Process Performance of the Pilot-Scale In Situ Vitrification of a Simulated Waste Disposal Site at the Oak Ridge National Laboratory

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PROCESS PERFORMANCE OF THE PILOT-SCALE IN SITU
VITRIFICATION OF A SIMULATED WASTE DISPOSAL SITE
AT THE OAK RIDGE NATIONAL LABORATORY

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SUMMARY

Process feasibility studies have been successfully performed on three developmental scales to determine the potential for applying in situ vitrification to intermediate-level (low-level) waste placed in seepage pits and trenches at Oak Ridge National Laboratory (ORNL).^(a) In the laboratory, testing was performed in crucibles containing a mixture of 50% ORNL soil and 50% limestone. In an engineering-scale test at Pacific Northwest Laboratory a 1/12-scale simulation of an ORNL waste trench was constructed and vitrified, resulting in a waste product containing soil and limestone concentrations of 68 wt% and 32 wt%, respectively. In the pilot-scale test a 3/8-scale simulation of the same trench was constructed and vitrified at ORNL, resulting in soil and limestone concentrations of 80% and 20%, respectively, in the waste product.

Results of the three scales of testing indicate that the ORNL intermediate-level (low-level) waste sites can be successfully processed by in situ vitrification; the waste form will retain significant quantities of the cesium and strontium. Because cesium-137 and strontium-90 are the major components of the radionuclide inventory in the ORNL seepage pits and trenches, final field process decontamination factors (i.e., losses to the off-gas system relative to the waste inventory) of 1.0×10^4 are desired to minimize activity buildup in the off-gas system. These values were realized during the engineering-scale tests for both cesium and strontium, but were 1.0×10^3 for cesium and 1.0×10^6 for strontium during pilot-scale processing. The vitrified material resulting from the engineering-scale tests effectively contained 99.99% of the cesium and strontium placed in the test site, with a 68%-soil to 32%-limestone ratio, while the pilot-scale test contained 99.90% cesium and 99.9999% strontium with 80 wt% soil and 20 wt% limestone. Volume reduction (as measured by subsidence) for the engineering-scale test was 60% while the reduction for the pilot-scale test was 43%. No migration of the cesium or strontium to the uncontaminated surrounding soil was detected in the engineering- or pilot-scale tests.

(a) Work performed under Contract DE-AC06-76RLO 1830 for the Department of Energy.

The pilot-scale waste form consisted of a glass phase and a multi-crystalline product. Both these phases had essentially the same elemental composition. The strontium and cesium in the monolith were found equally in both the glass and crystalline material and were generally uniformly distributed throughout the monolith. The durability of the waste form was evaluated by MCC-1, MCC-3, modified MCC-3, and Extraction Procedure toxicity tests. The durability of the waste form was similar to or better than that for two high-level nuclear waste glasses (i.e., PNL-76-78 and SRL-165). When compared to each other, waste forms resulting from the engineering- and pilot-scale tests were also found to be of similar durability.

These favorable results indicate that in situ vitrification can be used to treat the ORNL seepage pits and trenches. Vitrification of trench 7 would take approximately nine settings using a large-scale system and would produce a glass monolith of approximately 4.7×10^7 kg (see calculations in Appendix A). Using glass decontamination factors of 99.90% for cesium-137 and 99.99% for strontium-90, the scrub solution would accumulate 0.3 Ci of strontium-90 and 14.2 Ci cesium-137 at each setting. Actual dose calculations must be made for these radionuclide inventories to determine exposures to personnel. Previously conducted research on cesium retention indicates that higher dolomite concentrations reduce operating temperatures and improve cesium retention, as shown in the engineering-scale test. This effect from higher dolomite concentrations in large-scale tests needs to be verified.

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1.0 INTRODUCTION

Pacific Northwest Laboratory (PNL) has successfully performed laboratory, engineering-scale, and pilot-scale tests of the in situ vitrification (ISV) process on actual Oak Ridge National Laboratory (ORNL) soil and limestone. In situ vitrification is an emerging, in-ground thermal treatment technology that fixes radioactive contamination in the soil by converting it to a glass and crystalline waste form. The purpose for performing this test on the ORNL soil and limestone was to ascertain if ISV could be successfully applied to ORNL seepage pits and trenches.

ORNL used a series of seven seepage pits and trenches (Figure 1) between 1951 and 1966 for the disposal of approximately 2.5×10^7 gallons of liquid radioactive waste. Approximately 200,000 Ci of ^{90}Sr and 600,000 Ci of ^{137}Cs , (Spalding 1987) along with smaller quantities of other fission products, uranium, and transuranium elements, were disposed in this series of pits and trenches. To facilitate the seepage of liquids the trenches were constructed on the tops of ridges, oriented perpendicular to the strike of the bedding of the formation, and filled with crushed limestone or dolomite (Figure 2). As the liquid seeped, the Cs and Sr remained within, or in close proximity to, the trenches. Cesium is generally irreversibly sorbed by the illite-rich soils at ORNL. Strontium, on the other hand, is poorly sorbed. To reduce the mobility of Sr, the pits and trenches were treated with highly alkaline solution (NaOH) at the time of disposal. All of the pits and trenches are now covered with asphalt caps to reduce the direct flow of precipitation through the waste. Currently, the pits and trenches do not significantly contribute to surface water contamination, and most of the Cs and Sr remains in close proximity to the bottom of the pits and trenches. However, it will be necessary to apply either a long-term site maintenance and monitoring program or some form of remedial action so the sites can be permanently decommissioned. This need has evolved because of the large inventory of ^{137}Cs and ^{90}Sr , the close proximity of the waste to the surface, and the potential for significant release in the future.

PNL began development of the ISV technology in 1980 under contract to the U.S. Department of Energy (DOE) (Brouns, Buelte, and Bonner 1983). Since

FIGURE 1. Location of the Radioactive Liquid-Waste Disposal Pits and Trenches at ORNL and the Pilot-Scale ISV Demonstration (from Spalding 1987)

FIGURE 2. Construction Details of ORNL Liquid-Waste Disposal Trench 7 (Spalding 1987)

that time numerous experimental tests using a variety of conditions and waste types have been conducted (Buel et al. 1987; Timmerman and Oma 1984; Timmerman et al. 1983). A large-scale ISV unit was designed, fabricated, and tested (Buel and Carter 1986). The large-scale unit was designed for processing transuranic-contaminated soil, but the design is adaptable to a

variety of waste types (Buelte and Freim 1986), including Oak Ridge contaminated seepage pits and trenches. Table 1 describes the different scales of testing units that PNL used in developing ISV technology. The successful results of 52 bench-, engineering-, pilot-, and large-scale tests demonstrates the feasibility of the process.

In 1986, and under contract with ORNL, it was decided to test ISV technology using actual soil and limestone from ORNL. Laboratory and engineering-scale tests were performed and reported (Carter, Bates and Maupin 1987). A 3/8-scale, pilot-scale ISV test was designed based on the findings of the laboratory- and engineering-scale tests to simulate the processing of the ORNL seepage pits and trenches. The main objective of the test was to provide technical support for the application of large-scale ISV technology to ORNL intermediate-level waste in seepage pits and trenches. The test evaluated Cs and Sr retention in the vitrified soil and limestone representative of an actual ORNL site. In addition, the vitrified product and ORNL soil/limestone were characterized for composition, physical properties, melting properties, volume reduction, crystal structure/devitrification, and chemical durability.

TABLE 1. Scales of Testing Units for Developing Technology

<u>Equipment Size</u>	<u>Electrode Separation</u>	<u>Block Size</u>	<u>Test Completed^(a)</u>
Bench-Scale	4 in.	1 to 20 lb	7
Engineering-Scale	9 to 15 in.	100 lb to 1 ton	25
Pilot-Scale	3 to 4 ft	10 to 50 tons	15
Large-Scale	11 to 18 ft	400 to 800 tons	5

(a) As of December 1987.

2.0 CONCLUSIONS

In situ vitrification was successfully performed on a 3/8-scale, simulated test site at ORNL. The test was performed to determine the technical feasibility for applying ISV technology to ORNL intermediate-level waste. Evaluation of the test results indicates that the ISV process is suitable for immobilization of ORNL intermediate-level waste. In addition, analysis of the data from the 3/8 pilot-scale test resulted in the following observations:

- The ISV process is technically feasible for this application, as confirmed by the performance of the process equipment and the evaluation of the ORNL soil, limestone, pilot-scale off-gas scrub system, off-gas high-efficiency particulate air (HEPA) filters, and core samples from the vitrified mass.
- Soil-to-off-gas decontamination factors (DFs), as determined by the pilot-scale testing, were $1.0 \text{ E}+3$ for Cs and $1.4 \text{ E}+6$ for Sr. These factors are equivalent to a Cs retention of 99.90% and Sr retention of 99.9999% in the molten soil. Quantities of Cs and Sr used in the pilot-scale test were several orders of magnitude higher than the mass of radioisotopes present in the ORNL trenches and seepage pits.
- Volume reductions of greater than 40% may be expected. Volume reduction was 60% for the engineering-scale test and 43% for the pilot-scale test, thus eliminating concerns for future subsidence.
- The soil-to-limestone ratio of the vitrified mass for the pilot-scale test was estimated to be 80 wt% soil to 20 wt% limestone.
- A gray, spherical multi-phase crystalline product formed inside the vitrified mass in regions of slowest cooling (center of mass between the four electrodes). This product was found to be as durable as the vitrified glass product.

- The normalized mass release and dissolution rates at 90°C as determined by MCC-1, MCC-3, and modified MCC-3 testing of the vitrified mass samples are approximately equivalent to those for PNL 76-68 and SRL-165 high-level waste glasses. In addition, once the ISV vitrified product has cooled, the anticipated storage temperature would be essentially ambient ground temperature. At these temperatures dissolution rates could be as much as one or two orders of magnitude lower.
- The elemental compositions of the glass and multi-crystalline phases were essentially equal. This indicates that the resulting monolith was once a relatively homogeneous melt and the crystalline material formed from the glass during slow cooling.
- Semi-quantitative x-ray fluorescence (XRF) analysis indicated that the Sr was very uniformly distributed throughout the vitrified monolith. Distribution of Cs varied by as much as 50% in the cores, but Cs was generally uniformly dispersed throughout the monolith. Little variation in Cs or Sr was observed vertically in any of the cores. The grab samples from the outer areas of the monolith contained the same levels of both Cs and Sr as did the core samples.
- The ISV process was not observed to induce migration of the Cs or Sr below the monolith into unreacted soil. However, some Cs was observed in partially reacted soil near the edge of the melt. Whether the Cs enters the partially reacted material before, during, or after the test as a result of core drilling is not known.
- The crystalline material was identified as a mixture of pseudowollastonite (CaO-SiO_2) and anorthite (a feldspar, $\text{CaO-Al}_2\text{O}_3\text{-SiO}_2$).
- Based on Extraction Procedure (EP) toxicity testing, the pilot-scale waste form, both glass and crystalline phases, is not EP toxic.

- The compositions of the waste forms in the pilot-scale test differed from that of the engineering-scale test, due to the much higher level of MgO in the "limestone" used in the engineering-scale test.
- The durability of the waste form from the engineering-scale ISV test was very similar to the durability of the waste form from the pilot-scale test, despite the difference in composition (the engineering-scale test revealed a higher MgO wt%).
- Pilot-scale test DF's show processing system accumulation for a large-scale system of 0.3 Ci of ^{90}Sr and 14.2 Ci ^{137}Cs at each setting. The additional research on Cs retention as reported in Section 6.0 indicates that although Cs volatility is directly proportional to viscosity, it is a much stronger function of temperature. Data indicate that reducing soil operation temperatures by a factor of 1.2 from 1650°C to 1325°C, while adjusting the composition to hold viscosity constant, will reduce Cs volatility by a factor of 3. More laboratory studies are recommended on how to better control Cs volatility by adjusting soil composition on ORNL soil. The effect of higher dolomite concentrations was demonstrated in the engineering-scale test for temperature reduction and higher Cs retention.

The laboratory-, engineering-, and pilot-scale tests indicate the potential for using ISV to treat the trenches and seepage pits at the ORNL contaminated waste sites. Based on the results of these feasibility tests, it appears that adequate technical bases are available to recommend proceeding with a large-scale demonstration on a trench at ORNL.

The composition of the waste form in the pilot-scale test differed from that of the bench-scale test, due to the much higher level of MO in the "limonite" used in the engineering-scale test.

The composition of the waste form from the engineering-scale test was very similar to the bench-scale test, but the pilot-scale test, due to the difference in composition (the engineering-scale test received a higher level of MO).

Pilot-scale tests of a show processing system operation for a large-scale system of 10, 20, and 100 Gt of waste. The additional research on CS retention as reported in Section 2.1 indicates that although CS volatility is directly proportional to volatility, it is a much stronger function of temperature. Data indicate that during soft operation, retention by a factor of 1.5 from 100°C to 150°C, while during the operation to hold volatility constant, will reduce CS volatility by a factor of 1.5. More laboratory studies are recommended on the effect of CS volatility by adjusting soft operation to better control CS volatility.

The effect of higher volatile concentrations will be studied in the engineering-scale test for the future reduction of higher CS retention.

The laboratory, engineering, and pilot-scale tests indicate the potential for using CS to treat the crushed and screened pits at the BSM processing waste site. Based on the results of these feasibility tests, it appears that separate technical data are available to treatment processes with a large-scale demonstration of a branch at BSM.

3.0 PROCESS DESCRIPTION

The ISV process as applied to contaminated soil stabilization involves the insertion of electrodes into the soil, typically in a square array. A starter path for electrical current is established by using a small amount of a graphite and glass frit mixture placed between the electrodes on the soil surface. Dissipation of power through the starter material creates temperatures that are high enough to melt a layer of soil, thus establishing a molten, conductive path. This molten zone continues to grow downward and encompass the contaminated soil. Rocks (if present), which are less dense, can create a floating layer near the molten surface. The rocks are eventually incorporated into the molten mass.

Figure 3 illustrates the process sequence. At the high temperatures created (approximately 1300°C to 1600°C), organic materials pyrolyze, diffuse to the surface, and combust. This movement of gas through the melt may produce some porosity near the surface of the melt. Any off-gases from the process are collected, treated, and monitored to ensure their environmentally safe release. Remaining ash, along with other noncombustible material, dissolves or becomes encapsulated in the molten soil. Natural convective currents within the molten soil help to uniformly distribute the stabilized

FIGURE 3. Operating Sequence of In Situ Vittrification System

materials. The molten soil cools to a durable glass and crystalline waste form physically resembling natural obsidian.

The principles of the ISV operation are based on extensive joule-heated melter work performed at PNL for various nuclear immobilization projects (Buel et al. 1979). The joule-heated principle operates by internal resistance heating of the conductive material as an electrical current passes through the molten media. In ISV, the resistance decreases as the molten mass grows. To maintain a power level high enough (according to the formula $P=I^2R$) to continue melting more soil, the current must be increased. A power transformer with multiple voltage taps is used to provide the variable currents needed during ISV processing. As the melt progresses and resistance decreases, the lower voltage taps on the power transformer allow increased amperage to the melt, maintaining a high power level. The process will continue until heat losses from the melt approach the energy delivered to the molten soil via the electrodes, or until power is discontinued to the melt.

A hood over the vitrification zone is maintained under a slight negative pressure to contain any hazardous gases or particulates that may be released. The hood also provides support for the electrodes. The negative pressure on the hood is supplied by the off-gas treatment system, which scrubs and filters any potentially hazardous components from the off-gas stream.

4.0 DESCRIPTION OF THE PILOT-SCALE SYSTEM

The pilot-scale test system at ORNL used four electrodes having a 1.2-m separation, and consisted of a power-control, gas-scrubbing unit and an off-gas containment hood over the test site. A cutaway of the process trailer and off-gas hood is illustrated in Figure 4. Prior to the ORNL test, this system had been used on pilot-scale tests at the Hanford site.

4.1 POWER DELIVERY SYSTEM

The pilot-scale power system uses a Scott-Tee connection to transform a three-phase input to a balanced two-phase secondary load using diagonally opposed electrodes in a square pattern (Figure 5). The 500-kW power supply may be either voltage or current regulated. The alternating primary current is rated at 480 V, 600 A, 3 phase, and 60 Hz. The transformer has four separate voltage tap settings of 1000, 650, 430, and 250 V. Each voltage tap has a corresponding amperage rating of 250, 385, 580, and 1000 A per phase, respectively. The amount of three-phase input power delivered to the transformer is controlled by adjusting the conductive angle of the thyristor switches located in each of the three input lines. These switches, in conjunction with selectable taps on the transformer secondary, regulate the amount of power deliverable to both secondary phases. The Scott-Tee connection provides an even power distribution among the three primary phases when the molten zone approaches a uniform resistance load. During the test at ORNL, this power system proved effective in maintaining a balance load to the electrodes.

4.2 OFF-GAS CONTAINMENT AND ELECTRODES SUPPORT HOOD

The off-gas containment and electrode-support hood is constructed from seven panels of 20-gauge stainless steel bolted together. The hood is 3.1 m wide, 5.5 m long, and 0.9 m high. Four leveling supports are attached to the corners of the hood. The hood also has a port for viewing and providing access to the inside region of the hood. A central off-gas port allows direct coupling of the hood to the processing trailer and off-gas treatment

FIGURE 4. Cutaway View of the Pilot-Scale Process Trailer and Off-Gas Hood

FIGURE 5. Scott-Tee Electrical Connection for the Pilot-Scale ISV System

system. The hood is equipped with heat fins installed on the surfaces of panels to help dissipate radiant heat transferred from the partially molten surface during processing. The hood, designed to withstand a water vacuum of 18 cm, was sealed to the surface of the soil surrounding the molten zone by means of a flexible skirt of high-temperature-resistant, tightly woven fiber attached to the bottom of all side panels. The skirt extended approximately 0.6 m away from the hood to allow for a hood-to-ground seal when covered with a layer of soil. Electrical connections were made to the molybdenum electrodes protruding through the hood. The upper molybdenum electrodes were surrounded by electrically insulated sleeves that allowed adjustments of the electrode positions. The electrodes and busses were supported by insulators above the sleeves. The insulators were designed to withstand movement of the molten mass against the electrodes from convective currents and the gravitational and buoyant forces exerted on the electrodes. The electrodes consisted of 5.0-cm molybdenum rods surrounded by a 0.15-m graphite sleeve. The molybdenum rods were coated with a protective coating of MoSi_2 to prevent oxidation.

4.3 OFF-GAS TREATMENT SYSTEM

The off-gas treatment system is shown schematically in Figure 6. The off-gas passes through a venturi-ejector scrubber and separator, a Hydro-sonic^(a) scrubber, a separator, a condenser, another separator, a heater, two stages of HEPA filtration, and a blower. Liquid to the two wet scrubbers is supplied by two independent scrub recirculation tanks, each equipped with a pump and heat exchanger. The entire off-gas system is installed in a 13.7-m-long semitrailer to facilitate transportation (see Figure 4). All of the off-gas components except the second-stage HEPA filter and blower are housed within a removable containment module that has gloved access and is maintained under a slightly negative pressure to protect workers from potential contamination. Heat is removed from the off-gas by a closed-loop cooling system consisting of an air/liquid heat exchanger, a coolant storage tank, and a pump. A 1:1 mixture of water and ethylene glycol is pumped first from the storage tank through the shell side of the condenser and the two scrub-solution heat exchangers, and then through the air/liquid exchanger, where heat is removed from the coolant.

The venturi-ejector scrubber serves both as a quencher and high-energy scrubber. The second scrubber is a two-stage Hydro-Sonic scrubber (tandem nozzle scrubber) as illustrated in Figure 7. The first section condenses vapors, removes large particles, and initiates growth of the finer particles so that they are easily captured in the second stage. Particles are captured when the gas is mixed with fine water droplets produced by spraying water into the exhaust of the subsonic nozzle. Mixing and droplet growth continues down the length of the mixing tube. Large droplets containing the particles are then removed by a vane separator and drained back into the scrub tank. When operated at a differential pressure of 127 cm of water, the unit is designed to remove over 90% of all particles greater than 0.5 μm in diameter. Efficiency of removal increases with an increase in pressure differential.

(a) Hydro-Sonic scrubber is a product of Hydro Sonic Systems, Dallas, Texas.

FIGURE 6. Schematic Drawing of the Pilot-Scale ISV Off-Gas Treatment System

FIGURE 7. Tandem Nozzle Hydro-Sonic Scrubber (Hydro Sonic System, Dallas, Texas)

Additional water is removed from the gas system by a condenser having a heat exchanger area of 8.9 m^2 and a final separator. The gases are then reheated to approximately 25°C above the dew point in a 30 kW heater to prevent condensate carryover to the HEPA filters. The first stage of filtration consists of 61- x 61- x 29-cm HEPA filters in parallel. During operation, one filter is used and the other remains as a backup in case the operating filter becomes loaded. The primary filter can be replaced during operation. The second-stage HEPA filter acts as a backup in case a first-stage filter fails.

Additional water is removed from the gas system by a condenser having a heat exchanger area of 5.5 m² and a final separator. The gases are then released to approximately 25°C and the liquid is a 30 wt percent to 40 wt percent water solution. The first stage of filtration consists of 40 x 20 cm HEPA filters in parallel. During operation, one filter is used and the other remains as a backup in case the operating filter becomes loaded. The primary filter can be replaced during operation. The second-stage HEPA filter acts as a backup in case a first-stage filter

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5.0 TEST DESCRIPTIONS

This section describes the pilot-scale ISV testing of ORNL soil and limestone, the associated off-gas processing equipment, and the specific procedures and operations used to characterize the ORNL ISV waste form.

