.45 DF(DILUTION FACTOR)= 2.17

V/SA (VOL RATIO)= 1.3053E+02

SAMPLE WT.= 3.11E-02 GRAMS WATER WT.= 3.25E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	7.8120E-01	3.4647E-02	1.0466E-05	1.4435E-04
CA	2.3002E-01	0.	0.	0.
FE	1.1262E+01	0.	0.	0.
NA	5.8373E-01	0.	0.	0.
NI	1.3190E-02	0.	0.	0.
SI	9.4926E+01	0.	0.	0.
SR	8.6800E-03	0.	0.	0.
TI	1.0199E-01	8.3556E-04	1.3664E-06	3.5649E-06
CS	2.6040E+01	2.3653E+00	3.4887E-04	9.8552E-03
			SUM 3.61E-04	AVE 3.33E-03

PREP. COMPOSITION (WT.PCT)

AL	7.25E+00
TI	3.83E+01
BA	1.67E+01
CS	3.54E+00

COMMENTS:

ACCELERATED LEACH DATA SUMMARY

PREP NAME S03MP3A RUN NO. 88

SAMPLE FORM POWDER SIZE RANGE P=180- 900U SURFACE AREA 2.5440E-03 M2

CONDITIONS TEMP=300. DEG. C 10. DAYS PRESSURE= 1KB, H2O

W/S (WT RATIO)= 10.50 DF(DILUTION FACTOR)= 1.67

V/SA (VOL RATIO)= 1.3129E+02

SAMPLE WT.= 3.18E-02 GRAMS WATER WT.= 3.34E-01 GRAMS

ELEMENT	UG IN FLUID	PCT TOTAL IN FLUID	G(ELMNT)/ M2-DAY	G(SYNROC)/ M2-DAY
AL	8.8470E-02	2.9699E-03	2.6914E-06	3.7123E-05
CA	8.3500E-02	0.	0.	0.
FE	3.0311E+00	0.	0.	0.
NA	4.8597E-01	0.	0.	0.
JI	1.2475E+00	0.	0.	0.
SR	6.3500E-03	0.	0.	0.
TI	1.0020E-02	8.2209E-05	3.9367E-07	1.0276E-06
CS	2.6720E+01	2.3796E+00	1.0503E-03	2.9570E-02
			SUM 1.05E-03	AVE 9.90E-03

PREP. COMPOSITION (WT.PCT)

AL	7.25E+00
TI	3.63E+01
BA	1.67E+01
CS	3.54E+00

COMMENTS:

APPENDIX E

Apparent Leach Rates for S05HP4A, SYNROC C Powder

TABLE E-1. Results for S05HP4A, SYNROC C powder for 10-day runs.

200°C			300°C		
	Weight %	Apparent leach rate		Weight %	Apparent leach rate
	leached	g (SYNROC)/m ² ·day		leached	g (SYNROC)/m ² ·day
Al	0.002	7.8×10^{-6}	Al	0.001	5.6×10^{-6}
Ca	0.16	6.5×10^{-4}	Ca	0.04	1.8×10^{-4}
Ni	0.10	4.1×10^{-4}	Ni	0.03	1.3×10^{-4}
Sr	0.64	2.6×10^{-3}	Sr	0.17	6.7×10^{-4}
Ba	N/A		Ba	0.76	3.1×10^{-3}
Cs	N/A		Cs	9.3	3.8×10^{-2}
Fe	5.2	2.1×10^{-2}	Fe	0.16	6.7×10^{-4}
Ti	0.0002	1.0×10^{-6}			

APPENDIX F

Apparent Leach Rates for U17HPLA SYNROC D Powder

TABLE F-1. Results for U17HPIA SYNROC D formulation.