5.1 TEST PROCESS FOR ORNL ISV DEMONSTRATION

The pilot-scale ISV demonstration test conducted at ORNL was designed to address key differences between conditions during previous tests of the ISV technology and those anticipated for full-scale remediation of a contaminated site at ORNL. For example, the waste trenches at ORNL contain large quantities of ^{137}Cs that could volatilize at high temperatures and be carried into the process trailer with the off-gas, resulting in additional exposure to operators and producing excess wastes. Therefore, it was necessary that the retention factors of $>10,000$ for Cs (Cs in melted soil divided by Cs in off-gas) obtained in engineering-scale tests (Carter, Bates and Maupin 1987) be confirmed at a larger scale under field conditions. Also, the soils at ORNL are more structurally and chemically heterogenous than those used in previous tests at Hanford. The trench design, with a significant quantity of crushed limestone present, resulted in a bulk composition of the melt lower in silica and higher in calcium than previously studied compositions (Buel et al. 1987). Thus, the operational performance of the ISV technology, as well as the long-term durability of the resulting waste form, was addressed specifically for the ORNL site. Some of these issues were investigated during laboratory and engineering-scale test conditions at PNL during 1985 through 1986 (Carter, Bates and Maupin 1987). Evaluations of ISV technology on the pilot-scale test in actual soil at ORNL provide more reliable scale-up predictions.

Trench 7 (see Figure 1 and 2) was chosen as a model because of its size, inventory characteristics, and the fact that much characterization of the trench has already been accomplished (Olsen et al. 1983). To enable the pilot-scale ISV system to be used, a 3/8-scale model of trench 7 was constructed in a pristine (i.e., uncontaminated) portion of ORNL (see Figure 1).

The site, located on top of a ridge in the Maryville Limestone (an interlayered limestone-shale), was chosen for the similarity of its physical and geological characteristics to the area previously used for seepage disposal at ORNL (Figure 8). After preparation of the site (e.g., clearing, leveling, electrical service), the trench was constructed perpendicular to the strike of the bedding. The 9.2-m-long trench was 1 m wide at the top and tapered to 0.4 m at the bottom. A schematic cross section at the midpoint of the trench is shown in Figures 9, 10, and 11. The trench was constructed to a depth of 1.5 m, except for the central section, which was excavated to a depth of 2.5 m to allow for the placement of a vertical array of eight type-K thermocouples (one thermocouple at every 0.31 m depth) for monitoring the depth of the melt.

To simulate the contaminated sludge that is present in Trench 7, 526 kg of an 18 wt% Cs- and 82 wt% Sr-carbonate mixture was placed in the central portion of the trench within the square electrode array (Figure 12). These quantities of Cs and Sr were selected to yield a waste form with sufficient concentrations of Cs and Sr that their leach characteristics could be determined. The entire trench was then filled from the 0.6- to 1.5-m level with limestone. The upper 0.6 m of the trench was backfilled with original soil.

In addition to the array of thermocouples in the center of the trench, type-K thermocouples were placed at depths of 0.6 m, 1.2 m, and 1.5 m along both sides of the trench at distances of 2.1 m and 3.1 m from the center of the trench. Three type-R thermocouples, which have a higher maximum operating temperature than type-K thermocouples, were placed in a vertical array at the center of the trench at depths of 0.9, 1.5, and 2 m in an ultimately unsuccessful attempt to monitor melt temperatures. Moisture detection cells were placed in the trench at several locations but did not function properly and will not be discussed further.

The four molybdenum electrodes (5 cm diameter and 3.7 m long) were placed in graphite sleeves (15 cm O.D.) and placed 1.2 m apart in a square array of augured holes approximately 2.5 m deep. The off-gas hood was then placed over the trench and connected to the off-gas treatment system. The

FIGURE 8. Pilot-Scale Test Site Prior to Site Preparation

FIGURE 8. PILOT-SCALE TEST SITE PRIOR TO SITE PREPARATION

FIGURE 9. Central Cross Section of the Pilot-Scale ISV Demonstration Trench (approximate scale)

FIGURE 10. Predicted Shape of the Pilot-Scale ISV Mass (overlayed on the original trench dimensions)

FIGURE 11. Excavation of the 3/8-Scale Model of Trench 7

FIGURE 12. View of Chemical and Crushed Limestone as Placed in the 3/8-Scale Trench

electrodes were connected to the power delivery system. Run data (e.g., temperatures, off-gas flow rate and CO and CO₂ concentrations, electrical parameters) were recorded every 6 minutes and logged into a computerized data storage system. Off-gas scrub solution samples were collected approximately every 2 hours; duplicate samples were obtained for analysis at both PNL and ORNL.

The ISV test was scheduled to begin on June 26, 1987, but transformer circuitry malfunctions resulted in delay. The manufacturer repaired and tested the transformers and the ISV test was restarted on July 14, 1987. The test ran continuously for 110 h until power was shut off on July 19. Soil temperatures and manual probing of the melt zone with a steel rod confirmed that the desired depth of melting (approximately 2.1 m) had been reached. During the 110 h of continuous operation, one equipment failure occurred. At 5 h into the test the pump to the venturi scrubber was shut down because of a leak in the pump surge tank, thus requiring the Hydro-Sonic scrubber to perform all the off-gas stream scrubbing. The single scrubber has proven effective in this performance (Timmerman and Oma 1984) and was actually designed to handle such an occurrence.

Table 2 shows predicted and actual operating data obtained from the ISV/ORNL pilot-scale test. Predicted data is based on a mathematical model developed for ISV (Buel et al. 1987). In reviewing the data, note the differences when comparing the actual test results to the model predictions. The computer model bases the prediction on the production of a square, symmetrical melt area and does not account for the vitrification down the length of the trench that was observed during the ORNL test (see Figure 10).

A description of the vitrified mass as observed after hood removal, during core drilling, and as the mass was later exposed for mass sampling is given below:

- Subsidence from the surface was 0.91 m (36 in.), giving a volume reduction of 43%.
- Two cold cap surfaces were observed. The top cold cap surface was at a depth 0.41 m (16 in.) from the soil surface, and the second

TABLE 2. Predicted and Actual Data Obtained from ISV/ORNL Pilot-Scale Test

	Predicted	Actual
Run Time, h	54.6	110
Melt Depth, m	2.19	2.13
Melt Width, m	2.57	---(a)
Melt Length, m	---(b)	3.8 to 5.34
ISV Mass, 1000 kg	16.3	22.9 ^(c)
Average Power, kW	309	263
Energy, 1000 kWh	16.9	28.9
Energy/Mass, kWh/kg	1.04	1.26

- (a) Actual width measurements of the vitrified mass were not taken because the vitrified mass was not completely exhumed.
- (b) Model actually predicts a symmetrical block of equal width and length.
- (c) The ISV mass is a calculated number from the Cs retention quantities. The vitrified mass was not exhumed to obtain actual weights or measurements. The calculation is $\frac{\text{Cs addition to test site}}{\text{Cs wt\% of vitrified mass}}$.

was the melt surface at a depth of 0.91 m. The top cold cap thickness was up to 5.0 cm (2 in.) and had little structural strength. Because the cold caps had little structural strength and would collapse during backfilling, there would be no concerns for future subsidence over the trench.

- The side walls of the subsided surfaces were vertical, with a thickness of 1.3 cm (1/2 in.). The surface that traversed the length of the trench had void surfaces between the replaced ORNL soil and the area filled with limestone. As noted in the engineering-scale test, sloughing of the crushed limestone material could occur during the pilot-scale test. Because of the information on sloughing obtained during the engineering-scale test, the hood for the pilot-scale test was lengthened to accommodate potential sloughing.

- The surface of the melt zone was very smooth at first observation, but core drilling revealed a porous area containing very small bubbles to a depth of 6.4 to 7.5 cm (2.5 to 3 in.).
- The soil around the exhumed section of the vitrified mass had changed to a red rusty color, as seen in earlier tests. This indicated a ferrous-to-ferric ratio change due to oxidation at temperatures between 200°C and 300°C but had no effect on the processing behavior.
- The vitrified mass contained a gray crystalline material with the largest concentration of the gray material between the electrodes. This gray crystalline material is explained in detail in the Devitrification Section of this report.

5.2 PROCESS EQUIPMENT EVALUATION AND PERFORMANCE

This section evaluates the electrical system and the performance of the process scrubber system.

5.2.1 Electrical System

The electrical data obtained from the pilot-scale test are shown in Figure 13, which gives A-phase and B-phase volts versus run time, and Figure 14, which gives A-phase and B-phase amps versus run time. Figure 15 shows total power (kilowatts) versus run time, while Figure 16 shows cumulative energy (megawatt-hours) versus run time. These curves show typical ISV electrical system operation where the voltage decreases, with melt growth and corresponding lower resistivity, requiring higher amperage to maintain constant power. Figure 17 shows the depth of the vitrified mass during the processing period derived from thermocouples imbedded in the trench. As the molten glass approaches a thermocouple, the soil temperature increases to 100°C and remains as the moisture is driven off. The temperature rapidly increases off-scale as the molten glass reaches the thermocouple.

FIGURE 13. A-Phase and B-Phase Voltage Versus Run Time

FIGURE 14. A-Phase and B-Phase Amperages Versus Run Time

FIGURE 15. Total Power (kilowatts) Versus Run Time

FIGURE 16. Cumulative Energy (megawatt-hours) Versus Run Time

FIGURE 17. Temperature and Vitrified Mass Depth Versus Run Time

After one false start on June 26, 1987 (a result of a transformer circuitry malfunction) power was continuously applied to the electrodes for 110 h starting July 14, 1987. The voltage applied to the transformer was manually controlled for this operating period.

The electrodes performed acceptably during the entire demonstration. At the completion of demonstration the upper sections of the electrodes were removed from the melt interface surface and inspected. The sacrificial graphite sleeves placed over the molybdenum electrodes oxidized in two locations on the four electrodes. The electrode oxidation occurred at the locations of the two subsided areas described in Section 5.1. No oxidation of the molybdenum electrode was observed on any of the four electrodes. Oxidation of the molybdenum was prevented by the molybdenum disilicide/zirconium diboride electrically conductive powder placed in the annulus between the molybdenum electrodes and the graphite sleeves. Where the graphite sleeves oxidized away, the conductive powder formed a sintered coating that protected the molybdenum electrode surfaces.

5.2.2 Process Off-Gas System

The process off-gas system operated as designed for the demonstration test. One piece of equipment failed during the processing period. This failure occurred within the pump pressure tank that supplies scrub solutions to the venturi scrubber. The venturi scrubber is at the front end of the process off-gas system and is used to remove large off-gas particles entering the scrub system, and to reduce the off-gas temperature. The process off-gas system is designed for continuous operations, even when processing radionuclides, if specific equipment such as the venturi scrubber pump fails. Particulate removal by the hydro-sonic scrubber while the venturi scrubber is inoperative is sufficient to prevent loading of the HEPA filters.

Table 3 shows the accumulation of particulate in the process scrub solutions. Because of the design of the processing tanks, large quantities of particulate are transferred from the tank bottoms (particulate not in suspension) during each transfer. The total particulate accumulated was verified by the quantities accumulated and analyzed by ORNL in the waste drums generated during the ISV test. No particulate sizing analysis was performed during the ISV test. Sizing data from previous pilot-scale radioactive tests indicate that mass loading of entrained particles downstream of the hydro-sonic scrubber averaged 0.8 mg/m^3 . The mass mean particle diameter averaged less than $0.5 \text{ }\mu\text{m}$, the approximate lower limit of the hydro-sonic scrubber (Oma and Timmerman 1984).

Evaluation of the pilot-scale processing equipment showed the accumulations and quantities of Cs and Sr in the following process locations. (See Appendices A and B, respectively, for sample calculations and sample concentrations. Appendix E describes the analytical procedures that were used.)

• Off-gas hood	Cs - 0.02 g
	Sr - 0.01 g
• Off-gas line	Cs - 0.10 g
	Sr - 0.0013 g
• Process scrub solutions	Cs - 69.534 g
	Sr - 0.133 g

TABLE 3. Particulate Accumulation in Scrub Solutions

Run Hours	Tank Volume (L)	Tank Transfer (L)	Solids (mg/L)	Total (g)	Transfer Out (g)	Cumulative (g)
0	139	0	1837	254.6	0.0	254.6
23.5	319	51	29400	9378.6	1499.4	9378.6
25.5	316	31	24100	7615.6	747.1	9115.0
30.2	307	0	21700	6661.9	0.0	8908.4
35.5	326	48	16500	5379.0	792.0	7625.5
39.5	324	30	10600	3434.4	318.0	6472.9
43.5	323	27	8070	2606.6	217.9	5963.1
45.3	304	0	6280	1909.1	0.0	5483.1
49.5	374	23	5080	1645.9	116.8	5220.3
55.5	326	32	3610	1176.9	115.5	4868.0
57.5	305	0	3290	1003.5	0.0	4608.1
61.4	322	33	2630	846.9	86.8	4653.6
63.5	308	0	2320	714.6	0.0	4810.2
67.5	333	19	1900	632.7	36.1	4526.2
69.5	327	18	1710	559.2	30.8	4488.8
71.8	310	9	1440	446.4	13.0	4406.8
73.4	315	15	1390	437.9	20.9	4411.2
75.4	300	0	1100	330.0	0.0	4324.2
77.5	305	0	1220	372.1	0.0	4366.3
81.4	331	28	1170	387.3	32.8	4381.5
85.5	333	30	1030	343.0	30.9	4369.9
87.5	323	35	1040	335.9	36.4	4393.8
89.5	307	0	701	215.7	0.0	4309.4
93.5	357	48	907	323.8	43.5	4418.0
95.6	322	39	805	259.2	31.4	4397.0
97.5	305	0	853	260.7	0.0	4429.3
99.6	307	0	762	233.9	0.0	4403.1
103.5	326	0	849	276.8	0.0	4445.9
107.5	314	0	11900	3736.6	0.0	7905.8
110.5	324	283	11600	3758.4	3282.8	7927.6
FLUSH	332	304	12200	4050.4	3708.8	11502.4
FLUSH	381	277	12600	4800.6	4750.2	15961.4
				0.0	15911.0	15911.0

- Process scrub solutions transferred out Cs - 63.51 g (These quantities
Sr - 0.166 g are verification of
the process scrub
solution)
- Process Primary HEPA filter Cs - 2.32 g
Sr - 0.003 g
- Process Final HEPA Filter Cs - <0.001 g
Sr - <0.001 g

The following quantities of Cs and Sr were placed in the soil at the ORNL test site prior to vitrification (see Appendix A for Calculations):

$\text{Cs}_2\text{CO}_3 = 89,892 \text{ g}$
expressed as Cs = 73,274 g

$\text{SrCO}_3 = 408,600 \text{ g}$
expressed as Sr = 236,931 g

Using those quantities, the following DF and percent retention were determined:

Cs DF = 1.018 E+3
Cs retention = 99.90%

Sr DF = 1.394 E+6
Sr retention = 99.9999%

Figure 18 shows the rate of total Cs accumulation in the process scrub tank solution as compared to the processing depth of the vitrified mass. The rate of Sr is not shown because of its high retention in the vitrified mass and hence its low concentration, and because of its near background level in the scrub solution samples.

Distribution of the Cs and Sr through the off-gas system provides data on the operational procedural requirements, projected results, and scrub

FIGURE 18. Total Cs Accumulation in Scrub Solution Versus Vitriified Mass Depth

efficiencies (Figure 19). The scrub system accounted for removal of 96% of cesium and 92% of Sr of the total release from the melt zone. The primary HEPA filter collected 3.5% of the Cs and 1.7% of the Sr. The final HEPA filter had less than detectable levels of both Cs and Sr. The remaining 0.5% is accounted for in the off-gas hood and off-gas line. These quantities compare closely with those previously reported for pilot-scale radioactive tests (Timmerman and Oma 1984). The venturi scrubber pump failure had no effect on process efficiency or system accumulations.

Other information that is not critical to operations calculation but would be useful for future design considerations is shown in Appendix C, Figures C.1 through C.6.

5.3 MATERIAL CHARACTERIZATION STUDIES

The objective of this evaluation was to characterize the composition and phase behavior properties of the ORNL ISV waste form. Because the primary duty of the ISV waste form is to contain the waste components, the waste form's durability is of prime importance and will also be described.

FIGURE 19. Distribution of Cs and Sr Released from Melt Zone (a) scrub solution sample quantities; (b) transferred scrub solution sample quantities

5.3.1 Product Characterization

Samples were received from cores 2 through 6 taken from the ISV monolith. The relative position of the cores with respect to the electrodes is shown in Figures 20 and 21. Visual observation of these samples found a frothy, vitreous area at the top of the cores, with the bulk of the core consisting of glass, a gray crystalline (rock) material, or a mixture of both glass and crystalline material. Some soil or calcined soil was also observed at the bottom of some of the deeper cores. Core 2, which was taken from near the center of the ISV monolith, was comprised almost entirely of the crystalline material. In contrast, core 4 consisted almost completely of glass. The remaining cores consisted of a mixture of both phases. Additional grab samples were received after the monolith was exposed by excavation. The relative positions of the grab samples are shown in Figure 22.

Four representative samples were selected for detailed evaluation. Because core 3 was typical of most of the other cores and represented all of the observed phases, three samples from this core were chosen for detailed

FIGURE 20. View of Vitrified Mass After Excavation and Sampling

FIGURE 21. Relative Positions of Core Samples Taken from ORNL ISV Monolith

evaluation. These three samples consisted of a sample of the frothy glass from the surface of the monolith (sample #230), the gray crystalline material (sample #233), and a mixture of glass and crystalline material (sample #232). Because the outer region and the major bulk of the ISV monolith was primarily glass, the vitreous phase of the monolith was also evaluated. A sample from core 4 was also chosen for detailed evaluation of the vitreous phase (sample #231). Table 4 describes the location from which these samples were taken.

5.3.1.1 Sample Composition

Elemental analysis of the four samples was conducted by inductively coupled plasma (ICP) analysis. After digestion samples were analyzed for Cs

FIGURE 22. Position of Grab Samples Taken from the ISV Monolith (Samples Obtained after Excavation)

by atomic adsorption (AA). The oxide compositions of the four samples are presented in Table 5, along with the compositions of the original soil and limestone from the pilot-scale test area. A reference analysis from the engineering-scale test is also provided in Table 5. The composition of all the samples, both crystalline and glass phases, was essentially equal,

TABLE 4. Location of Samples Chosen for Detailed Evaluation

Sample #	Core	Position in Core	Description of Sample
230	3	0-37", top crust	Frothy, foamed vitreous layer found on the top surface of the monolith
231	4	13-31", top	Glass phase only
232	3	0-37", upper middle	Glass with ~5% crystalline material
233	3	0-37", bottom	Crystalline phase only
236	3	37-52", middle	Crystalline nodules
240	3	37-52', middle	Glass phase only

TABLE 5. Oxide Compositions for ORNL ISV Pilot-Scale Test Samples. Values are averages of unnormalized ICP analysis given as oxide weight-percent

	Pilot-Scale Test					Engineering-Scale Product	
Oxides	230	231	232	233	Original Soil	Lime-stone	
Al ₂ O ₃	12.8	13.1	13.2	13.2	18.3	0.97	14.7
BaO	0.074	0.077	0.078	0.077	0.063		0.10
CaO	17.2	18.6	18.7	18.7	3.09	87.3	15.0
Cs ₂ O	0.33	0.34	0.34	0.37			1.35
Fe ₂ O ₃	4.30	4.41	4.46	4.52	6.32	1.37	4.14
K ₂ O	2.36	2.66	2.34	2.86	2.7		2.28
MgO	2.02	2.15	2.16	2.16	1.83	6.8	10.9
MnO ₂	0.14	0.14	0.14	0.15	0.12	0.39	0.14
Na ₂ O	1.50	1.38	1.47	1.74	0.77	0.65	0.93
SiO ₂	51.8	51.5	52.0	52.4	63.1	2.95	45.4
SrO	1.30	1.40	1.40	1.39	0.13	0.05	4.17
TiO ₂	0.58	0.60	0.60	0.60	0.83		0.64
ZrO ₂	0.029	0.043	0.035	0.046			0.035
Total	94.5	96.2	96.9	98.2	92.3	100.5	99.8

indicating that the monolith was at one time a relatively homogeneous melt and the gray crystalline material resulted from devitrification of the glass upon cooling. This hypothesis is supported by the increased amount of crystalline phase near the center of the monolith where the cooling rate would have been the slowest. Cesium and strontium levels in all samples, both glass and crystalline rock, were essentially the same--0.35 wt% Cs_2O and 1.4 wt% SrO as analyzed by ICP/AA.

To evaluate the distribution of Cs and Sr throughout the monolith, all the samples were semi-quantitatively analyzed by XRF for Cs and Sr. Spiked standards analyzed with the samples indicated levels of approximately 0.3 to 0.5 wt% Cs_2O and 1.5 wt% SrO in the ISV monolith, confirming the values obtained from ICP/AA analysis. The XRF results indicated that the Sr was very uniformly distributed throughout the monolith. XRF results for Cs varied by as much as 50% between the cores, but generally Cs was evenly dispersed throughout the monolith. The variations in Cs may have been due to the low level of Cs in the product and analytical uncertainties. Little variation was observed vertically in any of the cores. The grab samples taken from each end of the monolith (see Figure 22) contained the same levels of both Cs and Sr as did the core samples from the middle.

The very bottom samples of several cores were unreacted soil, which revealed no detectable levels of Cs and Sr (same as for the reference soil and limestone samples). This would indicate that the ISV process contains the Cs and Sr within the vitrified mass and does not induce any migration of these elements down into the nearby soil. However, in one sample near the bottom of core 3, the Sr level was observed to reach background levels before the Cs level. This sample was material that had sintered and only partially melted. The unreacted soil samples taken just below the partially melted samples had only background levels of Cs and Sr. The greater solubility of Cs compounds as compared to Sr could have allowed the Cs to be washed farther into the soil from the chemical addition before the test or from the core drilling after the test.

To determine the soil-to-limestone ratio of the vitrified mass, five major elements were identified from the mass analysis. The five elements were SiO_2 , MgO , Fe_2O_3 , CaO , and Al_2O_3 . Examination of the concentrations of

these elements revealed that weight percent concentration of soil and limestone in the pilot-scale test are 20% limestone and 80% soil (see Appendix A for calculations.)

5.3.1.2 Phase Behavior

The structure of the waste form was evaluated by x-ray diffraction (XRD) and scanning electron microscopy with energy dispersive analysis by x-ray (SEM/EDAX).

The vitreous samples submitted for XRD analysis exhibited no peaks, as expected. All the crystalline samples exhibited the same XRD pattern as shown in Figure 23. This pattern was quite complex and was the sum of more than one crystalline phase. In addition, substitutions of minor elements into the crystalline phases have likely offset the peaks, making precise identification difficult. However, it appears that the crystalline material consists predominately of anorthite (feldspar, $\text{CaO-Al}_2\text{O}_3\text{-SiO}_2$) and a wollastonite-like phase (CaO-SiO_2), which is consistent with the phase diagram of the $\text{CaO-Al}_2\text{O}_3\text{-SiO}_2$ system (Levin, Robins and McMurdie 1964). The XRD patterns for anorthite and a wollastonite are also presented in Figure 23 for comparison.

SEM/EDAX was conducted on thin sections of the four major samples to identify the different phases present. Thin sections of the glass samples found the glass to be homogeneous, with no detectable non-vitreous phases. The frothy glass layer found on the top surface of the monolith was also observed to be vitreous. X-ray mapping of Cs in the glass samples found the Cs did not segregate and was uniformly dispersed throughout the glass. Because the levels of Cs in the samples were near the detection limits, the x-ray mapping can only indicate that no concentrations of Cs occurred. X-ray mapping of Sr was not possible due to overlap of the Sr peak by a very strong silicon peak.

The samples consisting of gray crystalline material were observed to be similar in morphology. A typical cross section is presented in Figure 24. The microstructure is represented by alternate layers of the three crystalline phases (lamellar) typically found when an eutectic composition cools.

FIGURE 23. X-Ray Diffractometry Results of Gray Crystalline Material from Pilot-Scale ORNL ISV Test

SiO_2 , CaO , and Al_2O_3 are the major components of ISV product. If only these three components are considered, the normalized composition of the ORNL ISV product is 62 wt% SiO_2 , 22.2 wt% CaO , and 15.7 wt% Al_2O_3 . This normalized composition was very near a low melting eutectic and may account for the microstructure of the crystalline phase (Osborn and Muan 1960). A cross section of one of the gray crystalline nodules found the crystal size to decrease from approximately 5 μm thick at the center to less than 0.5 μm at the outer surface of the nodule.

FIGURE 24. Typical Microstructure of Gray Crystalline Material from Pilot-Scale ORNL ISV Test

The EDAX scans of the three phases are presented in Figures 25 through 27. The lighter phase (see Figure 24 and 25, phase A) had approximately equal amounts of Ca and Si with some Mg and Fe present, but little Al or K. This phase is probably pseudowollastonite (CaO-SiO_2).

The two darker phases shown previously (see Figure 24) have lower Ca/Si ratios than the pseudowollastonite phase but increased amounts of Al and K. Both darker phases had feldspar-type compositions. The lighter of the darker phases is probably a solid-solution of an anorthite phase (see Figure 24 and 26, phase B). The darker phase was similar to the anorthite phase but with increased amounts of K and Fe, and reduced amounts of Al and Na (see Figure 24 and 27, phase C).

X-ray mapping of Cs in the gray crystalline phase indicated that even after devitrification, the Cs did not concentrate significantly in any one phase. Figure 28 shows an area of crystalline product and the x-ray mapping of the Cs over the same area. The Cs show no segregation within any of the phases present.

FIGURE 25. EDAX Spectra of Phases A in Figure 24

FIGURE 26. EDAX Spectra of Phases B in Figure 24

FIGURE 27. EDAX Spectra of Phases C in Figure 24

FIGURE 28. X-Ray Cesium Mapping of Typical Microstructure of Gray Crystalline Material from Pilot-Scale ORNL ISV Test

5.3.2 Chemical Durability of Product

The durability of the glasses was evaluated using four types of tests: MCC-1 (Mendel 1984), MCC-3 (Mendel 1984), a modified MCC-3 (MCC-3mod; Bunnell, Maupin and Oma 1987), and the Extraction Procedure (EP) toxicity test (U.S. EPA 1986). To allow the direct comparison of data, the leachate, temperature, and surface area/volume (SA/V) used in testing the ISV waste form were identical to those parameters used to test high-level nuclear borosilicate glasses. The differences in application (repository conditions, groundwater, temperature, etc.) and the nature of the waste form (multiphased ceramic glass versus single-phased glass) makes such comparison difficult. Most high-level nuclear waste glasses are tested at 90°C. By conducting the leach testing of the ORNL ISV waste form at 90°C, the results can be compared to the data base of leaching data on the high-level glasses. Leachants were analyzed for cation content only.

To allow the comparison of leach tests results from waste forms with different compositions, the results are given in terms of normalized elemental mass release for the MCC-1 and MCC-3 test and normalized concentration for the modified MCC-3 test. Normalized elemental mass releases were calculated with the following equation:

$$NR_i = m_i / (F_i \times SA)$$

where NR_i = normalized mass release of element i (g/m^2)

m_i = mass of element i in leachate (g)

F_i = fraction of element i in glass (dimensionless)

SA = surface area of monolith or powder (m^2)

The following equation was used to calculate normalized elemental concentrations:

$$NC_i = C_i / (F_i)$$

where NC_i = normalized concentration of element i (g/m^3)
 C_i = concentration of element i in leachate (g/m^3)
 F_i = fraction of element i in glass (dimensionless)

5.3.2.1 MCC-1 Tests

The MCC-1 static leach test (Mendel 1984) measures the elemental mass loss of a sample of glass as a function of time. For this type of test a glass monolith is suspended within a sealed TeflonTM container. The surface-area-to-volume ratio (surface area of sample/volume of leachant, SA/V) is selected, nominally 10m^{-1} . The leachant can be a synthetic silicate ground water, a synthetic brine, or reagent water. The sealed container is maintained at 90°C for 3, 7, 14, or 28 days. The test results are based on leachate ICP analysis (AA for Cs) from which the total concentrations of materials removed from the sample are determined. For this evaluation, testing was conducted with an SA/V of 10m^{-1} in deionized water (DIW) at 90°C for 28 days.

Because the MCC-1 procedure requires a small monolith of sample, test samples consisted of only the glass or crystalline phase. Testing was conducted on sample numbers 230, 231, 232 (glass phase only), and 233 (crystalline phase). The results from the MCC-1 leaching tests are presented in Table 6. Leaching data from two high-level nuclear waste glasses are also presented for comparison. Raw ICP data for MCC-1 are presented in Appendix D.

For the glass samples (230, 231, and 232) normalized releases for each element did not vary significantly, suggesting that the dissolution of the waste form is congruent. The normalized releases for the crystalline samples varied slightly, indicating that some incongruent dissolution occurred. However, the crystalline phase (sample 233) appears to be more durable than the glass phase (samples 230, 231, or 232), as the normalized releases from the

TM Teflon is a tradename of the E. I. du Pont de Nemours and Company.

TABLE 6. Comparison of Normalized Release from MCC-1 Leach Testing for ORNL Pilot-Scale ISV Products and Some High-Level Nuclear Waste Glasses^(a)

Element	Normalized Elemental Release (g/m ²)					
	230	231	232	233	76-68 ^(b)	SRL165 ^(c)
Al	5.9	6.0	5.6	2.8	--	12
Ca	6.9	6.5	6.3	3.8	3.0	--
Si	6.3	6.5	6.2	4.8	26	15
Sr	7.5	7.2	6.9	1.7	3.8	1.7
Cs	9.0	9.0	8.7	8.5	14.7	18
(pH)	(9.3)	(9.2)	(9.1)	(9.1)	--	--

(a) Conditions: MCC-1 in DIW, 28 days, SA/V = 10⁻¹, 90°C.

(b) Kindle, C. H. and M. R. Kreiter. 1987. Comprehensive Data Base of High-Level Nuclear Waste Glasses - September 1987 Status Report. Volume 1 - Discussion and Glass Durability Data. PNL-6353 Vol 1, Pacific Northwest Laboratory, Richland, Washington.

(c) Chandler, G. T., G. G. Wicks, and R. M. Wallace. 1984. Chemical Durability of SRP Waste Glass - Saturation Effects and Influence of SA/V. DP-MS-84-37, E. I. du Pont de Nemours & Co., Savannah River Plant, Aiken, South Carolina.

crystalline sample were lower than those of the glass samples. The normalized releases for the ISV product were very comparable to those of the high-level nuclear waste glasses.

5.3.2.2 MCC-3 Tests

The MCC-3 agitated powder leach test (Mendel 1984) is very similar to the MCC-1 test procedure, with two exceptions: the glass is in a powdered form, and glass powder and leachant are agitated by rotating the Teflon container in which the sample is suspended. The elemental leachate concentrations from MCC-3 tests are estimated to be representative of long-term extrapolation of MCC-1 test results. The MCC-3 tests also define maximum upper concentration limits under closed system static conditions. These objectives can be achieved more rapidly in the MCC-3 test because higher surface-area-to-volume ratios are used than those used for the MCC-1 tests.

For this evaluation, tests were conducted with an SA/V of 2000 m^{-1} in DIW at 90°C for 28 days. Minus 100 mesh + 200 mesh glass powder was used for all tests. Because of the higher SA/V used in the MCC-3 testing compared to that used for MCC-1 testing (2000 m^{-1} and 10 m^{-1} , respectively), the leachants in the MCC-3 tests became saturated much sooner than the leachants in the MCC-1 tests. This saturation slows the dissolution process. Therefore, direct comparison of normalized release values from the MCC-1 and MCC-3 tests are not appropriate.

Because a powdered sample is used for the MCC-3 tests, a combination of glass and gray crystalline material was also tested. A 50/50 wt% mixture of sample 236 (crystalline nodules) and 240 (glass) was used (see Table 4). All tests were run in duplicate.

The results from the MCC-3 leach tests are presented in Tables 7 and 8. MCC-3 leachants were filtered through $0.45\text{-}\mu\text{m}$ filters, then 18-angstrom filters, to determine the amount of colloidal material in the leachant. ICP results, standard deviations, and percent relative standard deviations are presented in Appendix D. The same trends observed in the MCC-1 test results

TABLE 7. Comparison of Average Normalized Releases from MCC-3 Leach Testing: $0.45\text{-}\mu\text{m}$ Filtrate for ORNL Pilot-Scale ISV Products and Some High-Level Nuclear Waste Glasses(a)

Element	0.45- μm Normalized Elemental Release (g/m^2)					
	230P	231P	232P	233P	236/240	SRL165
Al	0.019	0.020	0.019	0.014	0.018	0.27
Ca	0.058	0.048	0.041	0.032	0.037	0.07
Si	0.039	0.039	0.038	0.040	0.039	0.32
Sr	0.046	0.039	0.036	0.020	0.026	0.05
Cs	0.097	0.073	0.072	0.147	0.143	--
(pH)	(9.4)	(9.4)	(9.6)	(9.5)	(9.5)	--

(a) Conditions: MCC-3 in DIW, 28 days, SA/V = 2000 m^{-1} , 90°C , 2 replicates.

TABLE 8. Comparison of Average Normalized Releases from MCC-3 Leach Testing: 18-Angstrom Filtrate for ORNL Pilot-Scale ISV Products and Some High-Level Nuclear Waste Glasses(a)

Element	18A Normalized Elemental Release (g/m ²)					
	230P	231P	232P	233P	236/240	SRL165
Al	0.018	0.019	0.018	0.013	0.017	0.10
Ca	0.054	0.039	0.038	0.029	0.033	0.02
Si	0.038	0.038	0.037	0.039	0.038	0.26
Sr	0.042	0.033	0.032	0.017	0.022	>0.01
Cs	0.085	0.070	0.070	0.140	0.123	----

(a) Conditions: MCC-3 in DIW, 28 days, SA/V = 2000 m⁻¹, 90°C, 2 replicates

were apparent in the MCC-3 test results. The releases from the combined glass-crystalline sample were between the glass-only and crystalline-only samples, suggesting that no interactions occurred during leaching. The waste form from the ISV test, both glass and crystalline, had releases approximately half to 10 times lower than those for the SRL-165.

5.3.2.3 Modified MCC-3 Tests

To assess the glass durability over a wider range of conditions, the modified MCC-3 leach tests (Bunnell, Maupin, and Oma 1987) were conducted in the three regimes typically observed in glass dissolution: 1) the time the glass first contacts a leachate and the glass dissolution rate is uninhibited by any solubility effects (the initial or forward rate), 2) a transient regime where the increasing concentrations of dissolved glass components in the leachate slows the dissolution rate through solubility effects, and 3) a final constant dissolution rate where alteration processes (saturation) have reached a steady rate. Because the ISV waste form will be in a near-surface environment where water flow rates will probably be relatively high, saturation of the water probably will not occur and the forward rate of dissolution will be most important.

The modified MCC-3 procedure was used to evaluate the relative chemical durability of various glass samples over a wide range of SA/V•time conditions, including the forward rate of dissolution. Testing was conducted at

surface area/leachant volumes (SA/V) of 50, 2000, and 10000 m^{-1} . To simulate high flow-rate conditions, a static dissolution test was conducted in which 1 g of -100 + 200 mesh glass powder was added to 400 mL of DIW and placed in a 90°C oven. This procedure provided the desired SA/V ratio of 50 m^{-1} . At specified time intervals, a 5-mL sample of leachate will be removed and replaced with fresh DIW. Using this technique, multiple leachate samples were extracted from a single dissolution test. Six samples were taken from each SA/V test. The tests using SA/V of 2000 m^{-1} and 10000 m^{-1} were similarly conducted, with the amount of sample and DIW adjusted accordingly. For 2000 m^{-1} , 7 g of powder were added to 70 mL of DIW. For 10000 m^{-1} , 10 gr powder were added to 20 mL of DIW. Minus 100 + 200 mesh powder was used for all tests.

The modified MCC-3 test is also being used to evaluate obsidian, which is the natural analog to the ISV waste form. Comparing the release characteristics for the ORNL ISV waste form with those for obsidian may be helpful in qualifying the ISV waste form. The results from the natural analog tests will be available later this year.

The results from the modified MCC-3 tests are plotted as a log/log plot of normalized elemental concentration as a function of (time•SA/V). Note that on a log/log plot, lines having unit slope represent constant rate. The Y-intercept (at $\log(\text{time} \cdot \text{SA/V}) = 0$) of a line having unit slope, and going through any point on the functional curve, will represent the average functional rate at that point. The results from the modified MCC-3 tests for each sample are presented in Figures 29 through 32. The error bars (plotted only for Si) in Figure 30 indicate ± 2 standard deviations. In each plot, the normalized concentrations at low saturation (smaller values of $[t \cdot \text{SA/V}]$) follow a unit slope. The intersection of that unit slope with the Y-intercept define the forward dissolution rate for each sample. Dissolution at the forward rate appears to be congruent. As $t \cdot \text{SA/V}$ increases, the dissolution rate begins to slow as solubility becomes a factor. As $t \cdot \text{SA/V}$ increase further, the elements with low solubilities begin to precipitate. This was the reason for the higher values of the more soluble Cs when compared to the other components plotted at higher $t \cdot \text{SA/V}$'s. ICP data and results for modified MCC-3 tests are presented in Appendix D.

FIGURE 29. Normalized Elemental Concentrations (in leachate) Versus $(t \cdot \text{SA}/V)$ for ORNL Pilot-Scale ISV sample 230

FIGURE 30. Average Normalized Elemental Concentrations (in leachate) Versus $(t \cdot \text{SA}/V)$ for ORNL Pilot-Scale ISV Sample 231

FIGURE 31. Normalized Elemental Concentrations (in leachate) Versus $(t \cdot \text{SA}/V)$ for ORNL Pilot-Scale ISV Sample 232

FIGURE 32. Normalized Elemental Concentrations (in leachate) Versus $(t \cdot \text{SA}/V)$ for ORNL Pilot-Scale ISV Sample 233

In Figure 33, the normalized Si concentrations for each of the four tested samples are compared. The dissolution behavior of each sample was very similar. No major differences exist between the glass or crystalline samples. Plotting the combined unit slope back to the y-intercept, a forward dissolution rate of approximately $0.4 \text{ g}/(\text{m}^2 \cdot \text{days})$ can be established for the ORNL ISV waste form. This rate is about two times less than the approximate forward reaction rate of the SRL-165 at $0.8 \text{ g}/(\text{m}^2 \cdot \text{days})$, and four times lower than PNL 76-68 at $1.6 \text{ g}/(\text{m}^2 \cdot \text{days})$ (Bunnell, Maupin, and Oma 1987). Because ambient storage temperature of the ISV waste form will be nearer 20°C , the forward rate would decrease further by approximately one to two orders of magnitude due to the temperature reduction.

5.3.3.4 Extraction Procedure (EP) Toxicity Tests

Extraction procedure toxicity tests (U.S. EPA 1986) were conducted to compare the durability of the ORNL ISV waste form to a currently established release requirement. The EP toxicity test is designed to evaluate the

FIGURE 33. Normalized Silicon Concentrations (in leachate) Versus $(t \cdot SA/V)$ for ORNL Pilot-Scale ISV Samples and ORNL Engineering-Scale Sample

extraction toxicity of a waste form. The testing consists of extracting 100 g of the waste form with 1600 g of DIW. Acetic acid is used to maintain the DIW at a pH of 5 ± 0.2 . The duration of the EP toxicity test was 24 hours. The extract was then analyzed by ICP or AA (Hg and Ag). EP toxicity maximum concentration limits that have been established for some elements are presented in Table 9.

Barium is the only detectable element in the ORNL pilot-scale ISV product for which maximum concentrations limits have been set. The limit for barium is 100.0 mg/L, and the highest concentration detected for any of the samples tested was 0.044 mg/L. Unless the concentrations of any of the elements listed in Table 8 increase substantially in the ISV soil or limestone, the ISV waste form should easily meet any EP toxicity requirements.

TABLE 9. Results from EP Toxicity Testing of the Pilot-Scale ISV Test at ORNL

Contaminant	Sample Numbers				Maximum Concentration Allowed (mg/L)
	230	231	232	233	
Arsenic	<1	<1	<1	<1	5.0
Barium	0.015	0.012	0.016	0.044	100.0
Cadmium	<0.005	<0.005	<0.005	<0.005	1.0
Chromium	<0.02	<0.02	<0.02	<0.02	5.0
Lead	<0.05	<0.05	<0.05	<0.05	5.0
Mercury	<0.001	<0.001	<0.001	<0.001	0.2
Selenium	<1	<1	<1	<1	1.9
Silver	<0.1	<0.1	<0.1	<0.1	5.0

...the testing consists of extracting ...
 100 g of the waste form with 100 ml of water ...
 the limit of 2 x 0.5. The ...
 24 hours. The extract was then analysed by ICP or AA (Pb and Ag). ...
 toxicity maximum concentration limit have been established for ...
 elements are presented in Table 2.

Barium is the only detectable element in the ORNL pilot scale ...
 not for which maximum concentration limits have been set. The ...
 detected at 100.0 mg/l, and the highest concentration detected for any of the ...
 samples tested was 0.041 mg/l. Thus, the concentrations of any of the ...
 elements listed in Table 2 increase substantially in the ISV soil ...
 the ISV waste form should easily meet any EP toxicity requirements.

TABLE 2. Results from EP Toxicity Testing of the Pilot-Scale ISV
 Test at ORNL

Concentration	Sample Number	Concentration (mg/l)	Maximum Concentration (mg/l)
As	<1	<1	2.0
Barium	0.012	0.014	100.0
Cadmium	<0.002	<0.002	1.0
Chromium	<0.02	<0.02	2.0
Copper	<0.02	<0.02	2.0
Manganese	<0.001	<0.001	0.2
Selenium	<1	<1	1.0
Silver	<0.1	<0.1	20.0

6.0 COMPARISON OF CESIUM RETENTION FOR ORNL AND HANFORD ISV GLASSES

Engineering-scale ISV testing of ORNL and Hanford soils indicate that the retention of Cs in the ORNL ISV product was greater than in the Hanford ISV product (99.999% compared to 99.0%). The major difference in the ORNL and Hanford ISV soils and products was the large amount of dolomite vitrified with the ORNL soil. This difference not only resulted in a significant compositional difference, but also reduced the viscosity of the ORNL ISV melt compared to the Hanford ISV melt. Because of this reduction in viscosity, the operating temperatures were lower for the ORNL ISV process. This study evaluated whether or not the viscosity, and thus the operating temperature of the ISV process, was a significant factor in the observed difference in Cs retention and whether or not the composition of the ISV melt affects Cs and/or Sr retention.

6.1 TECHNICAL APPROACH

To determine the Cs and Sr retention in vitrified ORNL and Hanford ISV products, soil compositions from the two sites were melted after being doped with nonradioactive Cs and Sr. Each glass was then held at the 100 poise temperatures (T100P) of the ORNL and Hanford ISV glass to determine the amount of Cs and Sr retention. The viscosity of the Hanford glass was reduced to that of the ORNL glass by the addition of different glass components, and the retention of Cs and Sr was determined in order to evaluate the effects of compositional differences.

Batches of ORNL (soil plus dolomite) and Hanford ISV products were melted after being doped with additional nonradioactive Cs and Sr. The additional Cs and Sr were added to help exceed the detection limits of the analytical evaluations. Each melt was melted for 2 hours at their respective, approximate T100P and then air-quenched. The compositions of each batch were determined by ICP, XRF, and AA. The viscosity curve for each glass was then determined. The T100P for the ORNL ISV glass was 1324°C and for the Hanford ISV glass was 1665°C. Table 10 summarizes the wt% Cs₂O and SrO in each glass, plus the T100P that was used.