1 day--300°C			10 day--300°C			1 day--450°C		
		Apparent leach rate			Apparent leach rate			Apparent leach rate
Weight %	leached	g(SYNROC)/ m ² ·day	Weight %	leached	g(SYNROC)/ m ² ·day	Weight %	leached	g(SYNROC)/ m ² ·day
Al	1.79	3.3×10^{-2}	3.8		6.9×10^{-3}	0.32		5.9×10^{-3}
Ca	0.007	1.3×10^{-4}	0.01		2.2×10^{-5}	0.005		5.9×10^{-5}
Fe	0.002	3.4×10^{-5}	—		—	0.001		2.6×10^{-5}
Mn	0.002	2.9×10^{-5}	0.0004		6.7×10^{-7}	0.0006		1.1×10^{-5}
Na	—	—	—		—	20.6		3.7×10^{-1}
Ni	0.0006	1.1×10^{-5}	0.0004		7.8×10^{-7}	—		—
Si	0.8	1.5×10^{-2}	0.34		6.1×10^{-4}	0.05		8.9×10^{-4}
Sr	—	—	0.005		8.7×10^{-6}	—		—
Ti	0.0004	6.6×10^{-6}	—		—	—		1.4×10^{-6}
Cs	4.5	8.1×10^{-2}	8.7		1.6×10^{-2}	37.6		6.8×10^{-1}

APPENDIX G

Results of Chromel-Alumel Thermocouple Calibrations

FIG. G-1. Chromel-alumel calibration data using NaCl for F/4, Cycle 1.

FIG. G-2. Chromel-alumel calibration data using NaCl for F/4, Cycle 2.

FIG. G-3. Chromel-alumel calibration data using NaCl for F/4, Cycle 3.

FIG. G-4. Chromel-alumel calibration data using NaCl for F/4, Cycle 4.

TABLE G-1. Calibration data using NaCl.

Run No.	Up ($^{\circ}\text{C}$)	Down ($^{\circ}\text{C}$)
1	799.5	797.0
2	799.0	796.5
3	799.0	796.0
4	798.0	796.0

NOTES:

Mean = 797.62°C

Standard deviation = 1.43°C

FIG. G-5. Chromel-alumel calibration data using NaCl_(30.5) - Na₂SO_{4(69.5)} for F/4, Cycle 1.

FIG. G-6. Chromel-alumel calibration data using NaCl_(30.5) - Na₂SO₄(69.5) for F/4, Cycle 2.

FIG. G-7. Chromel-alumel calibration data using $\text{NaCl}_{(30.5)} - \text{Na}_2\text{SO}_{4(69.5)}$ for F/4, Cycle 3.

TABLE G-2. Calibration data using NaCl (30.5) - Na₂SO₄ (69.5)

Run No.	Up (°C)	Down (°C)
1	626.0	624.5
2	626.0	624.0
3	628.0	621.0

NOTES:

Mean = 625.25°C

Standard deviation = 2.68°C

pyG. G-8. Chromel-alumel calibration data using KCl for F/4, Cycle 1.

FIG. G-9. Chromel-alumel calibration data using KCl for F/4, Cycle 2.

FIG. G-10. Chromel-alumel calibration data using KCl for F/4, Cycle 3.

FIG. G-11. Chromel-alumel calibration data using KCl for F/4, Cycle 4.

TABLE G-3. Calibration data using KCl.

Run No.	Up ($^{\circ}\text{C}$)	Down ($^{\circ}\text{C}$)
1	770.0	769.0
2	770.0	765.0
3	770.0	768.5
4	769.5	769.0

NOTES:

Mean = 768.88°C

Standard deviation = 1.67°C

FIG. G-12. Chromel-alumel calibrations using $K_2Cr_2O_7$ F/4, Cycle 1.

FIG. G-13. Chromel-alumel calibrations using $K_2Cr_2O_7$ F/4, Cycle 2.

FIG. G-14. Chromel-alumel calibrations using $K_2Cr_2O_7$ F/4, Cycle 3.

FIG. G-15. Chromel-alumel calibrations using $K_2Cr_2O_7$ F/4, Cycle 4.

FIG. G-16. Chromel-alumel calibrations using $\text{K}_2\text{Cr}_2\text{O}_7$ F/4, Cycle 5.

TABLE G-4. Calibration data using $K_2Cr_2O_7$.

Run No.	Up ($^{\circ}C$)	Down ($^{\circ}C$)
1	394.0	394.0
2	394.0	394.0
3	394.0	395.0
4	395.0	394.0
5	395.5	394.0

NOTES:

Mean = $394.35^{\circ}C$

Standard deviation = $0.58^{\circ}C$

TABLE G-5. Melting points of salts used
(Roberts, 1924).