TABLE 10. Summary of Glass Cs and Sr Concentrations and 100 Poise Temperatures

<u>Glass Product</u>	<u>Cs₂O wt%</u>	<u>SrO wt%</u>	<u>T100P (°C)</u>
ORNL ISV	1.96	4.16	1324
Hanford ISV	2.18	3.72	1665
Hanford ISV (CaO Adjust)	1.95	3.64	1325
Hanford ISV (Na ₂ O Adjust)	2.15	3.73	1325

The elemental off-gas from the melt is a function of the volatility of the element and the mobility of the element within the melt, which is a function of the melt viscosity. As the temperature increases, the volatility increases and the viscosity decreases, both of which increase volatilization from the melt. To evaluate the effects of temperature on the retention of Cs and Sr, both the ORNL and Hanford ISV glasses were held at 1300°C and 1650°C within a tube furnace with an H-Ar cover gas. The resulting off-gas was passed through two bubblers. The solutions within the bubblers were used to rinse out the furnace tube after the run to recover any deposited Cs and Sr, concentrated, and analyzed. It is estimated that the test is sensitive to 99.99% retention.

To evaluate the effects from Cs and Sr composition on retention, the T100P of the Hanford soil was reduced to that of the ORNL soil (1325°C) by the addition of CaO in one case and Na₂O in another. The amount of CaO in the ISV product is the major difference between the two ISV product compositions. These two modified Hanford compositions were tested for Cs and Sr retention at approximately 1325°C. The analyzed compositions for all the glass tested are show in Table 11.

6.2 TEST EVALUATIONS

A summary of the concentrations found in the scrub solutions is presented in Table 12. The retention of Sr was observed to be 100.00% and was unaffected by composition and melt temperatures. Increasing the melt temperature of an ORNL ISV glass from its T100P of 1325°C to 1650°C (≈3 poise) increased the Cs concentration in the off-gas solutions approximately

TABLE 11. Analyzed Compositions of the Glasses Used in the Cesium Retention Study

Oxide	ORNL ISV (Cs Spike)	Hanford ISV (Cs Spike)	Hanford ISV (CaO Adjusted)	Hanford ISV (Na ₂ O Adjusted)
Al ₂ O ₃	13.6	12.2	10.2	10.3
B ₂ O ₃	0.16	0.09	0.08	
BaO	0.10	0.12	0.11	0.11
CaO	13.9	4.54	18.1	3.93
Cr ₂ O ₃			0.08	
Cs ₂ O	1.96	2.18	1.95	2.15
Fe ₂ O ₃	3.78	6.57	5.50	5.59
K ₂ O	3.2	1.9	1.5	0.9
Li ₂ O	0.08		0.05	0.03
MgO	10.1	2.21	1.92	1.83
MnO ₂	0.13	0.14	0.12	0.12
Na ₂ O	1.05	3.13	3.01	17.8
NiO	0.04	0.05	0.25	0.04
SiO ₂	48.5	61.6	51.1	52.2
SrO	4.16	3.72	3.64	3.73
TiO ₂	0.62	1.13	0.94	0.96
V ₂ O ₃		0.03	0.02	0.02
ZrO ₂	0.03	0.04	0.02	0.03
Total	101.4	99.7	98.6	99.7

TABLE 12. Summary of Cesium Off-Gas and Retention Results

Glass Product	Test Temperature	Viscosity Poise	Off-Gas Conc. Cs (μg/ml)	Retention (wt%)
ORNL ISV	1325	100	5.3	99.865
ORNL ISV	1650	3	220	94.388
Hanford ISV	1650	100	17.8	99.592
Hanford ISV (CaO Adjusted)	1325	100	5.9	99.849
Hanford ISV (Na ₂ O Adjusted)	1325	100	12.8	99.702

40 times. This increase was due to increased Cs vapor pressure and/or the decrease in melt viscosity due to the higher temperature. Further testing is required to determine if this increase in volatility is a linear function with temperature.

When the Hanford ISV glass was tested at its T100P of 1650°C, the Cs release was three times that of the ORNL ISV glass at its T100P. Because the viscosities at the testing temperatures were the same, this difference must be due to the increased vapor pressure at 1650°C or the compositional differences in the two glasses. When the T100P of the Hanford ISV glass was reduced to that of the ORNL glass by the addition of CaO, the Cs releases were the same. This indicated that composition does have an effect on Cs retention but is small compared to temperature and viscosity effects.

When the viscosity of the Hanford glass was reduced with Na₂O instead of CaO, the Cs release was a factor of two greater than the CaO adjusted glass. This indicates that calcium oxide was slightly more effective in lowering Cs loss while reducing the T100P of the melt (see Table 12).

The increased Cs retention in the ORNL ISV glass compared to the Hanford ISV glass could have been due to the operating temperatures of the two processing tests. The operating temperatures for the Hanford ISV test could have been such that the viscosity of the melt was much greater than the melt viscosity for the ORNL ISV processing test. The melt temperatures for these two processing tests are not available to confirm this. The composition of the test melt could also have contributed to the difference in Cs retention, but could not have accounted for all of the difference.

7.0 PILOT-SCALE TEST RESULTS AND ANALYSIS

7.1 GENERAL OBSERVATIONS

Sampling strategies were used to compile a material balance for Cs and Sr retention. Samples were taken from HEPA filter media, each of the two liquid scrubbers, the off-gas line and off-gas hood, and the soil below the vitrified mass. Core samples were also taken from the vitrified mass.

Sampling of the off-gas scrub solution provided a quantitative analysis of the amount of Cs and Sr released during processing. During the processing period, 58 liquid samples were taken from the liquid scrub system. Duplicate samples were provided to ORNL for independent evaluations.

The data from samples were corrected for off-gas line and hood smear sizes, tank volumes, and solution transfer volumes for conversion to grams released from the soil to the off-gas system during processing. The converted gram quantities collected in the off-gas system were divided into the amounts of Cs and Sr placed in the soil prior to testing. This method provided a soil/mass-to-off-gas DF of 1.018×10^3 for Cs and 1.394×10^6 for Sr.

The data in Table 13 indicate that the Sr converts to a larger wt% quantity than that placed in the test site prior to vitrification. The same phenomenon was noted in the engineering-scale test and was thought to occur because the sample was taken in a melt zone created by a higher concentration of Sr than that distributed throughout the remaining vitrified mass. Previous convection data from testing shows distribution of radionuclides to be within a factor of 3 from the normal distribution (Timmerman and Oma 1984). For the pilot-scale test a sufficient number of samples were analyzed, and the data evaluated, to show an even distribution of Sr throughout the vitrified mass. All samples evaluated gave equal wt% quantities of Sr, which would rule out zones of higher concentration for this element. No explanation for the high Sr value could be determined during evaluation of the pilot-scale vitrified mass.

The concentration of Cs and Sr placed in the soil prior to vitrification testing was several orders of magnitude greater than that found in ORNL Trench 7, where only radioisotopes of these elements were disposed. This

TABLE 13. Oxide Compositions for ORNL ISV Pilot- and Engineering-Scale Tests^(a)

Oxides	Pilot-Scale Test			Engineering-Scale Test		
	Soil	Limestone	Average Prod.	Soil	Limestone	Product
Al ₂ O ₃	18.3	0.97	13.1	18.8	1.55	14.7
BaO	0.063		0.077	0.05	0.01	0.10
CaO	3.09	87.3	18.3	1.57	49.7	15.0
Cs ₂ O			0.35			1.35
Fe ₂ O ₃	6.32	1.37	4.42	6.48	0.58	4.14
K ₂ O	2.7		2.56			2.28
MgO	1.83	6.8	2.13	3.01	37.0	10.9
MnO ₂	0.12	0.39	0.14	0.21	0.00	0.14
Na ₂ O	0.77	0.65	1.52	0.61	0.07	0.93
SiO ₂	63.1	2.95	51.9	68.2	10.8	45.4
SrO	0.13	0.05	1.37	0.01	0.02	4.17
TiO ₂	0.83		0.60	0.88	0.04	0.64
ZrO ₂	0.035		0.038	0.06	0.06	0.035
Total	97.29	100.48	96.41	99.88	99.76	99.79

(a) Values in oxide wt%.

increased concentration was used to provide detectable levels of Cs and Sr in the off-gas sampling system and detectable quantities for the MCC tests of the vitrified mass. The similarity of leach characteristics for pilot- and engineering-scale test specimens (with their order-of-magnitude differences in Cs levels) indicate little effect due to mass loading on the waste from leach behavior.

Durability tests were performed on the pilot-scale vitrified mass. The tests were performed to determine product durability for the 80/20 soil and limestone mixture. The tests also verified the findings of the laboratory- and engineering-scale testing against ORNL's soil and limestone for future scale-up of the ISV process, and application of the process to ORNL trenches and seepage pits. Samples taken directly from the pilot-scale vitrified mass

were subjected to MCC-1, MCC-3, and a modified MCC-3 tests. All leach tests were performed at 90°C in DIW (see Section 5.0).

7.2 COMPARISON OF ENGINEERING- AND PILOT-SCALE TEST

The oxide compositions of the soils, limestones, and waste forms from the pilot- and engineering-scale ORNL ISV tests are presented in Table 13. The soil used in the previously conducted engineering-scale test was very similar to the soil used in the pilot-scale test. However, the crushed limestone used in the engineering-scale test contained approximately 37 wt% oxides MgO, compared to 6.8 wt% in the limestone used in the pilot-scale test. In the engineering-scale test, the soil-to-limestone ratio was 68/32 wt%. Analysis of the compositions from the pilot-scale test indicated the soil-to-limestone ratio was 80/20 wt%. These factors resulted in the compositional difference between the waste form product from the engineering-scale and pilot-scale tests.

Because of the differences in composition, the phase behavior of the two waste forms cannot be directly compared. However, the durability of the two waste forms can be compared because normalized concentrations and releases were used in the leach testing. Figure 34 compares the results from the MCC-1 testing of the engineering-scale product with the pilot-scale product. The releases are essentially equivalent for both tests, with the exception of potassium in the engineering-scale comparison. The engineering-scale and pilot-scale durability is also compared with PNL 76-68. Figure 33 presented the normalized Si concentrations versus $\text{Log}(t \cdot SA/V)$ for the pilot- and engineering-scale products. The forward rates of reaction for the two waste forms are very close, with the engineering-scale product being slightly higher. The differing compositions between the two tests are the major reasons for these small differences.

With leach testing for the laboratory-, engineering-, and pilot-scale tests performed at 90°C, the ISV process with the different wt% soil-to-limestone ratio presents a very durable product, comparable to a specially developed high-level waste form (i.e., PNL 76-68). It is anticipated that if

FIGURE 34. Comparison of MCC-1 Tests from Engineering-Scale Product to the Pilot-Scale Product

the vitrified mass leach tests are performed at the lower temperature of 20°C, to simulate ambient temperature leaching conditions, the leach rates would be one to two orders of magnitude lower.

Higher concentrations of Na₂O were detected in the samples of the vitrified mass (see Table 4) than that analyzed in the ORNL soil and limestone. One-hundred pounds of soda ash were added to the melt zone starter material to reduce the melt temperature of the ORNL soil, and to accelerate the establishment of the melt path between the electrodes. The 100 lb addition would account for 0.1 wt% Na₂O. No conclusion could be determined for the higher concentrations.

The ORNL ISV pilot-scale test exceeded the computer model prediction for run time, ISV mass, and energy consumption, and was less than the predicted and average power. The ORNL ISV test required additional operating hours to vitrify the ORNL 3/8-scale test site to the required depth for complete vitrification of the Cs and Sr chemicals placed in the test site. The additional required hours resulted from the longitudinal or lengthwise vitrification into the crushed limestone region of the trench. This lateral vitrification was previously observed in the engineering-scale test. The

pilot-scale off-gas hood for the ORNL test was designed to allow for longitudinal growth. However, the computer model is not programmed to account for longitudinal vitrification and only predicts vitrification of a square, tear-drop shape vitrified formation.

Based on the test conclusions resulting from the laboratory-, engineering-, and pilot-scale tests of ORNL soil and limestone at differing soil-to-limestone ratios, the ISV process can vitrify ORNL seepage trenches and pits to produce a very durable product.

8.0 REFERENCES

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APPENDIX A

CALCULATIONS

Liquid Transfer Conc. Sr

(Sample Conc) (Mg/l) (Volume Transferred l) = mg ÷ 1000 = g

Date and Time

Sample No.

$$\begin{array}{l} 7/15/87 @ 0915 (0.35) (51) \frac{17.85}{1000} = 0.02 \\ 1-21 \end{array}$$

$$\begin{array}{l} 7/15/87 @ 1400 (0.27) (31) \frac{8.37}{1000} = 0.01 \\ 1-23 \end{array}$$

$$\begin{array}{l} 7/15/87 @ 1500 (0.27) (39) \frac{10.53}{1000} = 0.01 \\ 1-23 \end{array}$$

$$\begin{array}{l} 7/15/87 @ 2120 (0.35) (48) \frac{16.80}{1000} = 0.02 \\ 2-28 \end{array}$$

$$\begin{array}{l} 7/16/87 @ 0149 (0.31) (30) \frac{9.30}{1000} = 0.01 \\ 2-30 \end{array}$$

$$\begin{array}{l} 7/16/87 @ 0625 (0.27) (27) \frac{7.29}{1000} = 0.01 \\ 2-32 \end{array}$$

$$\begin{array}{l} 7/16/87 @ 1100 (0.21) (23) \frac{4.83}{1000} = 0.005 \\ 2-35 \end{array}$$

$$\begin{array}{l} 7/16/87 @ 1830 (0.17) (32) \frac{5.44}{1000} = 0.005 \\ 2-38 \end{array}$$

$$\begin{array}{l} 7/16/87 @ 2341 (0.13) (33) \frac{4.29}{1000} = 0.004 \\ 2-41 \end{array}$$

$$\begin{array}{l} 7/17/87 @ 0540 (0.12) (19) \frac{2.28}{1000} = 0.002 \\ 2-44 \end{array}$$

$$\begin{array}{l} 7/17/87 @ 0740 (0.13) (18) \frac{2.34}{1000} = 0.002 \\ 2-45 \end{array}$$

$$\begin{array}{l} 7/17/87 @ 0830 (0.13) (9) \frac{1.17}{1000} = 0.001 \\ 2-45 \end{array}$$

Liquid Transfer Conc. Sr

(Sample Conc) (Mg/l) (Volume Transferred l) = mg ÷ 1000 = g

Date and Time
Sample No.

$$\begin{array}{l} 7/17/87 @ 1244 (0.09) (15) \frac{1.350}{1000} = 0.001 \\ 2-47 \end{array}$$

$$\begin{array}{l} 7/17/87 @ 1900 (0.08) (28) \frac{2.24}{1000} = 0.002 \\ 2-51 \end{array}$$

$$\begin{array}{l} 7/17/87 @ 2300 (0.07) (30) \frac{2.10}{1000} = 0.002 \\ 2-53 \end{array}$$

$$\begin{array}{l} 7/18/87 @ 0240 (0.06) (35) \frac{2.10}{1000} = 0.002 \\ 2-54 \end{array}$$

$$\begin{array}{l} 7/18/87 @ 0710 (0.05) (48) \frac{2.40}{1000} = 0.002 \\ 2-57 \end{array}$$

$$\begin{array}{l} 7/18/87 @ 1022 (0.05) (39) \frac{1.95}{1000} = 0.002 \\ 2-58 \end{array}$$

$$\begin{array}{l} 7/18/87 @ 0050 (0.09) (283) \frac{25.47}{1000} = 0.025 \\ 2-66 \end{array}$$

$$\begin{array}{l} 7/18/87 @ 0215 (0.09) (347) \frac{31.23}{1000} = \underline{0.031} \\ 2-68 \end{array}$$

Total 0.166 g

Liquid Transfer Conc. Cs

(Sample Conc) (Mg/l) (Volume Transferred l) = mg ÷ 1000 = g

Date and Time

Sample No.

$$\begin{array}{l} 7/15/87 @ 0915 (0.27) (51) \frac{13.77}{1000} = 0.014 \\ 1-21 \end{array}$$

$$\begin{array}{l} 7/15/87 @ 1400 (0.45) (31) \frac{13.95}{1000} = 0.014 \\ 1-23 \end{array}$$

$$\begin{array}{l} 7/15/87 @ 1500 (0.45) (39) \frac{17.55}{1000} = 0.018 \\ 1-23 \end{array}$$

$$\begin{array}{l} 7/15/87 @ 2120 (5.7) (48) \frac{273.6}{1000} = 0.274 \\ 2-28 \end{array}$$

$$\begin{array}{l} 7/16/87 @ 0149 (7.9) (30) \frac{237}{1000} = 0.237 \\ 2-30 \end{array}$$

$$\begin{array}{l} 7/16/87 @ 0625 (8.0) (27) \frac{216}{1000} = 0.216 \\ 2-32 \end{array}$$

$$\begin{array}{l} 7/16/87 @ 1100 (9.0) (23) \frac{207}{1000} = 0.207 \\ 2-35 \end{array}$$

$$\begin{array}{l} 7/16/87 @ 1830 (20.0) (32) \frac{640}{1000} = 0.640 \\ 2-38 \end{array}$$

$$\begin{array}{l} 7/16/87 @ 2341 (32.0) (33) \frac{1056}{1000} = 1.056 \\ 2-41 \end{array}$$

$$\begin{array}{l} 7/17/87 @ 0540 (61.0) (19) \frac{1159}{1000} = 1.159 \\ 2-44 \end{array}$$

$$\begin{array}{l} 7/17/87 @ 0740 (56.5) (18) \frac{1017}{1000} = 1.017 \\ 2-45 \end{array}$$

Liquid Transfer Conc. Cs

(Sample Conc) (Mg/l) (Volume Transferred l) = mg ÷ 1000 = g

Date and Time

Sample No.

$$\begin{array}{l} 7/17/87 @ 0830 (56.5) (9) \frac{508.5}{1000} = 0.509 \\ 2-45 \end{array}$$

$$\begin{array}{l} 7/17/87 @ 1244 (58.1) (15) \frac{871.5}{1000} = 0.872 \\ 2-47 \end{array}$$

$$\begin{array}{l} 7/17/87 @ 1900 (64.6) (28) \frac{1808}{1000} = 1.809 \\ 2-51 \end{array}$$

$$\begin{array}{l} 7/17/87 @ 2300 (64.3) (30) \frac{1929}{1000} = 1.929 \\ 2-53 \end{array}$$

$$\begin{array}{l} 7/18/87 @ 0240 (75.7) (35) \frac{2649.5}{1000} = 2.650 \\ 2-54 \end{array}$$

$$\begin{array}{l} 7/18/87 @ 0710 (105.4) (48) \frac{5059.2}{1000} = 5.059 \\ 2-57 \end{array}$$

$$\begin{array}{l} 7/18/87 @ 1022 (96.1) (39) \frac{3747.9}{1000} = 3.748 \\ 2-58 \end{array}$$

$$\begin{array}{l} 7/18/87 @ 0050 (127.0) (283) \frac{35.941}{1000} = 35.941 \\ 2-66 \end{array}$$

$$\begin{array}{l} 7/18/87 @ 0215 (17.7) (347) \frac{6141.9}{1000} = \underline{6.142} \\ 2-68 \end{array}$$

Total 63.51 g

Calculation for Limestone to Soil Ratio

$$\left(\frac{\text{Amount in Core Sample} - \text{Amount in Soil}}{\text{Amount in Limestone} - \text{Amount in Soil}} \right) (100) = \%$$

	<u>Average Amount in Core Sample</u>	<u>Amount in Soil</u>	<u>Amount in Limestone</u>
SiO ₂	51.93	58.4	2.95
MgO	2.12	1.69	6.8
Fe ₂ O ₃	4.42	5.86	1.3
CaO	18.3	2.86	87.3
Al ₂ O ₃	13.08	16.9	0.97
SiO ₂	$\frac{51.93 - 58.4}{2.95 - 58.4} = 0.117 (100) = 11.67\%$		
MgO	$\frac{2.12 - 1.69}{6.8 - 1.69} = 0.084 (100) = 8.42\%$		
Fe ₂ O ₃	$\frac{4.42 - 5.86}{1.3 - 5.86} = 0.316 (100) = 31.6\%$		
CaO	$\frac{18.3 - 2.86}{87.3 - 2.86} = 0.183 (100) = 18.3\%$		
Al ₂ O ₃	$\frac{13.08 - 16.9}{0.97 - 16.9} = 0.240 (100) = 23.98\%$		
	<div style="text-align: right;">Average = 20%</div>		

SrCO₃ and Cs₂CO₃ Corrected to Cs and Sr Placed in Test Trench

SrCO₃ Correction to Sr

$$(408,600 \text{ g SrCO}_3) (97.7\% \text{ purity}) = 399,202 \text{ g SrCO}_3$$

$$399,202 \text{ g SrCO}_3 \left(\frac{87.62}{87.62 + 12 + 3(16)} \right) =$$

$$(399,202 \text{ g SrCO}_3) \left(\frac{87.62}{147.63} \right) = 236,931 \text{ g Sr placed in test trench}$$

Cs₂CO₃ Correction to Cs

$$(89,892 \text{ g Cs}_2\text{CO}_3) (99.9\% \text{ purity}) = 89,802 \text{ g Cs}_2\text{CO}_3$$

$$89,802 \text{ g Cs}_2\text{CO}_3 \left(\frac{2(133)}{2(133) + 12 + 3(16)} \right) =$$

$$(89,802 \text{ g Cs}_2\text{CO}_3) \left(\frac{266}{326} \right) = 73,274 \text{ g Cs placed in test trench}$$