Salt	Melting point ($^{\circ}C$)
$K_2Cr_2O_7$	397.5 ± 0.5
KCl	770.3 ± 0.5
NaCl	800.4 ± 0.5
NaCl (30.4) - Na_2SO_4 (69.5)	627.0 ± 0.5

APPENDIX H

Scanning Electron Microscope Analyses of SYNROC Formulations

SCANNING ELECTRON MICROSCOPE ANALYSES OF SYNROC FORMULATIONS

Surfaces of two U12SA, SYNROC B, cores were studied after hydrothermal treatment at 300°C using a scanning electron microscope (SEM). One core was run for 10 days; the other was run for 30 days. Macroscopic views of these cores, compared with prerun cores, are shown in Fig. H-1. Postrun cores appear intact and virtually unaltered to the naked eye. SEM examination of the surface of the core, which was run for 10 days shows little metastable and/or quench growth and that material is not well crystallized. The surface of the core which was run for 30 days contains abundant metastable and/or quench crystals (see Figs. H-2 and H-3). These precipitates are readily distinguished from the original annealed surface of the core by comparing postrun SEM pictures in Figs. H-2a, H-2b, and H-3 with the prerun pictures shown in Fig. H-4. The crystals are commonly subhedral to euhedral and less than 10 μm in their longest direction. There appears to be at least two distinct types of precipitates found on the surfaces of the U12SA, SYNROC B, core:

- Euhedral, elongate crystals that form radiating rosettes.
- Anhedral to subhedral, equant grains that form "globs."

Unfortunately, we were not able to obtain elemental analyses of the crystals found on the surfaces of the U12SA, SYNROC B, cores.

Surfaces of one U12HP, SYNROC B, core were studied after treatment at 300°C for 10 days, using the SEM. The 1000x enlargement of the postrun U12HP core, see Fig. H-5, shows that the core is apparently intact. The black material seen on the core surface is carbon paint, which is used to attach the core to the sample platform on the SEM. Detailed examination of the U12HP core surface reveals the presence of metastable and/or quench crystals that are mostly subhedral to euhedral, with individual grains ranging from <1 μm to 10 μm in size (Fig. H-6). The smaller crystals (see Fig. H-6a) appear to be tetrahedral in shape; qualitative analysis by a Kevex Energy Dispersive System (EDS) shows that these quench crystals are high in titanium relative to the SYNROC B matrix. Some larger crystals (see Fig. H-6b) are somewhat higher in calcium relative to the SYNROC B matrix.

Surfaces of three U11HP, SYNROC C cores were examined after hydrothermal treatment at 300°C using a SEM. The cores were run for 10, 30, and 60 days. Pretreatment SEM photographs were not taken of all these U11HP cores.

A postrun, macroscopic picture of the 10-day core is given in Fig. H-7, along with a picture of some prerun cores. The postrun core appears dull in tone and slightly whitish in color. This appearance is probably caused by the presence of numerous small crystals on the core surface. SEM photographs of this core surface presented in Fig. H-8 show the "net" of fine crystals (approximately 1 μm elongate grains) that blanket the core surface as well as the large (10 to 20 μm) well-formed crystals. A single crystal of the latter is shown in Fig. H-9. Qualitative analysis of one of these larger crystals indicates that it is composed almost entirely of aluminum. Qualitative EDS analyses of the crystals forming the "net" could not be obtained because of their small size.

Surfaces of cores that were run for 30 and 60 days at 300°C show similar results. A net of fine, elongate crystals ($\leq 1 \mu\text{m}$) covers the surface of these cores. In addition, larger, well-formed crystals, 10 μm to 20 μm long, were found adhering to the core surface. EDS qualitative analysis indicates that the major component of these grains is also aluminum. The surface of the 30-day run is shown in Figs. H-10 and H-11. Figures H-12 and H-13 illustrate the surface of the 60-day run. Two varieties of precipitates were identified by the SEM in this 60-day run:

- Al-rich crystals, subhedral to euhedral.
- Anhedral Si(Al) grains occurring in smaller quantities (see Fig. H-13).

Silicon was one of the ubiquitous contaminants commonly detected in fluids from the runs. The aluminum-rich quench crystals were identified in the x-ray diffraction patterns obtained on the U11HP2A cores and powders as boehmite, AlOOH (see Table J-I, Appendix J). Phase equilibrium relationships in the system $\text{Al}_2\text{O}_3\text{-SiO}_2\text{-H}_2\text{O}$ by Roy and Osborn (1954) indicate that boehmite is not a stable phase at 300°C and 100-MPa water pressure. This lends support to our interpretation of boehmite as a metastable or quench product. Furthermore, silica quenched from the vapor phase is frequently seen in hydrothermal studies on silicate-volatile systems (see discussions in Kennedy et al., 1962).

Unleached

Leached 300°C

FIG. H-1. Macroscopic views of annealed cores of U12SA6A, SYNROC B, unleached and leached at 300°C or 1, 10, and 30 days. (Grey material behind cores is adhesive used to hold them in place.)

—| |—10 μ—|

—| |—1 μ—|

FIG. R-2. High magnification SEM photographs of U12SA6A, SYNROC B, which was leached at 300°C, 100-MPa water pressure for 30 days. Light colored, well-formed crystals located on the surface are precipitates which form during hydrothermal treatment. Compare these photos with Fig. R-4, the original *annealed* core surface.

FIG. H-3. Precipitates of euhedral crystals and anhedral "globs" occurring on core surfaces of U12SAS6A after hydrothermal treatment of 300°C and 100-MPa water pressure for 30 days.

FIG. H-4. SEM photographs of preleached, annealed core surfaces of U12SA6A.

FIG. H-5. SEM photograph of SYNROC C, U11HP core after hydrothermal treatment at 300°C and 100-MPa water pressure for 10 days. Note that the core is intact. The black material on the bottom surface is carbon paint, which was used to mount the core.

FIG. H-6. SEM photographs of SYNROC B, U12HP cores after hydrothermal treatment at 300°C and 100-MPa water pressure for 10 days. (a) Light-colored euhedral crystals occurring on the core surface are titanium-rich precipitates. (b) Large, euhedral crystal is a Ca-rich precipitate.

Unleached

Leached

300°C, 10 d

—|—| 1 mm

FIG. H-7. Photographs of unannealed cores of SYNROC C, U11HP2A before hydrothermal treatment (left) and after hydrothermal treatment (right) at 300°C and 100-MPa water pressure for 10 days.

FIG. H-8. SEM photographs of SYNROC, U11HP2A cores after hydrothermal treatment at 300°C and 100-MPa water pressure for 10 days. (a) Large, subhedral crystals are precipitates formed during hydrothermal treatment. (b) Net of fine, acicular crystals precipitated on the core surface as a result of hydrothermal treatment.

FIG. H-9. High-magnification SEM photograph of the surface of SYNROC C, U11HP2A after hydrothermal treatment at 300°C and 100-MPa water pressure for 10 days. Shown in the center of the field of view is a euhedral, aluminum-rich crystal occurring on the core surface.

FIG. H-10. SEM photograph of SYNROC C, U11HP2A core after hydrothermal treatment at 300°C and 100-MPa water pressure for 30 days.

FIG. H-11. SEM photographs of SYNROC C, U11HP2A after hydrothermal treatment at 300°C and 100-MPa water pressure for 30 days. (a) Large crystals in the center are aluminum-rich precipitates occurring on the core surface. (b) Fine net of acicular crystals that cover the surface of the core.

FIG. H-12. SEM photographs for SYNROC C, U11HP after hydrothermal treatment at 300°C and 100-MPa water pressure for 60 days. (a) Core subjected to hydrothermal treatment. Note that it is virtually intact. Upper right-hand corner shows carbon paint peeling away from the surface. (b) Large aluminum-rich precipitates occurring on the core surface.

FIG. R-13. SEM photograph of SYNROC C, U11HP after hydrothermal treatment at 300°C and 100-MPa water pressure for 60 days. Si-rich, globular precipitate, also containing aluminum, which occurs on the core surface, is shown in the center of the field of view.