Conc Sr Inside of Hood Surface
Conc Sr Inside of Off-Gas Line

Hood Measurement:

$$36 \text{ in.} \times 216 \text{ in.} \times 2 = 15,552 \text{ in.}^2 \text{ on 2 side panels}$$

$$36 \text{ in.} \times 120 \text{ in.} \times 2 = 8,640 \text{ in.}^2 \text{ on 2 end panels}$$

$$120 \text{ in.} \times 216 \text{ in.} = 25,920 \text{ in.}^2 \text{ on roof panel}$$

$$\text{Total } 50,112 \text{ in.}^2 \text{ of hood surface}$$

Smear Surface:

$$10 \text{ in.} \times 10 \text{ in.} = 100 \text{ in.}^2$$

$$50,112 \text{ in.}^2 \div 100 \text{ in.}^2 = 501.12$$

$$501.12 \times 13.16 \text{ } \mu\text{g/smear} = 6594.74$$

$$6594.74 \text{ } \mu\text{g} \div 1 \times 10^6 \text{ } \mu\text{g/g} = 0.01 \text{ g Sr on inside of off-gas hood}$$

Off-Gas Line Measurement (8 in. Sch 10 pipe):

$$21.80 \text{ ft}^2/\text{ft} \times 144 = 314 \text{ in.}^2/\text{ft}$$

$$314 \text{ in.}^2/\text{ft} \times 32.25 \text{ ft} = 10126.5 \text{ in.}^2$$

Smear Surface:

$$10 \text{ in.} \times 10 \text{ in.} = 100 \text{ in.}^2$$

$$10126.5 \text{ in.}^2 \div 100 \text{ in.}^2 \text{ smear} = 101.27$$

$$101.27 \times 12.78 \text{ } \mu\text{g/smear} = 1294.23 \text{ } \mu\text{g}$$

$$1294.23 \text{ } \mu\text{g} \div 1 \times 10^6 \text{ } \mu\text{g} = 0.0013 \text{ g Sr on inside of off-gas line}$$

Conc Cs Inside of Hood Surface
Conc Cs Inside of Off-Gas Line

Hood Measurements:

$$36 \text{ in.} \times 216 \text{ in.} \times 2 = 15,552 \text{ in.}^2 \text{ on 2 side panels}$$

$$36 \text{ in.} \times 120 \text{ in.} \times 2 = 8,640 \text{ in.}^2 \text{ on 2 end panels}$$

$$120 \text{ in.} \times 216 \text{ in.} = 25,920 \text{ in.}^2 \text{ on roof panel}$$

$$\text{Total } 50,112 \text{ in.}^2 \text{ of hood surfaces}$$

Smeared Surface:

$$10 \text{ in.} \times 10 \text{ in.} = 100 \text{ in.}^2$$

$$50,112 \text{ in.}^2 \div 100 \text{ in.}^2 = 501.12$$

$$501.12 \times 390 \text{ } \mu\text{g Cs/smear} = 195,436.8 \text{ } \mu\text{g Cs}$$

$$195,436.8 \text{ } \mu\text{g} \div 1 \times 10^6 \text{ } \mu\text{g/g} = 0.20 \text{ g Cs on inside of off-gas hood}$$

Off-Gas Line Measurement (8 in. sch 10 pipe):

$$2.180 \text{ ft}^2/\text{ft} \times 144 = 314 \text{ in.}^2/\text{ft}$$

$$314 \text{ in.}^2/\text{ft} \times 32.25 \text{ ft} = 10126.5 \text{ in.}^2$$

Smeared Surface:

$$10 \text{ in.} \times 10 \text{ in.} = 100 \text{ in.}^2$$

$$10126.5 \div 100 \text{ in.}^2 \text{ smear} = 101.27$$

$$101.27 \times 1000 \text{ } \mu\text{g/smear} = 101,270 \text{ } \mu\text{g Cs}$$

$$101,270 \text{ } \mu\text{g} \div 1 \times 10^6 \text{ } \mu\text{g} = 0.10 \text{ g Cs on inside of off-gas line}$$

Correction for Grams Cs on HEPA Filter

Calculation:

$$\mu\text{g}/\text{cm}^2 \div 0.155 \text{ in.}^2 = \mu\text{g}/\text{in.}^2$$

$$\mu\text{g}/\text{in.}^2 \div 1 \times 10^6 \mu\text{g}/\text{g} = \text{g}/\text{in.}^2$$

$$(\text{g}/\text{in.}^2) (30,960 \text{ in.}^2 \text{ in filter}) = \text{total grams on filter}$$

<u>Primary Filter Sample No.</u>	<u>Sample Conc $\mu\text{g}/\text{cm}^2$</u>
1-1	12.5
1-2	11.2
1-3	11.7
2-1	7.7
2-2	13.8
2-3	<u>12.9</u>
Average	11.63

$$\frac{11.63}{0.155} = 75.0 \mu\text{g}/\text{in.}^2$$

$$\frac{75.0 \mu\text{g}/\text{in.}^2}{1 \times 10^6 \mu\text{g}/\text{g}} = 7.50 \times 10^{-5} \text{ g}/\text{in.}^2$$

$$(7.50 \times 10^{-5} \text{ g}/\text{in.}^2) (30,960 \text{ in.}^2) = 2.32 \text{ g Cs on primary filter}$$

* Final filter had less than the $<0.005 \mu\text{g}/\text{cm}$ detectable limit

Correction for Grams Sr on HEPA Filter

Calculation:

$$\mu\text{g}/\text{cm}^2 \div 0.155 \text{ in.}^2 = \mu\text{g}/\text{in.}^2 - \text{blank } \mu/\text{g}/\text{in.}^2 \text{ Sr Conc.} = \mu\text{g}/\text{in.}^2$$

$$\mu\text{g}/\text{in.}^2 \div 1 \times 10^6 \mu\text{g}/\text{g} = \text{g}/\text{in.}^2$$

$$(\text{g}/\text{in.}^2) (30,960 \text{ in.}^2 \text{ in filter}) = \text{total grams on filter}$$

<u>Primary Filter Sample No.</u>	<u>Sample Conc $\mu\text{g}/\text{cm}^2$</u>
1-1	0.058
1-2	0.055
1-3	0.061
2-1	0.054
2-2	0.061
2-3	<u>0.058</u>
Average	0.058

$$\frac{0.058}{0.155} = 0.374 \mu\text{g}/\text{in.}^2 - 0.284 = 0.090 \mu\text{g}/\text{in.}^2$$

$$\frac{0.090 \mu\text{g}/\text{in.}^2}{1 \times 10^6 \mu\text{g}/\text{g}} 9.0 \times 10^{-8} \text{ g}/\text{in.}^2$$

$$(9.0 \times 10^{-8}) (30,960) = 0.003 \text{ gr Sr on primary filter}$$

* Final filter had less than detectable limit Sr

Calculation of Anticipated Trench 7 Radionuclide Conc's

Basis: 1 Trench contains: 48,000 Ci Sr^{90} } as of 1966
231,000 Ci Cs^{137}

(ref: ORNL/RAP-10 p. 14)

2 Trench size: length = 71 m (p. C-117)
width = 3.3 m
depth = 5.2 m

3 Melt size: vitrify to a depth of 6.5 m
electrode spacing 4.5 m
use 9 settings (overlap ~1 m or 10%)
melt width = 8.7 m

4 Mass mass = 576×10^3 kg/setting (less overlap)
Vitrified (see attached computer prediction)
TOTAL MASS = $9 \times 576 \times 10^{-3} \times 0.9 = 4.66 \times 10^6$ kg

5 DFs: Cs = 99.90% Sr = 99.99%

Amount of Sr, Cs left in year 1990

$$A = A_0 e^{-(0.693/T_{1/2})t} \quad t = 1990 - 1966 = 24 \text{ yr}$$

$$^{90}\text{Sr} = 48,000 \text{ Ci} \times e^{-(0.693/30) \times 24} = 27,600 \text{ Ci} \quad T_{1/2} \text{ } ^{90}\text{Sr} = 28.1 \text{ yr}$$

$$^{137}\text{Cs} = 231,000 \text{ Ci} \times e^{-(0.693/28.1) \times 24} = 127,800 \text{ Ci} \quad T_{1/2} \text{ } ^{137}\text{Cs} = 30.0 \text{ yr}$$

Amounts of Sr, Cs Collected in Scrub Soln

$$^{90}\text{Sr} = (1 - 0.9999) (27,600) = 2.76 \text{ Ci} \div 9 = 0.3 \text{ Ci/setting}$$

$$^{137}\text{Cs} = (1 - 0.9990) (127,800) = 127 \text{ Ci} \div 9 = 14.2 \text{ Ci/setting}$$

Conc of Sr, Cs in Glass

$${}^{90}\text{Sr}_{\text{glass}} = (0.9999)(27,600 \text{ Ci}) / \left(\frac{\text{total mass}}{(141 \text{ Ci/g})(4.66 \times 10^9 \text{ g})} \right) = 4.2 \times 10^{-8} \frac{\text{g Sr}}{\text{g}}$$

$${}^{137}\text{Cs}_{\text{glass}} = (0.9990)(127,800 \text{ Ci}) / \left(\frac{\text{total mass}}{(87 \text{ Ci/g})(4.66 \times 10^9 \text{ g})} \right) = 3.1 \times 10^{-7} \frac{\text{g Cs}}{\text{g}}$$

*** ELECTRICAL PARAMETERS ***

Power supply rating	= 3750.00 kW
Maximum supply voltage	= 4160.00 Volts
Maximum melt depth	= 6.50 m
Calculation depth increment	= 8.67 cm
Electrode spacing	= 4.50 m
Electrode diameter	= 5.10 cm
Number of voltage taps	= 16
Ratio between voltage taps	= 0.840
Frac power loss tap change	= 0.900

*** HEAT TRANSFER PARAMETERS ***

Ht flux through top surface	= 32.00 kW/m ²
Ht flux to surrounding soil	= 3.20 kW/m ²
Ave. vit. zone temperature	= 2000.00°C
Ave. electrical resistivity	= 1.20 ohm-m
Heat capacity molten glass	= 0.24 Cal/g°C
Soil moisture (dry bases)	= 25.00%
Soil density	= 1.60 g/cm ³
Glass density	= 2.20 g/cm ³

Process Scrub Solution Cs Conc.

Start Scrub Tank Cs Conc.

$$\text{Calculation (mg/l) (tank volume l)} = \frac{\text{mg}}{1000} = \text{total grams in tank}$$

Sample No.

$$2-14 (0.40) (139) = \frac{55.6}{1000} = 0.06 \text{ g}$$

$$2-15 (0.50) (139) = \frac{69.5}{1000} = 0.07 \text{ g}$$

Process Scrub Solution Cs Conc.

$$\text{Calculation (mg/l) (tank volume l)} = \frac{\text{mg}}{1000} = (\text{g}) - \text{total grams in tank}$$

(total gram in tank) - (total grams from previous sample)

+ (grams transferred to waste drum) = total grams
accumulated

Sample No.

$$1-21 (0.27) (339) = \frac{91.5}{1000} = 0.092 - 0.07 = 0.022 + 0.014 = 0.036$$

$$1-23 (0.45) (319) = \frac{143.6}{1000} = 0.144 - 0.092 = 0.052 + 0.032 = 0.084$$

$$2-25 (3.2) (307) = \frac{982.4}{1000} = 0.982 - 0.144 = 0.838 + 0 = 0.839$$

$$2-28 (5.7) (326) = \frac{1858.2}{1000} = 1.858 - 0.982 = 0.876 + 0.274 = 1.150$$

$$2-30 (7.9) (324) = \frac{2559}{1000} = 2.560 - 1.858 = 0.702 + 0.237 = 0.939$$

$$2-32 (8.0) (323) = \frac{2584}{1000} = 2.584 - 2.560 = 0.024 + 0 = 0.024$$

$$2-33 (8.0) (304) = \frac{2432}{1000} = 2.432 - 2.584 = (-)0.152 + 0.216 = 0.064$$

Sample No.

$$2-34 \text{ (8.0) (311)} = \frac{2488}{1000} = 2.488 - 2.432 = 0.056 + 0 = 0.056$$

$$2-35 \text{ (9.0) (324)} = \frac{2916}{1000} = 2.916 - 2.488 = 0.428 + 0.207 = 0.635$$

$$2-37 \text{ (20.0) (320)} = \frac{6400}{1000} = 6.400 - 2.916 = 3.484 + 0 = 3.484$$

$$2-38 \text{ (20.0) (326)} = \frac{6520}{1000} = 6.520 - 6.400 = 0.120 + 0.640 = 0.760$$

$$2-39 \text{ (22.6) (305)} = \frac{6893}{1000} = 6.893 - 6.520 = 0.373 + 0 = 0.373$$

$$2-40 \text{ (27.0) (322)} = \frac{8694}{1000} = 8.694 - 6.893 = 1.801 + 0 = 1.801$$

$$2-41 \text{ (32.0) (322)} = \frac{10,304}{1000} = 10.304 - 8.694 = 1.610 + 1.056 = 2.666$$

$$2-42 \text{ (47.9) (308)} = \frac{14,753}{1000} = 14.753 - 10.304 = 4.449 + 0 = 4.449$$

$$2-43 \text{ (56.3) (319)} = \frac{17,960}{1000} = 17.960 - 14.753 = 3.207 + 0 = 3.207$$

$$2-44 \text{ (61.0) (333)} = \frac{20,313}{1000} = 20.313 - 17.960 = 2.353 + 1.159 = 2.353$$

$$2-45 \text{ (56.5) (327)} = \frac{18,476}{1000} = 18.476 - 20.313 = (-)1.838 + 1.526 = (-)0.312$$

$$2-46 \text{ (59.0) (310)} = \frac{18,290}{1000} = 18.290 - 18.476 = (-)0.186 + 0 = (-)0.186$$

$$2-47 \text{ (58.1) (315)} = \frac{18,302}{1000} = 18.302 - 18.290 = 0.012 + 0.872 = 0.884$$

$$2-48 \text{ (57.2) (300)} = \frac{17,160}{1000} = 17.160 - 18.302 = (-)1.142 + 0.509 = (-)0.633$$

$$2-49 \text{ (64.6) (305)} = \frac{19,703}{1000} = 19.703 - 17.160 = 2.543 + 0 = 2.543$$

$$2-50 \text{ (63.4) (314)} = \frac{19,900}{1000} = 19.908 - 19.703 = 0.205 + 0 = 0.205$$

Sample No.

$$2-51 \text{ (64.6) (331)} = \frac{21,383}{1000} = 23.383 - 19.908 = 1.475 + 0 = 1.475$$

$$2-52 \text{ (65.1) (310)} = \frac{20,181}{1000} = 20.181 - 21.383 = (-)1.202 + 1.809 = 0.607$$

$$2-53 \text{ (64.3) (333)} = \frac{21,412}{1000} = 21.412 - 20.181 = 1.231 + 0 = 1.231$$

$$2-54 \text{ (75.7) (323)} = \frac{24,451}{1000} = 24.451 - 21.412 = 3.039 + 1.929 = 4.968$$

$$2-55 \text{ (79.7) (307)} = \frac{24,468}{1000} = 24.468 - 24.451 = 0.017 + 2.650 = 2.667$$

$$2-56 \text{ (103) (307)} = \frac{31,621}{1000} = 31.621 - 24.468 = 7.153 + 0 = 7.153$$

$$2-57 \text{ (105.4) (357)} = \frac{37,628}{1000} = 37.628 - 31.621 = 6.007 + 0 = 6.007$$

$$2-58 \text{ (96.1) (322)} = \frac{30,944}{1000} = 30.944 - 37.628 = (-)6.684 + 8.807 = 2.123$$

$$2-59 \text{ (96.5) (305)} = \frac{29,433}{1000} = 29.433 - 30.944 = (-)1.512 + 0 = (-) 1.512$$

$$2-60 \text{ (85.3) (307)} = \frac{26,187}{1000} = 26.187 - 29.433 = (-)3.246 + 0 = (-)3.246$$

$$2-62 \text{ (98.1) (326)} = \frac{31,981}{1000} = 31.981 - 26.187 = 5.794 + 0 = 5.794$$

$$2-63 \text{ (115) (309)} = \frac{35,535}{1000} = 35.535 - 31.981 = 3.554 + 0 = 3.554$$

$$2-64 \text{ (126) (314)} = \frac{39,564}{1000} = 39.564 - 35.535 = 4.029 + 0 = 4.029$$

$$2-65 \text{ (130) (313)} = \frac{40,690}{1000} = 40.690 - 39.564 = 1.126 + 0 = 1.126$$

$$2-66 \text{ (127) (324)} = \frac{41,148}{1000} = 41.148 - 40.690 = 0.458 + 0 = 0.458$$

Sample No.

$$2-67 \text{ (127) (332)} = \frac{42,164}{1000} = 42.164 - 41.148 = 1.016 + 35.941 = 36.957$$

$$2-68 \text{ (17.7) (381)} = \frac{6,744}{1000} = 6.744 - 42.164 = \underline{(-)35.420 + 6.142 = (-)29.278}$$

63.511

69.534

Material check for total gram transfers out (63.511) and total grams accumulated (69.534)

Process Scrub Solution Sr Conc.

Start Scrub Tank Sr Conc.

Calculation (mg/l) (tank volume l) = $\frac{\text{mg}}{1000}$ = total grams in tank

Sample No.

$$2-14 (0.39) (139) = \frac{54.2}{1000} = 0.054 \text{ g}$$

$$2-15 (0.41) (139) = \frac{57.0}{1000} = 0.057 \text{ g}$$

Process Scrub Solution Sr Conc

Calculation (mg/l) (tank volume l) = $\frac{\text{mg}}{1000}$ = (g) - total grams in tank

(total grams in tank) - (total grams from previous sample)

+ (grams transferred to waste drum) = total grams
accumulated

Sample No.

$$1-21 (0.35) (319) = \frac{111.65}{1000} = 0.112 - 0.057 = 0.055 + 0.02 = 0.075$$

$$1-23 (0.27) (316) = \frac{85.3}{1000} = 0.085 - 0.112 = (-)0.03 + 0.02 = (-)0.01$$

$$2-25 (0.20) (307) = \frac{61.4}{1000} = 0.061 - 0.085 = (-)0.024 + 0 = (-)0.024$$

$$2-28 (0.35) (326) = \frac{114.1}{1000} = 0.114 - 0.061 = 0.053 + 0.02 = 0.073$$

$$2-30 (0.31) (324) = \frac{100.4}{1000} = 0.100 - 0.114 = (-)0.014 + 0.01 = (-)0.004$$

$$2-32 (0.27) (323) = \frac{87.2}{1000} = 0.087 - 0.100 = (-)0.013 + 0.01 = (-)0.003$$

$$2-33 (0.25) (304) = \frac{76.0}{1000} = 0.076 - 0.087 = (-)0.011 + 0 = (-)0.011$$

Sample No.

$$2-35 \ (0.21) \ (324) = \frac{68.0}{1000} = 0.068 - 0.076 = (-)0.008 + 0.005 = (-)0.003$$

$$2-38 \ (0.17) \ (326) = \frac{55.4}{1000} = 0.055 - 0.068 = (-)0.013 + 0.005 = (-)0.008$$

$$2-39 \ (0.16) \ (305) = \frac{48.8}{1000} = 0.049 - 0.055 = (-)0.006 + 0 = (-)0.006$$

$$2-41 \ (0.13) \ (322) = \frac{41.8}{1000} = 0.042 - 0.049 = (-)0.007 + 0.004 = (-)0.003$$

$$2-42 \ (0.12) \ (308) = \frac{37.0}{1000} = 0.037 - 0.042 = (-)0.005 + 0 = (-)0.005$$

$$2-44 \ (0.12) \ (333) = \frac{39.9}{1000} = 0.040 - 0.037 = 0.037 + 0.002 = 0.005$$

$$2-45 \ (0.13) \ (327) = \frac{42.5}{1000} = 0.043 - 0.040 = 0.003 + 0.003 = 0.006$$

$$2-46 \ (0.10) \ (310) = \frac{31.0}{1000} = 0.031 - 0.043 = (-)0.012 + 0 = (-)0.012$$

$$2-47 \ (0.10) \ (315) = \frac{28.5}{1000} = 0.029 - 0.031 = (-)0.002 + 0.001 = (-)0.001$$

$$2-48 \ (0.08) \ (300) = \frac{24.0}{1000} = 0.024 - 0.029 = (-)0.005 + 0 = (-)0.005$$

$$2-49 \ (0.09) \ (305) = \frac{27.5}{1000} = 0.0275 - 0.024 = (-)0.003 + 0 = (-)0.003$$

$$2-51 \ (0.08) \ (331) = \frac{26.5}{1000} = 0.026 - 0.027 = (-)0.001 + 0.002 = 0.001$$

$$2-53 \ (0.07) \ (331) = \frac{23.3}{1000} = 0.023 - 0.026 = (-)0.003 + 0.002 = (-)0.001$$

$$2-54 \ (0.06) \ (323) = \frac{19.4}{1000} = 0.019 - 0.023 = (-)0.004 + 0.002 = (-)0.002$$

$$2-55 \ (0.05) \ (307) = \frac{15.4}{1000} = 0.015 - 0.019 = (-)0.004 + 0 = (-)0.004$$

$$2-57 \ (0.05) \ (357) = \frac{17.9}{1000} = 0.018 - 0.015 = 0.003 + 0.002 = 0.005$$

Sample No.