APPENDIX I

Detection Limits for Inductively Coupled Plasma Emission Spectroscopy Fluid Analysis

TABLE I-1. Detection limits for inductively coupled plasma emission spectroscopy fluid analysis.^a

Element	Detection limit (µg/ml)
Al	0.25
Ca	0.001
Ce	0.21
Fe	0.003
Lu	0.002
Mn	0.012
Na	0.003
Ni	0.011
Si	0.008
Sr	0.003
Ti	0.0004
U	0.072
Y	0.0004

^aThe detection limits presented are four times the standard deviation in the detection of the element in standard solutions. Fluid-analysis results using Inductively Coupled Plasma Emission Spectroscopy are accurate to $\pm 5\%$ of the measured value (Langhorst, 1980, personal communication).

APPENDIX J

X-Ray Diffraction Analyses of SYNROC B and C Formulations

X-RAY DIFFRACTION ANALYSES OF SYNROC B AND C FORMULATIONS

X-ray diffraction (XRD) analyses were carried out on prerun SYNROC B and C powders, as well as on select SYNROC C powders hydrothermally treated at elevated temperatures at the 100-MPa isobar. Table J-1 gives the raw net peak heights of the major diffraction peaks of the SYNROC minerals. As indicated, small amounts of excess TiO_2 and $\alpha\text{-Al}_2\text{O}_3$ were sometimes seen in the patterns. In addition, there were minor amounts of Al_2TiO_5 , as well as some other unidentified phases, which are presumed to be non-SYNROC phases. The amounts of material available for x-ray diffraction analyses varied considerably. Hence, the wide variation in the raw peak heights reported in Table J-1. The same data, therefore, are given in Table J-2, with the intensities normalized to the major line of zirconolite being 100.

We accumulated the most XRD data on the U11SA4A, SYNROC C powders. The intensity ratio of the strongest lines of zirconolite and perovskite in the prerun formulation is 100:35 (see Table J-2a). This intensity ratio remains very nearly constant at approximately 100:41 in products hydrothermally treated at elevated temperatures at the 100-MPa water pressure isobar (see Table J-2b). This ratio is slightly higher (but not significantly higher) than that of the starting material. It is possible that the relative peak heights of perovskite increase slightly in hydrothermally treated runs because of thermal annealing during long-term subsolidus exposure. Similar results were previously observed in the 10-Å reflection of biotite present in granitoid rocks when held for long periods of time under subsolidus conditions at 100 MPa (Piwinski, 1968; 1973).

Hollandite and rutile peaks show large intersample variation. However, with the possible exception of run No. 26, 10 days at 451°C, there does not appear to be a significant decrease in the amount of hollandite. Likewise, with the possible exception of run No. 25, 10 days at 302°C, there does not appear to be a significant increase in the amount of rutile, which would be expected if the major SYNROC components were to break down. Note also that in run No. 29, 30 days at 305°C, the amount of rutile appears to be "normal."

To evaluate more fully the hydrothermal stability of hollandite, four hydrothermal runs were carried out on the hollandite preparation, MO6SA1A. An

XRD scan of a powdered sample from run No. 70, 10 days at 306°C, showed a sharp pattern of hollandite, no alteration in lattice constants, and no new lines. The peak height of the major line in the hydrothermally treated hollandite was 840; the material not tested registered 840. We therefore conclude that the hollandite preparation, MO6SALA, is not noticeably affected by the hydrothermal treatment in this P-T régime.

X-ray diffraction patterns of the U11SA4A (SYNROC C) starting material, and U11SA powder hydrothermally treated at 305°C for 30 days, are compared in Fig. J-1. The major SYNROC minerals are clearly intact after exposure to elevated temperature at 100-MPa water pressure, according to the x-ray data.