$$2-58 (0.05) (322) = \frac{16.1}{1000} = 0.016 - 0.018 = (-)0.002 + 0.002 = 0.000$$

$$2-59 (0.05) (305) = \frac{15.3}{1000} = 0.015 - 0.016 = (-)0.001 + 0 = (-)0.001$$

$$2-60 (0.06) (307) = \frac{18.4}{1000} = 0.018 - 0.015 = 0.003 + 0 = 0.003$$

$$2-62 (0.06) (326) = \frac{19.6}{1000} = 0.020 - 0.018 = 0.002 + 0 = 0.002$$

$$2-64 (0.09) (314) = \frac{28.3}{1000} = 0.028 - 0.20 = 0.008 + 0 = 0.008$$

$$2-66 (0.09) (324) = \frac{29.2}{1000} = 0.029 - 0.028 = 0.001 + 0.025 = 0.026$$

$$2-67 (0.10) (332) = \frac{33.2}{1000} = 0.033 - 0.029 = 0.004 + 0 = 0.004$$

$$2-68 (0.09) (381) = \frac{34.3}{1000} = 0.034 - 0.033 = 0.001 + \underline{0.031} = \underline{0.032}$$

0.166 g 0.133 g

Material check for total gram transferred out (0.166) and total gram accumulated (0.133)

APPENDIX B

ANALYTICAL DATA FOR PROCESS SCRUB SOLUTIONS

**TABLE B.1. Reference Samples Taken Prior to Run
(all analyses are reported in mg/L)**

Element	<u>Sample Identification Number</u>	
	<u>2-14</u>	<u>2-15</u>
Al	17	17.04
B	120.1	133.70
Ca	34.5	35.70
Cr	3.7	4.1
Cs	0.40	0.50
Fe	29.07	30.06
K	57.2	64.2
Li	30.5	33.7
Mg	26.2	28.2
Mn	2.13	2.37
Mo	2.66	2.91
Na	389	144.3
Ni	0.13	0.14
P	14.8	18.6
Si	2066	2250
Sr	0.39	0.41
Zn	25.4	19.3
Ppt	1832 mg/L	1832 mg/L

TABLE B.2. Samples Analyzed for Process Performance (all analyses are reported in mg/L)

Element	Sample Identification Number							
	1-21	1-23	2-25	2-28	2-29	2-30	2-32	2-33
Al	43.4	34.7	31.8	27.7	24.9	20.4	15.3	13.8
B	802	712	552	600	514	433	310	270
Ca	43.2	40.7	45.8	49.9	42.0	36.9	26.4	22.6
Cd				0.36	2.01	0.34	0.23	0.21
Cr	4.19	2.76	2.90	4.49	4.38	5.19	5.63	5.63
Cs	0.27	0.45	3.2		5.5	8	8	8
Cu	1.33	0.84	0.69	2.04	1.81	1.79	1.81	1.70
Fe	49.3	39.6	39.4	43.9	44.2	44.0	45.2	44.6
Li	142.7	128	130	124	107	88.2	63.9	55.4
Mg	49.3	47.6	49.4	45.8	38.9	32.1	23.1	20.4
Mn	4.75	4.56	5.56	5.43	4.74	4.07	3.05	2.73
Mo	3.84	4.4	4.99	4.93	4.85	4.72	4.52	3.23
Na	4,610	4,470	4,470	3,770	3,190	2,720	1,950	1,680
Ni				4.05	4.77	4.88	4.80	4.35
P	67.8	62.6	49.1	37.0	39.2	28.1	23.6	21.4
Pb	25.1	20.0	20.4	18.3	14.7	12.9	9.8	9.46
S								
Si	10,270	8,260	8,280	5,940	5,230	3,940	2,940	2,600
Sr	0.35	0.27	0.20	0.35	0.33	0.31	0.27	0.25
Ti	2.08	1.68	0.74	0.85	0.55	0.70	0.53	0.53
Zn	50.0	45.8	53.6	58.2	51.6	50.0	35.9	32.4
Ppt	2.94×10^4	2.41×10^4	2.17×10^4		1.34×10^4	1.06×10^4	8.07×10^3	6.88×10^3

TABLE B.2. (contd)

Element	Sample Identification Number							
	2-34	2-35	2-37	2-38	2-39	2-40	2-41	2-42
Al	11.8	10.9	9.36	8.81	8.48	12.0	6.73	6.37
B	237	206	175	158	144	138	124	112
Ca	19.4	18.0	15.0	13.7	12.9	18.5	10.6	9.82
Cd	0.19	0.19	0.19	0.14	0.16	0.14	0.13	0.14
Cr	5.53	5.54	6.16	6.66	6.65	11.3	7.23	7.39
Cs	8	9	20	20	22.6	27	32	47.9
Cu	1.61	1.64	1.46	1.40	1.18	1.39	1.09	1.07
Fe	42.8	43.1	43.0	45.3	45.9	64.7	7.21	45.7
Li	45.9	41.7	35.5	32.3	29.3	24.8	25.5	22.3
Mg	16.7	15.5	12.7	11.6	11.7	17.0	8.56	7.87
Mn	2.35	2.19	1.90	1.82	1.73	3.64	1.62	1.57
Mo	2.66	2.35	2.14	1.76	1.82	1.55	1.50	1.42
Na	1,410	1,280	1,110	1,000	915	857	781	702
Ni	4.16	3.47	3.55	3.69	3.33	4.26	3.69	3.90
P	19.5	19.1	16.9	15.5	13.8	20.1	11.8	11.3
Pb	9.35	8.29	10.3	10.1	9.78	13.5	10.5	11.5
S								
Si	2,100	1,920	1,550	1,410	1,240	999	1,070	958
Sr	0.23	0.21	0.18	0.17	0.16	0.27	0.13	0.12
Ti	0.47	0.47	0.44	0.42	0.44	0.56	0.34	0.33
Zn	29.5	27.0	23.9	23.0	21.5	40.3	20.8	20.6
Ppt	5.78×10^3	5.08×10^3	4.03×10^3	3.61×10^3	3.29×10^3	2.99×10^3	2.63×10^3	2.32×10^3

TABLE B.2. (contd)

Element	Sample Identification Number							
	2-43	2-44	2-45	2-46	2-47	2-48	2-49	2-50
Al	5.92	6.30	5.96	4.91	4.53	4.37	4.71	4.44
B	102	95.9	87.5	77.0	69.1	63.7	64.3	61.7
Ca	9.07	9.60	9.08	6.97	6.17	5.78	6.62	6.19
Cd	0.12	0.21	0.20	0.20	0.13	0.12	0.24	0.18
Cr	8.04	9.83	11.2	11.6	12.8	14.0	17.7	19.5
Cs	56.3	61.0	56.5	59	58.1	57.2	64.6	63.4
Cu	1.11	0.31	0.29	0.21				
Fe	46.8	52.4	56.3	57.3	61.1	65	77.8	83.5
Li	20.2	18.1	16.6	15.5	14.0	12.8	11.9	11.4
Mg	7.25	7.49	7.09	5.59	5.04	4.56	5.25	5.07
Mn	1.52	1.65	1.72	1.65	1.70	1.77	2.15	2.27
Mo	1.34	1.23	1.13	0.84	0.68	0.64	0.66	0.68
Na	638	560	504	476	425	395	369	352
Ni	4.08	4.77	5.09	5.13	5.54	6.03	7.62	8.43
P	11.2	11.5	10.2	7.80	7.03	6.70	7.00	6.40
Pb	11.7	10.9	11.4	9.74	4.97	14.7	11.3	11.9
S								702
Si	869	794	757	638	609	513	551	530
Sr	0.13	0.12	0.13	0.10	0.09	0.08	0.09	0.09
Ti	0.38	0.43	0.45	0.30	0.29	0.30	0.38	0.35
Zn	19.4	17.8	16.5	14.3	12.9	12.1	13.1	12.9
Ppt	2.07×10^3	1.90×10^3	1.71×10^3	1.44×10^3	1.39×10^3	1.10×10^3	1.22×10^3	1.18×10^3

TABLE B.2. (contd)

Element	Sample Identification Number							
	2-51	2-52	2-53	2-54	2-55	2-56	2-57	2-58
Al	4.43	4.34	4.02	3.53	3.09	3.88	3.18	3.06
B	58.6	56.1	51.1	45.2	41.8	39.0	36.2	43.5
Ca	6.17	5.91	5.19	4.23	3.92	3.66	3.52	3.34
Cd	0.17	0.39	0.16	0.17	0.12	0.13	0.12	0.12
Cr	20.5	20.9	20.2	18.2	17.5	17.1	16.9	16.7
Cs	64.6	65.1	64.3	75.7	79.7	103	105.4	96.1
Cu	0.17	0.34	0.40	0.67	0.58	0.52	0.39	0.27
Fe	86.5	87.5	83.9	75.7	73.1	71.5	70.4	69.2
Li	10.8	10.4	9.54	9.06	8.39	7.88	7.25	6.67
Mg	4.90	4.77	4.44	3.83	2.96	2.08	3.13	2.71
Mn	2.16	2.39	2.27	2.04	1.97	1.92	1.86	1.78
Mo	0.72	0.78	0.78	0.74	0.77	0.77	0.81	0.84
Na	334	318	289	262	240	223	202	183
Ni	8.91	9.42	9.16	8.31	8.01	7.61	7.19	7.01
P	5.83	5.32	5.12	4.27	3.98	3.94	3.77	3.52
Pb	12.9	13.7	13.8	13.3	11.6	10.4	10.3	8.90
S								
Si	537	519	494	491	461	456	455	424
Sr	0.08	0.08	0.07	0.06	0.05	0.05	0.05	0.05
Ti	0.50	0.35	0.29	0.27	0.28	0.23	0.25	0.27
Zn	13.0	13.1	13.3	13.8	14.2	14.4	14.4	13.9
Ppt	1.17×10^3	1.10×10^3	1.03×10^3	1.04×10^3	701	933	907	805

TABLE B.2. (contd)

Element	Sample Identification Number							
	2-59	2-60	2-61	2-62	2-63	2-64	2-65	2-66
Al	3.08	3.26	2.77	2.95	3.80	4.07	4.41	4.12
B	31.4	29.9	31.0	33.1	40.7	43.4	45.6	45.7
Ca	3.26	3.74	3.10	3.25	3.53	3.66	4.99	4.03
Cd	0.11	0.11	0.13	0.12	0.15	0.14	0.13	0.14
Cr	15.0	13.8	13.8	13.5	15.9	17.1	17.3	17.3
Cs	96.5	85.3	87.1	98.1	115	126	130	127
Cu	0.37	0.60	0.68	0.73	0.92	0.97	1.00	0.92
Fe	62.6	57.2	47.0	56.1	65.8	70.8	72.3	72.0
Li	6.21	5.67	5.45	5.99	7.38	7.80	8.00	7.92
Mg	2.66	2.77	2.52	2.84	3.28	3.54	3.49	3.40
Mn	1.68	1.53	1.54	1.55	1.84	1.99	2.02	2.00
Mo	1.38	2.73	5.40	11.7	27.4	43.3	57.2	63.6
Na	167	159	150	165	184	168	204	202
Ni	8.43	8.25	8.53	8.30	9.72	10.3	10.2	10.2
P	2.72	2.64	2.97	3.06	3.73	4.52	4.52	4.52
Pb	10.0	11.5	11.2	10.9	10.8	12.3	12.9	13.3
S								
Si	416	383	381	436	547	603	602	591
Sr	0.05	0.06	0.05	0.06	0.08	0.09	0.10	0.09
Ti	0.25	0.31	0.30	0.30	0.37	0.42	0.65	0.44
Zn	14.8	17.2	21.1	24.0	31.3	34.8	39.1	40.8
Ppt	853	762	740	849	1.08×10^4	1.19×10^4	1.18×10^4	1.16×10^4

TABLE B.2. (contd)

Element	Sample Identification Number	
	2-67	2-68
Al	4.35	2.74
B	46.9	17.3
Ca	4.30	14.8
Cd	0.16	
Cr	17.7	2.47
Cs	127	17.7
Cu	0.95	
Fe	74.1	14.7
Li	8.22	3.90
Mg	3.45	10.1
Mn	2.06	0.37
Mo	68.6	15.3
Na	210	432
Ni	10.3	0.92
P	4.32	1.81
Pb	14.2	13.2
S		
Si	619	464
Sr	0.10	0.09
Ti	0.43	
Zn	43.0	5.79
Ppt	1.22×10^4	1.26×10^4

APPENDIX C

MISCELLANEOUS FIGURES

APPENDIX C

MISCELLANEOUS FIGURES

The following figures present data that are not critical for operations but would be useful for future design considerations.

FIGURE C.1. CO Concentration at Stack Versus Run Time.
(a) High CO concentration due to the burning of the graphite starter path

FIGURE C.2. CO₂ Concentration at Stack Versus Run Time.
 (a) Melt zone entered limestone material in trench.

FIGURE C.3. Off-gas Flow at Stack Versus Run Time

FIGURE C.4. Process Off-gas Stack Temperature Versus Run Time

FIGURE C.5. Off-gas Hood Plenum Temperature and Venturi Scrubber Inlet Temperature Versus Run Time

FIGURE C.6. Off-gas Hood Temperature Versus Run Time

APPENDIX D

ANALYTICAL DATA FOR VITRIFIED MASS

MCC-1 TEST RESULTS

The following are copies of spreadsheet files used to calculate the normalized mass release from MCC-1 leach testing. The ppm values listed are directly from ICP (AA for Cs) analytical results of test leachants. The equation used for the calculations are provide in the test. Oxide wt% values are from ICP analysis of the glass or crystalline product.

```

:-----:
SAMPLE: 230P
MCC-1 90C
SA/V = 10/M
SOLUTE DIW
DAYS 28
DATE 19-Feb-88
OPERATOR AMA
FACTOR = 10
  
```

```

ICP LAB# (GLASS POWDER): 200
ICP LAB# (LEACHATE): 413
  
```

CHEMICAL	ELEM.	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2
Al2O3	Al	12.80	0.068	4.000	5.91
CaO	Ca	17.20	0.123	8.490	6.90
SiO2	Si	51.80	0.242	15.200	6.27
SrO	Sr	1.30	0.011	0.825	7.50
Cs2O	Cs	0.33	0.003	0.280	9.00
pH	INITIAL			6.11	
	FINAL			9.26	

Leachate Sample #1490

```

:-----:
SAMPLE: 231P
MCC-1 90C
SA/V = 10/M
SOLUTE DIW
DAYS 28
DATE 19-Feb-88
OPERATOR AMA
FACTOR = 10
  
```

```

ICP LAB# (GLASS POWDER): 201
ICP LAB# (LEACHATE): 413
  
```

CHEMICAL	ELEM.	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2
Al2O3	Al	13.10	0.069	4.150	5.99
CaO	Ca	18.60	0.133	8.710	6.55
SiO2	Si	51.50	0.241	15.700	6.51
SrO	Sr	1.40	0.012	0.851	7.19
Cs2O	Cs	0.34	0.003	0.290	9.04
pH	INITIAL			6.11	
	FINAL			9.19	

Leachate Sample #1491

CONTINUED. MCC-1 TEST RESULTS

SAMPLE: 232P

MCC-1 90C

SA/V = 10/M

SOLUTE DIW

DAYS 28

DATE 19-Feb-88

OPERATOR AMA

FACTOR = 10

ICP LAB# (GLASS POWDER): 202

ICP LAB# (LEACHATE): 413

CHEMICAL ELEM.		OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2
Al2O3	Al	13.20	0.070	3.920	5.61
CaO	Ca	18.70	0.134	8.470	6.33
SiO2	Si	52.00	0.243	15.000	6.16
SrO	Sr	1.40	0.012	0.818	6.91
Cs2O	Cs	0.34	0.003	0.280	8.73

pH	INITIAL			6.11	
	FINAL			9.11	

Leachate Sample #1492

.....

SAMPLE: 233P

MCC-1 90C

SA/V = 10/M

SOLUTE DIW

DAYS 28

DATE 19-Feb-88

OPERATOR AMA

FACTOR = 10

ICP LAB# (GLASS POWDER): 203

ICP LAB# (LEACHATE): 413

CHEMICAL ELEM.		OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2
Al2O3	Al	13.20	0.070	1.970	2.82
CaO	Ca	18.70	0.134	5.030	3.76
SiO2	Si	52.40	0.245	11.800	4.81
SrO	Sr	1.39	0.012	0.201	1.71
Cs2O	Cs	0.36	0.003	0.290	8.54

pH	INITIAL			6.11	
	FINAL			9.06	

Leachate Sample #1493

MCC-3 TEST RESULTS

The following are copies of spreadsheet files used to calculate the normalized mass release from MCC-3 leach testing. The ppm values listed are directly from ICP (AA for Ca) analytical results of test leachants. The equation used for the calculations are provide in the test. Oxide wt% values are from ICP analysis of the glass or crystalline product.

SAMPLE: 230A									
MCC-3 90C									
SA/V = 2000/M-1						DATE 19-Feb-88			
SOLUTE DIW						OPERATOR AMA			
DAYS 28						FACTOR = 2000			
ICP LAB# (GLASS): 200 .45M FILTRATION 18A FILTRATION ACID STRIP									
ICP LAB# (LEACH): 412, 413									
CHEMICAL ELEMENT	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	
Al2O3 Al	12.80	0.068	2.600	0.019	2.480	0.018	0.038	0.000	
CaO Ca	17.20	0.123	14.100	0.057	13.300	0.054	0.093	0.000	
SiO2 Si	51.00	0.242	18.800	0.039	18.400	0.038	0.054	0.000	
SrO Sr	1.30	0.011	1.000	0.045	0.925	0.042	0.000	0.000	
Ca2O Ca	0.33	0.003	0.540	0.007	0.530	0.005	0.005	0.001	
SAMPLE DESIGNATION BY ICP LOG IN PSL/417:				949		959		1480	
pH	INITIAL	8.02							
	FINAL	9.49							

SAMPLE: 230B									
MCC-3 90C					DATE 19-Feb-88				
SA/V = 1780/M-1					OPERATOR AMA				
SOLUTE DIW					FACTOR = 2000				
DAYS 28									
ICP LAB# (GLASS): 200 .45M FILTRATION 18A FILTRATION ACID STRIP									
ICP LAB# (LEACH): 412, 413									
CHEMICAL	ELEMENT	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2
Al2O3	Al	12.00	0.068	2.620	0.019	2.500	0.018	0.095	0.001
CaO	Ca	17.20	0.123	14.200	0.058	13.300	0.054	0.178	0.001
SiO2	Si	51.00	0.242	18.900	0.039	18.400	0.038	0.181	0.000
SrO	Sr	1.30	0.011	1.010	0.046	0.933	0.042	0.018	0.001
Ca2O	Ca	0.33	0.003	0.540	0.007	0.530	0.005	0.005	0.001
SAMPLE DESIGNATION BY ICP LOG IN PSL/417:					960		960		1481
pH	INITIAL	8.02							
	FINAL	9.38							

CONTINUED. MCC-3 TEST RESULTS

SAMPLE: 231A
MCC-3 90C
SA/V = 1780/M-1
SOLUTE DIW
DAYS 28

DATE 19-Feb-88
OPERATOR AMA
FACTOR = 2888

ICP LAB# (GLASS): 281
ICP LAB# (LEACH): 412, 413

				.45M FILTRATION		18A FILTRATION		ACID STRIP	
CHEMICAL	ELEMENT	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2
Al2O3	Al	13.18	0.069	2.740	0.020	2.540	0.018	0.049	0.000
CaO	Ca	18.88	0.133	14.280	0.053	10.400	0.039	0.100	0.000
SiO2	Si	51.50	0.241	18.900	0.039	18.300	0.038	0.079	0.000
SrO	Sr	1.40	0.012	1.010	0.043	0.782	0.033	0.008	0.000
Cs2O	Cs	0.34	0.003	0.470	0.073	0.460	0.072	0.005	0.001

SAMPLE DESIGNATION BY ICP LOG IN PSL/417: 951 961 1482

pH INITIAL 6.02
FINAL 9.38

SAMPLE: 231B
MCC-3 90C
SA/V = 1780/M-1
SOLUTE DIW
DAYS 28

DATE 19-Feb-88
OPERATOR AMA
FACTOR = 2888

ICP LAB# (GLASS): 281
ICP LAB# (LEACH): 412, 413

				.45M FILTRATION		18A FILTRATION		ACID STRIP	
CHEMICAL	ELEMENT	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2
Al2O3	Al	13.18	0.069	2.860	0.021	2.850	0.019	0.030	0.000
CaO	Ca	18.88	0.133	11.100	0.042	10.100	0.038	0.044	0.000
SiO2	Si	51.50	0.241	18.900	0.039	18.100	0.038	0.022	0.000
SrO	Sr	1.40	0.012	0.861	0.038	0.774	0.033	0.003	0.000
Cs2O	Cs	0.34	0.003	0.480	0.072	0.440	0.069	0.005	0.001

SAMPLE DESIGNATION BY ICP LOG IN PSL/417: 952 962 1483

pH INITIAL 6.02
FINAL 9.44

CONTINUED. MCC-3 TEST RESULTS

SAMPLE: 232A
MCC-3 90C
SA/V = 1780/M-1
SOLUTE DIW
DAYS 28

DATE 19-Feb-88
OPERATOR AMA
FACTOR = 2000

ICP LAB# (GLASS): 202
ICP LAB# (LEACH): 412, 413

				.45M FILTRATION		18A FILTRATION		ACID STRIP	
CHEMICAL	ELEMENT	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2
Al2O3	Al	13.20	0.070	2.740	0.020	2.570	0.018	1.160	0.008
CaO	Ca	18.70	0.134	11.100	0.042	10.300	0.039	2.040	0.008
SiO2	Si	62.00	0.243	18.900	0.039	18.400	0.038	2.370	0.006
SrO	Sr	1.40	0.012	0.857	0.038	0.776	0.033	0.205	0.009
Cs2O	Cs	0.35	0.003	0.480	0.073	0.460	0.070	0.006	0.001

SAMPLE DESIGNATION BY ICP LOG IN PSL/417: 953 963 1484

pH INITIAL 6.02
FINAL 9.58

SAMPLE: 232B
MCC-3 90C
SA/V = 1780/M-1
SOLUTE DIW
DAYS 28

DATE 19-Feb-88
OPERATOR AMA
FACTOR = 2000

ICP LAB# (GLASS): 202
ICP LAB# (LEACH): 412, 413

				.45M FILTRATION		18A FILTRATION		ACID STRIP	
CHEMICAL	ELEMENT	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2
Al2O3	Al	13.20	0.070	2.640	0.019	2.400	0.017	0.119	0.001
CaO	Ca	18.70	0.134	10.900	0.041	9.820	0.037	0.224	0.001
SiO2	Si	62.00	0.243	18.300	0.038	17.400	0.036	0.232	0.000
SrO	Sr	1.40	0.012	0.831	0.035	0.736	0.031	0.022	0.001
Cs2O	Cs	0.35	0.003	0.470	0.071	0.470	0.071	0.005	0.001

SAMPLE DESIGNATION BY ICP LOG IN PSL/417: 954 964 1485

pH INITIAL 6.02
FINAL 9.65

CONTINUED. MCC-3 TEST RESULTS

SAMPLE: 233A
MCC-3 90C
SA/V = 1780/M-1
SOLUTE DIW
DAYS 28

DATE 19-Feb-88
OPERATOR AMA
FACTOR = 2000

ICP LAB# (GLASS): 203
ICP LAB# (LEACH): 412, 413

				.45M FILTRATION		18A FILTRATION		ACID STRIP	
CHEMICAL ELEMENT	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm
Al2O3	Al	13.20	0.070	2.060	0.015	1.890	0.014	0.000	0.000
CaO	Ca	18.70	0.134	8.460	0.032	7.610	0.028	0.050	0.000
SiO2	Si	52.40	0.245	19.400	0.040	19.100	0.039	0.028	0.000
SrO	Sr	1.39	0.012	0.463	0.020	0.390	0.017	0.007	0.000
Ca2O	Ca	0.36	0.003	1.000	0.147	0.940	0.138	0.005	0.001

SAMPLE DESIGNATION BY ICP LOG IN PSL/417: 955 955 1486

pH INITIAL 6.02
FINAL 9.47

SAMPLE: 233B
MCC-3 90C
SA/V = 1780/M-1
SOLUTE DIW
DAYS 28

DATE 19-Feb-88
OPERATOR AMA
FACTOR = 2000

ICP LAB# (GLASS): 203
ICP LAB# (LEACH): 412, 413

				.45M FILTRATION		18A FILTRATION		ACID STRIP	
CHEMICAL ELEMENT	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm
Al2O3	Al	13.20	0.070	1.920	0.014	1.740	0.012	0.000	0.000
CaO	Ca	18.70	0.134	8.890	0.033	7.970	0.030	0.042	0.000
SiO2	Si	52.40	0.245	19.800	0.040	19.100	0.039	0.017	0.000
SrO	Sr	1.39	0.012	0.470	0.020	0.404	0.017	0.005	0.000
Ca2O	Ca	0.36	0.003	1.000	0.147	0.960	0.141	0.005	0.001

SAMPLE DESIGNATION BY ICP LOG IN PSL/417: 956 956 1487

pH INITIAL 6.02
FINAL 9.52

CONTINUED. MCC-3 TEST RESULTS

SAMPLE: 240A
MCC-3 90C
SA/V = 1780/M-1
SOLUTE DIW
DAYS 28

DATE 19-Feb-88
OPERATOR AMA
FACTOR = 2000

ICP LAB# (GLASS): 200, 491
ICP LAB# (LEACH): 412, 413

.45M FILTRATION

18A FILTRATION

ACID STRIP

CHEMICAL	ELEMENT	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2
Al2O3	Al	12.90	0.000	2.430	0.018	2.250	0.018	0.000	0.000
CaO	Ca	18.60	0.132	9.840	0.030	8.470	0.032	0.025	0.000
SiO2	Si	52.10	0.244	19.000	0.039	18.300	0.030	0.014	0.000
SrO	Sr	1.45	0.012	0.620	0.025	0.532	0.022	0.004	0.000
Ca2O	Ca	0.35	0.003	0.060	0.129	0.010	0.123	0.005	0.001

SAMPLE DESIGNATION BY ICP LOG IN PSL/417:

957

907

1488

pH INITIAL 6.02
FINAL 9.40

SAMPLE: 240B
MCC-3 90C
SA/V = 1780/M-1
SOLUTE DIW
DAYS 28

DATE 19-Feb-88
OPERATOR AMA
FACTOR = 2000

ICP LAB# (GLASS): 200, 491
ICP LAB# (LEACH): 412, 413

.45M FILTRATION

18A FILTRATION

ACID STRIP

CHEMICAL	ELEMENT	OXIDE wt%	Fi	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2	ppm	NOR. MASS RELEAS g/m2
Al2O3	Al	12.90	0.000	2.400	0.018	2.200	0.017	0.000	0.000
CaO	Ca	18.60	0.132	9.830	0.037	8.710	0.033	0.054	0.000
SiO2	Si	52.10	0.244	19.200	0.039	18.500	0.030	0.000	0.000
SrO	Sr	1.45	0.012	0.635	0.026	0.548	0.022	0.000	0.000
Ca2O	Ca	0.35	0.003	0.060	0.130	0.010	0.123	0.005	0.001

SAMPLE DESIGNATION BY ICP LOG IN PSL/417:

958

908

1489

pH INITIAL 6.02
FINAL 9.62

CONTINUED. MCC-3 TEST RESULTS

The following is a summary of normalized mass releases from duplicate MCC-3 leach tests. The 0.45 μm are normalized release values from ICP (AA for Cs) analytical results for the leachants filter through a 0.45 μm filter. The 18 Ang. values are normalized release from 18 angstrom filtered samples. The A.S are from the acid strip of the leach vessel after the test to determine if significant amount of material plated to the leaching vessel.

NORMALIZED MASS RELEASE, g/m²

ELEMENT	230A::: .45 mic. 18 Ang. A.S			230B::: .45 mic. 18 Ang. A.S		
Al	0.019	0.018	0.000	0.019	0.018	0.001
Ca	0.057	0.054	0.000	0.058	0.054	0.001
Si	0.039	0.038	0.000	0.039	0.038	0.000
Sr	0.045	0.042	0.000	0.046	0.042	0.001
Cs	0.087	0.085	0.001	0.087	0.085	0.001

ELEMENT	231A::: .45 mic. 18 Ang. A.S			231B::: .45 mic. 18 Ang. A.S		
Al	0.020	0.018	0.000	0.021	0.019	0.000
Ca	0.053	0.039	0.000	0.042	0.038	0.000
Si	0.039	0.038	0.000	0.039	0.038	0.000
Sr	0.043	0.033	0.000	0.036	0.033	0.000
Cs	0.073	0.072	0.001	0.072	0.069	0.001

ELEMENT	232A::: .45 mic. 18 Ang. A.S			232B::: .45 mic. 18 Ang. A.S		
Al	0.020	0.018	0.008	0.019	0.017	0.001
Ca	0.042	0.039	0.008	0.041	0.037	0.001
Si	0.039	0.038	0.005	0.038	0.036	0.000
Sr	0.036	0.033	0.009	0.035	0.031	0.001
Cs	0.073	0.070	0.001	0.071	0.071	0.001

CONTINUED. MCC-3 TEST RESULTS

NORMALIZED MASS RELEASE, g/m²

ELEMENT	233A:.....			233B:.....		
	.45 mic. 18 Ang. A.S			.45 mic. 18 Ang. A.S		
Al	0.015	0.014	0.000	0.014	0.012	0.000
Ca	0.032	0.028	0.000	0.033	0.030	0.000
Si	0.040	0.039	0.000	0.040	0.039	0.000
Sr	0.020	0.017	0.000	0.020	0.017	0.000
Cs	0.147	0.138	0.001	0.147	0.141	0.001

ELEMENT	240A:.....			240B:.....		
	.45 mic. 18 Ang. A.S			.45 mic. 18 Ang. A.S		
Al	0.018	0.016	0.000	0.018	0.017	0.000
Ca	0.036	0.032	0.000	0.037	0.033	0.000
Si	0.039	0.038	0.000	0.039	0.038	0.000
Sr	0.025	0.022	0.000	0.026	0.022	0.000
Cs	0.129	0.123	0.001	0.130	0.123	0.001

CONTINUED. MCC-3 TEST RESULTS

The following are the average normalized release values, standard deviations, and percent relative standard deviations (%RSD) for the duplicate MCC-3 tests for the 0.45um and 18 angstrom results. Values list as ERR indicate that the duplicates had the same value and no standard deviation could be calculated.

	AVERAGES 0.45 um	NORMALIZED MASS RELEASE, g/m ²			
	230	231	232	233	236/240
Al	0.019	0.020	0.019	0.014	0.018
Ca	0.058	0.048	0.041	0.032	0.037
Si	0.039	0.039	0.038	0.040	0.039
Sr	0.046	0.039	0.036	0.020	0.026
Cs	0.087	0.073	0.072	0.147	0.130

STANDARD DEVIATION					
Al	0.00007	0.00043	0.00036	0.00050	0.00022
Ca	0.00020	0.00583	0.00037	0.00080	0.00036
Si	0.00010	0.00000	0.00062	0.00041	0.00021
Sr	0.00023	0.00315	0.00055	0.00015	0.00031
Cs	ERR	0.00078	0.00076	0.00000	0.00076

%RSD					
Al	0.38	2.14	1.86	3.52	1.22
Ca	0.35	12.25	0.91	2.48	0.98
Si	0.27	0.00	1.61	1.02	0.52
Sr	0.50	7.96	1.54	0.75	1.20
Cs	ERR	1.08	1.05	0.00	0.58

	AVERAGES 18A	NORMALIZED MASS RELEASE, g/m ²			
	230	231	232	233	236/240
Al	0.018	0.019	0.018	0.013	0.017
Ca	0.054	0.039	0.038	0.029	0.032
Si	0.038	0.038	0.037	0.039	0.038
Sr	0.042	0.033	0.032	0.017	0.022
Cs	0.085	0.070	0.070	0.140	0.123

STANDARD DEVIATION					
Al	0.00015	0.00040	0.00061	0.00054	0.00011
Ca	ERR	0.00056	0.00090	0.00067	0.00045
Si	ERR	0.00021	0.00103	0.00000	0.00021
Sr	0.00018	0.00017	0.00084	0.00017	0.00033
Cs	ERR	0.00156	0.00076	0.00147	0.00000

%RSD					
Al	0.81	2.12	3.42	4.13	0.66
Ca	ERR	1.46	2.39	2.31	1.40
Si	ERR	0.55	2.79	0.00	0.54
Sr	0.43	0.51	2.65	1.00	1.48
Cs	ERR	2.22	1.08	1.05	0.00

MCC-MOD TEST RESULTS

The following are copies of spreadsheet files used to calculate the normalized concentration from MCC-3 leach testing. The leach ICP data values listed are directly from ICP (AA for Cs) analytical results of test leachants and are given as ppm. The equation used for the calculations are provide in the test. Oxide wt% values are from ICP analysis of the glass or crystalline product. All concentrations are listed as g/m³.

---Al CALCULATIONS---					---Ca CALCULATIONS---											
TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Al	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Ca
230 A	A1	292	200	50	0.040	1	0.040	12.800	0.078	0.5278718	0.078	1	0.078	17.200	0.123	0.6342495
230 A	A8	292	200	50	0.066	1	0.066	12.800	0.078	0.8709882	0.094	1	0.094	17.200	0.123	0.7643519
230 A	A15	292	200	50	0.191	1	0.191	12.800	0.078	2.5265870	0.336	1	0.336	17.200	0.123	2.7321518
230 A	A22	292	200	50	0.464	1	0.464	12.800	0.078	0.1233108	0.942	1	0.942	17.200	0.123	7.6597821
230 A	A29	292	200	50	2.260	1	2.260	12.800	0.078	29.8247488	4.310	1	4.310	17.200	0.123	35.0483498
230 A	A36	292	200	50	3.430	1	3.430	12.800	0.078	45.2849918	7.120	1	7.120	17.200	0.123	57.8955928
230 B	B1	294	200	2000	0.137	5	0.685	12.800	0.078	9.0398015	0.175	5	0.875	17.200	0.123	7.1149780
230 B	B8	294	200	2000	0.139	5	0.695	12.800	0.078	9.1717894	0.258	5	1.290	17.200	0.123	10.4895185
230 B	B15	294	200	2000	0.332	5	1.660	12.800	0.078	21.9868723	0.636	5	3.180	17.200	0.123	25.8578831
230 B	B22	294	200	2000	0.582	5	2.910	12.800	0.078	38.4826605	1.200	5	6.000	17.200	0.123	48.7884209
230 B	B29	294	200	2000	0.758	5	3.780	12.800	0.078	49.8838882	1.580	5	7.900	17.200	0.123	64.2388875
230 B	B36	294	200	2000	0.812	5	4.060	12.800	0.078	53.5789898	2.110	5	10.550	17.200	0.123	85.7863867
230 C	C1	296	200	10000	0.250	10	2.500	12.800	0.078	32.9919784	0.463	10	4.630	17.200	0.123	32.7695560
230 C	C8	296	200	10000	0.312	10	3.120	12.800	0.078	41.1739865	0.521	10	5.210	17.200	0.123	42.3646121
230 C	C15	296	200	10000	0.381	10	3.810	12.800	0.078	50.2797720	0.738	10	7.380	17.200	0.123	60.0097577
230 C	C22	296	200	10000	0.375	10	3.750	12.800	0.078	49.4879845	0.978	10	9.780	17.200	0.123	79.5251260
230 C	C29	296	200	10000	0.360	10	3.600	12.800	0.078	48.3082534	1.290	10	12.900	17.200	0.123	104.8951049
230 C	C36	296	200	10000	0.337	10	3.370	12.800	0.078	44.4731841	1.540	10	15.400	17.200	0.123	125.2236136

---Fe CALCULATIONS---					---Mg CALCULATIONS---											
TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Fe	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Mg
230 A	A1	292	200	50	0.000	1	0.000	4.300	0.030	0.0000000	0.000	1	0.000	2.020	0.012	0.0000000
230 A	A8	292	200	50	0.000	1	0.000	4.300	0.030	0.0000000	0.000	1	0.000	2.020	0.012	0.0000000
230 A	A15	292	200	50	0.000	1	0.000	4.300	0.030	0.0000000	0.000	1	0.000	2.020	0.012	0.0000000
230 A	A22	292	200	50	0.000	1	0.000	4.300	0.030	0.1896397	0.092	1	0.092	2.020	0.012	7.5529941
230 A	A29	292	200	50	0.281	1	0.281	4.300	0.030	9.3489837	0.481	1	0.481	2.020	0.012	32.9212028
230 A	A36	292	200	50	0.422	1	0.422	4.300	0.030	14.0399987	0.306	1	0.306	2.020	0.012	25.1219152
230 B	B1	294	200	2000	0.007	5	0.034	4.300	0.030	1.1145490	0.000	5	0.000	2.020	0.012	0.0000000
230 B	B8	294	200	2000	0.004	5	0.018	4.300	0.030	0.5822271	0.000	5	0.000	2.020	0.012	0.0000000
230 B	B15	294	200	2000	0.000	5	0.039	4.300	0.030	1.2975347	0.057	5	0.285	2.020	0.012	23.3978822
230 B	B22	294	200	2000	0.012	5	0.060	4.300	0.030	1.9298670	0.109	5	0.545	2.020	0.012	44.7432803
230 B	B29	294	200	2000	0.010	5	0.050	4.300	0.030	1.0635080	0.053	5	0.265	2.020	0.012	21.7559069
230 B	B36	294	200	2000	0.005	5	0.023	4.300	0.030	0.7485777	0.000	5	0.000	2.020	0.012	0.0000000
230 C	C1	296	200	10000	0.025	10	0.250	4.300	0.030	0.3176300	0.000	10	0.000	2.020	0.012	0.0000000
230 C	C8	296	200	10000	0.009	10	0.090	4.300	0.030	2.9943100	0.000	10	0.000	2.020	0.012	0.0000000
230 C	C15	296	200	10000	0.009	10	0.090	4.300	0.030	2.9943100	0.052	10	0.520	2.020	0.012	42.0908362
230 C	C22	296	200	10000	0.032	10	0.320	4.300	0.030	10.8484384	0.000	10	0.000	2.020	0.012	0.0000000
230 C	C29	296	200	10000	0.011	10	0.110	4.300	0.030	3.6597132	0.000	10	0.000	2.020	0.012	0.0000000
230 C	C36	296	200	10000	0.010	10	0.100	4.300	0.030	3.3270120	0.000	10	0.000	2.020	0.012	0.0000000

CONTINUED. MCC-MOD TEST RESULTS

TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	---Na CALCULATIONS---					---Si CALCULATIONS---						
					LEACH DATA	ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Na	LEACH DATA	ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)
230 A	A1	292	200	50	0.040	1	0.040	1.500	0.011	3.5938984	0.059	1	0.059	51.800	0.242	0.2433752
230 A	A8	292	200	50	0.062	1	0.062	1.500	0.011	5.5705381	0.122	1	0.122	51.800	0.242	0.503250
230 A	A15	292	200	50	0.054	1	0.054	1.500	0.011	4.0517520	0.500	1	0.500	51.800	0.242	2.0955021
230 A	A22	292	200	50	0.107	1	0.107	1.500	0.011	0.6130500	1.540	1	1.540	51.800	0.242	0.3525004
230 A	A29	292	200	50	0.340	1	0.340	1.500	0.011	30.5400683	7.910	1	7.910	51.800	0.242	32.6287826
230 A	A36	292	200	50	0.509	1	0.509	1.500	0.011	53.8185085	12.000	1	12.000	51.800	0.242	52.8000520
230 B	B1	294	200	2000	0.054	5	0.270	1.500	0.011	24.2587001	0.210	5	1.080	51.800	0.242	4.4550045
230 B	B8	294	200	2000	0.050	5	0.250	1.500	0.011	20.0557053	0.420	5	2.140	51.800	0.242	8.8275088
230 B	B15	294	200	2000	0.120	5	0.600	1.500	0.011	59.9003550	1.110	5	5.550	51.800	0.242	22.8937729
230 B	B22	294	200	2000	0.170	5	0.850	1.500	0.011	79.9040011	2.100	5	10.500	51.800	0.242	44.5500446
230 B	B29	294	200	2000	0.201	5	1.005	1.500	0.011	90.2904900	2.930	5	14.650	51.800	0.242	60.4313104
230 B	B36	294	200	2000	0.353	5	1.765	1.500	0.011	150.580413	3.540	5	17.700	51.800	0.242	73.0125730
230 C	C1	296	200	10000	0.093	10	0.930	1.500	0.011	83.557951	0.754	10	7.540	51.800	0.242	31.1025311
230 C	C8	296	200	10000	0.146	10	1.460	1.500	0.011	131.178999	1.070	10	10.700	51.800	0.242	44.1375441
230 C	C15	296	200	10000	0.213	10	2.130	1.500	0.011	191.374003	1.470	10	14.700	51.800	0.242	60.6375600
230 C	C22	296	200	10000	0.310	10	3.100	1.500	0.011	270.526505	1.700	10	17.000	51.800	0.242	72.0000720
230 C	C29	296	200	10000	0.365	10	3.650	1.500	0.011	327.942490	2.100	10	21.000	51.800	0.242	89.9250099
230 C	C36	296	200	10000	0.480	10	4.800	1.500	0.011	436.657002	2.320	10	23.200	51.800	0.242	95.7000057

TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	---Sr CALCULATIONS---					---Cs CALCULATIONS---						
					LEACH DATA	ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Sr	LEACH DATA	ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)
230 A	A1	292	200	50	0.004	1	0.004	1.300	0.011	0.3102397	0.000	1	0.000	0.330	0.003	0.0000000
230 A	A8	292	200	50	0.007	1	0.007	1.300	0.011	0.5910105	0.000	1	0.000	0.330	0.003	0.0000000
230 A	A15	292	200	50	0.027	1	0.027	1.300	0.011	2.4549910	0.000	1	0.000	0.330	0.003	0.0000000
230 A	A22	292	200	50	0.079	1	0.079	1.300	0.011	7.1407540	0.000	1	0.000	0.330	0.003	0.0000000
230 A	A29	292	200	50	0.390	1	0.390	1.300	0.011	35.4009929	0.120	1	0.120	0.330	0.003	30.5010504
230 A	A36	292	200	50	0.643	1	0.643	1.300	0.011	60.4051755	0.220	1	0.220	0.330	0.003	70.6903591
230 B	B1	294	200	2000	0.012	5	0.050	1.300	0.011	5.2730001	0.000	5	0.000	0.330	0.003	0.0000000
230 B	B8	294	200	2000	0.020	5	0.090	1.300	0.011	8.0652402	0.000	5	0.000	0.330	0.003	0.0000000
230 B	B15	294	200	2000	0.051	5	0.250	1.300	0.011	23.2709594	0.000	5	0.000	0.330	0.003	0.0000000
230 B	B22	294	200	2000	0.095	5	0.470	1.300	0.011	43.2351337	0.000	5	0.000	0.330	0.003	0.0000000
230 B	B29	294	200	2000	0.132	5	0.660	1.300	0.011	60.0109111	0.060	5	0.330	0.330	0.003	100.0445307
230 B	B36	294	200	2000	0.163	5	0.810	1.300	0.011	74.1953002	0.092	5	0.460	0.330	0.003	147.8190600
230 C	C1	296	200	10000	0.031	10	0.310	1.300	0.011	20.1009431	0.010	10	0.100	0.330	0.003	51.4155339
230 C	C8	296	200	10000	0.041	10	0.410	1.300	0.011	37.2795054	0.024	10	0.240	0.330	0.003	77.1233009
230 C	C15	296	200	10000	0.055	10	0.550	1.300	0.011	50.0090020	0.032	10	0.320	0.330	0.003	102.8310070
230 C	C22	296	200	10000	0.080	10	0.800	1.300	0.011	61.7304979	0.050	10	0.500	0.330	0.003	100.3013105
230 C	C29	296	200	10000	0.091	10	0.907	1.300	0.011	82.4095399	C29 0.077	10	0.770	0.330	0.003	247.4372570
230 C	C36	296	200	10000	0.105	10	1.050	1.300	0.011	95.4719040	C36 0.093	10	0.930	0.330	0.003	290.8527909