X-ray diffraction patterns of the U11HP2A (SYNROC C) starting material, and U11HP powder hydrothermally treated at 450°C for 1 day, are compared in Fig. J-2. A dramatic difference is noted. The postrun pattern discloses the appearance of boehmite (AlOOH) and anatase (TiO₂), as well as the disappearance a small amount of Al₂TiO₅ found in the starting material. According to Austin and Schwartz (1953), Al₂TiO₅ is isomorphous with pseudobrookite (Fe₂TiO₅). The data given in Table J-2 indicate that the SYNROC minerals remain essentially unaltered to the level of sensitivity of x-ray diffraction. We thus conclude that the Al₂TiO₅ phase breaks down during hydrothermal treatment to form boehmite and anatase as follows:

SEM data contained in Appendix H clearly reveal the presence of boehmite on the surfaces of the run products. Because this breakdown of Al₂TiO₅ may open up channels for the penetration of fluid into the interior of the radioactive-waste compact during storage in an underground repository, we suggest that the formation of Al₂TiO₅ be avoided during fabrication.

As noted above, small amounts of non-SYNROC phases were found in the starting materials. Some of these phases break down under hydrothermal treatment, as evidenced by the disappearance of weak lines in the diffraction patterns of postrun samples. We estimate that the total amount of these non-SYNROC phases is small. However, this should be kept in mind when evaluating the chemistry of the solutions (see Appendix E). Some ions reported in these analyses may have come from these non-SYNROC phases.

TABLE J-1. Raw net intensities of the major diffraction peak for each of the principle phases in SYNROC B or C.

A. Before hydrothermal treatment

Sample	H	P	Z	R	ATO	C
U12HP3A, SYNROC B	110	256	324	No	No	Yes, weak
U11HP2A, SYNROC C Powder	59	160	224	10	Yes	No
U11SA4A, SYNROC C Powder	160	210	600	102	No	No
U20HP3A, SYNROC C	166	190	284	No	No	Yes
S05HP4A, SYNROC C	248	242	440	No	No	No

B. After hydrothermal treatment

Sample	Run No.	T(C°)	Time (days)	H	P	Z	R
U11SA4A, SYNROC C	48	153	1	84	98	237	46
U11SA4A, SYNROC C	22	159	10	12	23	56	12
U11SA4A, SYNROC C	25	302	10	24	37	83	32
U11SA4A, SYNROC C	29	305	30	127	162	400	93
U11SA4A, SYNROC C	49	452	1	92	98	241	54
U11SA4A, SYNROC C	26	451	10	54	115	280	70
U11HP2A, SYNROC C	53	303	30	47*	112	150	No
U11HP2A, SYNROC C	81	450	1	108*	262	428	No

Notes:

* = Includes contribution from boehmite (AlOOH), $-\text{AlO}(\text{H})$; see Fig. J-2.

H = Ba hollandite ($\text{BaAl}_2\text{Ti}_6\text{O}_{16}$)

P = Perovskite (CaTiO_3)

Z = Zirconolite ($\text{CaZrTi}_2\text{O}_7$)

R = Rutile (TiO_2)

ATO = Al_2TiO_5

C = Corundum ($-\text{Al}_2\text{O}_3$).

TABLE J-2. Raw net intensities normalized to the diffraction peak for zirconolite, being 100 in each pattern.

A. Before hydrothermal treatment

Sample	H	P	Z	R
U12HP3A, SYNROC B	34	79	100	No
U11SA4A, SYNROC C Powder	27	35	100	17
D20HP3A, SYNROC C	58	67	100	No
S05HP4A, SYNROC C	56	55	100	No
U11HP2A, SYNROC C	26	71	100	4

B. After hydrothermal treatment

Sample	Run No.	T(C°)	Time (days)	H	P	Z	R
U11SA4A, SYNROC C	48	153	1	35	41	100	19
U11SA4A, SYNROC C	22	159	10	21	41	100	21
U11SA4A, SYNROC C	25	302	10	29	45	100	38
U11SA4A, SYNROC C	29	305	30	32	41	100	23
U11SA4A, SYNROC C	49	452	1	38	41	100	22
U11SA4A, SYNROC C	26	451	10	19	41	100	25
U11HP2A, SYNROC C	53	303	30	31	75	100	No
U11HP2A, SYNROC C	81	450	-	25	61	100	No

FIG. J-1. U11SA4A hydrothermally treated at 300°C for 30 days, run No. 29 and U11SA4A powder--100 mesh.

FIG. J-2. U11HP2A hydrothermally treated at 450°C for 1 day, run No. 81, and U11HP2A starting material.

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