CONTINUED. MCC-MDD TEST RESULTS

TEST #	ICP ID#	ICP LAB#	ICP LAB#	SA/V	Al CALCULATIONS						Ca CALCULATIONS					
					LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Al	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Ca
231 I A	A2	292	201	50	0.049	1	0.049	13.1	0.078	0.6318341	0.133	1	0.133	18.8	0.133	1.0000752
231 I A	A9	292	201	50	0.125	1	0.125	13.1	0.078	1.0118217	0.200	1	0.200	18.8	0.133	1.5840274
231 I A	A16	292	201	50	0.360	1	0.36	13.1	0.078	4.6420466	0.684	1	0.684	18.6	0.133	5.1432439
231 I A	A23	292	201	50	0.609	1	0.609	13.1	0.078	8.0843616	1.300	1	1.300	18.6	0.133	9.8353260
231 I A	A30	292	201	50	2.830	1	2.83	13.1	0.078	36.4916443	5.32	1	5.32	18.6	0.133	40.0030077
231 I A	A37	292	201	50	3.410	1	3.41	13.1	0.078	43.9704972	6.97	1	6.97	18.6	0.133	52.4099556
231 I B	B2	294	201	2000	0.104	5	0.52	13.1	0.078	6.7051786	0.100	5	0.54	18.6	0.133	4.0604557
231 I B	B9	294	201	2000	0.149	5	0.745	13.1	0.078	9.6064576	0.240	5	1.2	18.6	0.133	9.0232348
231 I B	B16	294	201	2000	0.351	5	1.755	13.1	0.078	22.0299773	0.621	5	3.105	18.6	0.133	23.3476201
231 I B	B23	294	201	2000	0.620	5	3.1	13.1	0.078	39.9731793	1.170	5	5.85	18.6	0.133	43.9882698
231 I B	B30	294	201	2000	0.775	5	3.875	13.1	0.078	49.9684741	1.49	5	7.45	18.6	0.133	56.0192496
231 I B	B37	294	201	2000	0.811	5	4.055	13.1	0.078	52.2874974	1.91	5	9.55	18.6	0.133	71.8099105
231 I C	C2	296	201	10000	0.221	10	2.21	13.1	0.078	28.4970085	0.308	10	3.08	18.6	0.133	23.1696361
231 I C	C9	296	201	10000	0.318	10	3.18	13.1	0.078	40.7488637	0.500	10	5	18.6	0.133	37.5988118
231 I C	C16	296	201	10000	0.380	10	3.8	13.1	0.078	48.9993811	0.699	10	6.99	18.6	0.133	52.5603429
231 I C	C23	296	201	10000	0.372	10	3.72	13.1	0.078	47.9678151	0.839	10	8.39	18.6	0.133	63.0074502
231 I C	C30	296	201	10000	0.346	10	3.46	13.1	0.078	44.6152259	0.972	10	9.72	18.6	0.133	73.0082021
231 I C	C37	296	201	10000	0.326	10	3.26	13.1	0.078	42.0363111	1.1	10	11	18.6	0.133	82.7129859

TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	Fe CALCULATIONS				Mg CALCULATIONS							
					LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Fe	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Mg
231 I A	A2	292	201	50	0.000	1	0.000	4.41	0.031	0.0000000	0.000	1	0.000	2.15	0.013	0.0000000
231 I A	A9	292	201	50	0.000	1	0.000	4.41	0.031	0.0000000	0.000	1	0.000	2.15	0.013	0.0000000
231 I A	A16	292	201	50	0.000	1	0.000	4.41	0.031	0.0000000	0.065	1	0.065	2.15	0.013	5.0130912
231 I A	A23	292	201	50	0.005	1	0.005	4.41	0.031	0.1686893	0.120	1	0.120	2.15	0.013	9.7188478
231 I A	A30	292	201	50	0.279	1	0.279	4.41	0.031	9.0500306	0.504	1	0.504	2.15	0.013	38.8753005
231 I A	A37	292	201	50	0.300	1	0.300	4.41	0.031	12.5219377	0.328	1	0.328	2.15	0.013	25.2990573
231 I B	B2	294	201	2000	0.003	5	0.016	4.41	0.031	0.5190441	0.000	5	0.000	2.15	0.013	0.0000000
231 I B	B9	294	201	2000	0.005	5	0.027	4.41	0.031	0.8758088	0.000	5	0.000	2.15	0.013	0.0000000
231 I B	B10	294	201	2000	0.010	5	0.048	4.41	0.031	1.5571322	0.050	5	0.295	2.15	0.013	22.7544448
231 I B	B23	294	201	2000	0.010	5	0.052	4.41	0.031	1.6068932	0.111	5	0.558	2.15	0.013	42.8477760
231 I B	B30	294	201	2000	0.014	5	0.070	4.41	0.031	2.2708177	0.060	5	0.340	2.15	0.013	26.2254618
231 I B	B37	294	201	2000	0.008	5	0.040	4.41	0.031	14.2737114	0	5	0.000	2.15	0.013	0.0000000
231 I C	C2	296	201	10000	0.005	10	0.050	4.41	0.031	1.6220127	0.000	10	0.000	2.15	0.013	0.0000000
231 I C	C9	296	201	10000	0.005	10	0.050	4.41	0.031	1.6220127	0.000	10	0.000	2.15	0.013	0.0000000
231 I C	C16	296	201	10000	0.004	10	0.040	4.41	0.031	1.2978101	0.050	10	0.500	2.15	0.013	38.5600558
231 I C	C23	296	201	10000	0.009	10	0.087	4.41	0.031	2.8223020	0.000	10	0.000	2.15	0.013	0.0000000
231 I C	C30	296	201	10000	0	10	0.000	4.41	0.031	0.0000000	0	10	0.000	2.15	0.013	0.0000000
231 I C	C37	296	201	10000	0	10	0.000	4.41	0.031	0.0000000	0	10	0.000	2.15	0.013	0.0000000

CONTINUED. MCC-MOD TEST RESULTS

Na CALCULATIONS											Si CALCULATIONS					
TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Na	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Si
231 I A	A2	292	201	50	0.014	1	0.014	1.38	0.010	1.387241	0.131	1	0.131	51.5	0.241	0.5436234
231 I A	A9	292	201	50	0.067	1	0.067	1.38	0.010	0.543224	0.338	1	0.338	51.5	0.241	1.4023732
231 I A	A16	292	201	50	0.071	1	0.071	1.38	0.010	0.933885	1.180	1	1.180	51.5	0.241	4.8958593
231 I A	A23	292	201	50	0.125	1	0.125	1.38	0.010	12.207508	2.320	1	2.320	51.5	0.241	9.6257572
231 I A	A30	292	201	50	0.434	1	0.434	1.38	0.010	42.384468	9.9	1	9.900	51.5	0.241	41.0754294
231 I A	A37	292	201	50	0.59	1	0.590	1.38	0.010	57.619438	12.7	1	12.700	51.5	0.241	52.6927226
231 I B	B2	294	201	2000	0.064	5	0.320	1.38	0.010	31.251221	0.172	5	0.860	51.5	0.241	3.5801686
231 I B	B9	294	201	2000	0.045	5	0.225	1.38	0.010	21.973516	0.445	5	2.225	51.5	0.241	9.2315990
231 I B	B16	294	201	2000	0.138	5	0.690	1.38	0.010	67.385446	1.180	5	5.900	51.5	0.241	24.4792963
231 I B	B23	294	201	2000	0.196	5	0.980	1.38	0.010	95.706864	2.310	5	11.550	51.5	0.241	47.9213343
231 I B	B30	294	201	2000	0.188	5	0.940	1.38	0.010	91.800461	2.90	5	14.900	51.5	0.241	61.8205958
231 I B	B37	294	201	2000	4.05	5	20.250	1.38	0.010	1977.61831	3.55	5	17.750	51.5	0.241	73.6453406
231 I C	C2	298	201	10000	0.054	10	0.540	1.38	0.010	52.736435	0.650	10	6.500	51.5	0.241	26.9687163
231 I C	C9	298	201	10000	0.130	10	1.300	1.38	0.010	132.817688	1.180	10	11.800	51.5	0.241	45.6393668
231 I C	C16	298	201	10000	0.213	10	2.130	1.38	0.010	200.015938	1.470	10	14.700	51.5	0.241	60.9907891
231 I C	C23	298	201	10000	0.296	10	2.960	1.38	0.010	289.073792	1.720	10	17.200	51.5	0.241	71.3633723
231 I C	C30	298	201	10000	0.32	10	3.200	1.38	0.010	312.512208	2.07	10	20.700	51.5	0.241	85.8849888
231 I C	C37	298	201	10000	0.428	10	4.280	1.38	0.010	417.985078	2.17	10	21.700	51.5	0.241	90.8340221

Sr CALCULATIONS											Cs CALCULATIONS						
TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Sr	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Cs	
231 I A	A2	292	201	50	0.007	1	0.0067	1.4	0.0118	0.5656873	0.000	1	0	0.34	0.003	0.0000000	
231 I A	A9	292	201	50	0.010	1	0.0101	1.4	0.0118	1.5201999	0.000	1	0	0.34	0.003	0.0000000	
231 I A	A16	292	201	50	0.061	1	0.0611	1.4	0.0118	5.1587302	0.000	1	0	0.34	0.003	0.0000000	
231 I A	A23	292	201	50	0.118	1	0.1175	1.4	0.0118	9.9206349	0.000	1	0	0.34	0.003	0.0000000	
231 I A	A30	292	201	50	0.485	1	0.485	1.4	0.0118	40.9498937	0.150	1	0.15	0.34	0.003	46.784355	
231 I A	A37	292	201	50	0.637	1	0.637	1.4	0.0118	53.7825059	0.210	1	0.21	0.34	0.003	65.498097	
231 I B	B2	294	201	2000	0.009	5	0.043	1.4	0.0118	3.8305302	0.000	5	0	0.34	0.003	0.0000000	
231 I B	B9	294	201	2000	0.021	5	0.103	1.4	0.0118	0.8963884	0.000	5	0	0.34	0.003	0.0000000	
231 I B	B16	294	201	2000	0.055	5	0.273	1.4	0.0118	23.0498454	0.000	5	0	0.34	0.003	0.0000000	
231 I B	B23	294	201	2000	0.101	5	0.505	1.4	0.0118	42.6378224	0.042	5	0.21	0.34	0.003	65.498097	
231 I B	B30	294	201	2000	0.132	5	0.66	1.4	0.0118	55.7244174	0.061	5	0.305	0.34	0.003	95.128189	
231 I B	B37	294	201	2000	0.150	5	0.78	1.4	0.0118	65.8501297	0.079	5	0.395	0.34	0.003	123.190802	
231 I C	C2	298	201	10000	0.028	10	0.28	1.4	0.0118	21.9520432	0.012	10	0.12	0.34	0.003	37.427484	
231 I C	C9	298	201	10000	0.043	10	0.43	1.4	0.0118	38.3853023	0.021	10	0.21	0.34	0.003	65.498097	
231 I C	C16	298	201	10000	0.057	10	0.57	1.4	0.0118	48.1266332	0.033	10	0.33	0.34	0.003	102.926582	
231 I C	C23	298	201	10000	0.065	10	0.65	1.4	0.0118	54.0801081	0.050	10	0.5	0.34	0.003	155.947851	
231 I C	C30	298	201	10000	0.0751	10	0.751	1.4	0.0118	63.4076326	0.063	10	0.63	0.34	0.003	198.494292	
231 I C	C37	298	201	10000	0.0808	10	0.808	1.4	0.0118	68.2201959	0.071	10	0.71	0.34	0.003	221.445948	

CONTINUED. MCC-MOD TEST RESULTS

--Al CALCULATIONS--											--Ca CALCULATIONS--						
TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Al	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Ca	
231 II A	A3	292	201	50	0.059	1	0.059	13.1	0.078	0.7667799	0.082	1	0.082	10.600	0.133	0.6165877	
231 II A	A10	292	201	50	0.100	1	0.100	13.1	0.078	1.3926140	0.160	1	0.160	10.600	0.133	1.2030980	
231 II A	A17	292	201	50	0.217	1	0.217	13.1	0.078	2.7981228	0.370	1	0.370	10.600	0.133	2.7821641	
231 II A	A24	292	201	50	0.593	1	0.593	13.1	0.078	7.6404024	1.120	1	1.120	10.600	0.133	8.4216858	
231 II A	A31	292	201	50	1.670	1	1.670	13.1	0.078	21.5339385	3.15	1	3.150	10.600	0.133	23.6859914	
231 II A	A38	292	201	50	3.120	1	3.120	13.1	0.078	40.2310700	6.39	1	6.390	10.600	0.133	48.0487255	
231 II B	B3	294	201	2000	0.121	5	0.605	13.1	0.078	7.0012172	0.128	5	0.630	10.600	0.133	4.7371903	
231 II B	B10	294	201	2000	0.140	5	0.740	13.1	0.078	9.5419047	0.246	5	1.230	10.600	0.133	9.2480157	
231 II B	B17	294	201	2000	0.335	5	1.675	13.1	0.078	21.5004114	0.620	5	3.100	10.600	0.133	23.3100233	
231 II B	B24	294	201	2000	0.587	5	2.935	13.1	0.078	37.8455746	1.110	5	5.550	10.600	0.133	41.7324011	
231 II B	B31	294	201	2000	0.774	5	3.870	13.1	0.078	49.0020012	1.49	5	7.450	10.600	0.133	58.0192496	
231 II B	B38	294	201	2000	0.783	5	3.915	13.1	0.078	50.4822571	1.86	5	9.300	10.600	0.133	69.9300699	
231 II C	C3	296	201	10000	0.194	10	1.940	13.1	0.078	25.0154735	0.291	10	2.910	10.600	0.133	21.8813445	
231 II C	C10	296	201	10000	0.324	10	3.240	13.1	0.078	41.7784196	0.547	10	5.470	10.600	0.133	41.1309121	
231 II C	C17	296	201	10000	0.384	10	3.840	13.1	0.078	49.5161640	0.713	10	7.130	10.600	0.133	53.6130538	
231 II C	C24	296	201	10000	0.390	10	3.900	13.1	0.078	50.2888385	0.942	10	9.420	10.600	0.133	70.8323934	
231 II C	C31	296	201	10000	0.343	10	3.430	13.1	0.078	44.2283887	0.998	10	9.980	10.600	0.133	75.0432363	
231 II C	C38	296	201	10000	0.309	10	3.090	13.1	0.078	39.8442335	1.09	10	10.900	10.600	0.133	81.9610497	

--Fe CALCULATIONS--											--Mg CALCULATIONS--						
TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Fe	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Mg	
231 II A	A3	292	201	50	0.000	1	0	4.410	0.031	0.0000000	0.000	1	0	2.150	0.013	0.0000000	
231 II A	A10	292	201	50	0.000	1	0	4.410	0.031	0.0000000	0.000	1	0	2.150	0.013	0.0000000	
231 II A	A17	292	201	50	0.000	1	0	4.410	0.031	0.0000000	0.000	1	0	2.150	0.013	0.0000000	
231 II A	A24	292	201	50	0.005	1	0.0045	4.410	0.031	0.1459011	0.100	1	0.100	2.150	0.013	0.1781734	
231 II A	A31	292	201	50	0.201	1	0.201	4.410	0.031	0.5204900	0.301	1	0.301	2.150	0.013	23.2172471	
231 II A	A38	292	201	50	0.417	1	0.417	4.410	0.031	13.5275056	0.329	1	0.329	2.150	0.013	25.3789910	
231 II B	B3	294	201	2000	0.004	5	0.02	4.410	0.031	0.0488051	0.000	5	0	2.150	0.013	0.0000000	
231 II B	B10	294	201	2000	0.003	5	0.0125	4.410	0.031	0.4055032	0.000	5	0	2.150	0.013	0.0000000	
231 II B	B17	294	201	2000	0.000	5	0.0405	4.410	0.031	1.3138303	0.001	5	0.305	2.150	0.013	23.5257819	
231 II B	B24	294	201	2000	0.105	5	0.525	4.410	0.031	17.0311320	0.100	5	0.54	2.150	0.013	41.0522041	
231 II B	B31	294	201	2000	0.011	5	0.055	4.410	0.031	1.7842139	0.064	5	0.32	2.150	0.013	24.0827876	
231 II B	B38	294	201	2000	0.000	5	0.03	4.410	0.031	0.9732076	0	5	0	2.150	0.013	0.0000000	
231 II C	C3	296	201	10000	0.005	10	0.049	4.410	0.031	1.5895724	0.000	10	0	2.150	0.013	0.0000000	
231 II C	C10	296	201	10000	0.005	10	0.049	4.410	0.031	1.5895724	0.047	10	0.47	2.150	0.013	38.2528443	
231 II C	C17	296	201	10000	0.000	10	0	4.410	0.031	0.0000000	0.051	10	0.51	2.150	0.013	47.0515039	
231 II C	C24	296	201	10000	0.100	10	1.00	4.410	0.031	35.0354734	0.000	10	0	2.150	0.013	0.0000000	
231 II C	C31	296	201	10000	0.005	10	0.05	4.410	0.031	1.6220127	0.000	10	0	2.150	0.013	0.0000000	
231 II C	C38	296	201	10000	0.000	10	0	4.410	0.031	0.0000000	0.000	10	0	2.150	0.013	0.0000000	

D.15

CONTINUED. MCC-MOD TEST RESULTS

CONTINUED: SEC-202 TEST RESULTS																		
Na CALCULATIONS										Si CALCULATIONS								
TEST #	ICP ID#	ICP LAB#	ICP LAB#	SA/V	LEACH ICP	DILUTION	C	Oxide Wt%	F	Normalized	LEACH ICP	DILUTION	C	Oxide Wt%	F	Normalized		
	(Leach)	(Leach)	(Glass)	(/m)	DATA	FACTOR		(glass ICP)		Conc. Na	DATA	FACTOR		(glass ICP)		Conc. Si		
231 II A	A3		292	201	50		0.007	1	0.007	1.380	0.010	0.543224	0.128	1	0.128	51.5	0.241	0.5310783
231 II A	A10		292	201	50		0.009	1	0.009	1.380	0.010	0.601740	0.259	1	0.259	51.5	0.241	1.0745990
231 II A	A17		292	201	50		0.004	1	0.004	1.380	0.010	0.180040	0.593	1	0.593	51.5	0.241	2.4603767
231 II A	A24		292	201	50		0.107	1	0.107	1.380	0.010	10.449627	1.990	1	1.99	51.5	0.241	8.2565762
231 II A	A31		292	201	50		0.235	1	0.235	1.380	0.010	22.950115	5.8	1	5.8	51.5	0.241	24.0043030
231 II A	A38		292	201	50		0.514	1	0.514	1.380	0.010	50.197273	11.5	1	11.5	51.5	0.241	47.7130827
231 II B	B3		294	201	2000		0.073	5	0.365	1.380	0.010	35.645924	0.107	5	0.935	51.5	0.241	3.8793461
231 II B	B10		294	201	2000		0.040	5	0.2	1.380	0.010	19.532013	0.430	5	2.19	51.5	0.241	9.0803829
231 II B	B17		294	201	2000		0.090	5	0.49	1.380	0.010	47.853432	1.170	5	5.05	51.5	0.241	24.2710447
231 II B	B24		294	201	2000		0.130	5	0.60	1.380	0.010	87.305445	2.170	5	10.05	51.5	0.241	45.0170110
231 II B	B31		294	201	2000		0.101	5	0.005	1.380	0.010	80.302359	2.90	5	14.0	51.5	0.241	61.8205958
231 II B	B38		294	201	2000		0.311	5	1.555	1.380	0.010	151.001401	3.49	5	17.45	51.5	0.241	72.4000307
231 II C	C3		296	201	10000		0.071	10	0.71	1.380	0.010	60.330040	0.613	10	6.13	51.5	0.241	25.4335740
231 II C	C10		296	201	10000		0.102	10	1.02	1.380	0.010	99.613206	1.100	10	11.8	51.5	0.241	48.9585920
231 II C	C17		296	201	10000		0.218	10	2.18	1.380	0.010	212.000041	1.500	10	15	51.5	0.241	62.2354991
231 II C	C24		296	201	10000		0.310	10	3.1	1.380	0.010	302.748201	1.790	10	17.9	51.5	0.241	74.2670956
231 II C	C31		296	201	10000		0.334	10	3.34	1.380	0.010	320.184617	2.090	10	20.9	51.5	0.241	80.7147955
231 II C	C38		296	201	10000		0.435	10	4.35	1.380	0.010	424.021202	2.160	10	21.6	51.5	0.241	89.0191187

Sr CALCULATIONS																	Ca CALCULATIONS																
TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Sr	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Ca																	
231 II A	A3	292	201	50	0.007	1	0.0006	1.4	0.012	0.5572442	0.000	1	0	0.34	0.003	0.0000000																	
231 II A	A10	292	201	50	0.014	1	0.014	1.4	0.012	1.1820331	0.000	1	0	0.34	0.003	0.0000000																	
231 II A	A17	292	201	50	0.031	1	0.0300	1.4	0.012	2.0004728	0.000	1	0	0.34	0.003	0.0000000																	
231 II A	A24	292	201	50	0.101	1	0.101	1.4	0.012	8.5275245	0.000	1	0	0.34	0.003	0.0000000																	
231 II A	A31	292	201	50	0.29	1	0.29	1.4	0.012	24.4849713	0.005	1	0.005	0.34	0.003	26.511135																	
231 II A	A38	292	201	50	0.502	1	0.502	1.4	0.012	49.1300045	0.190	1	0.19	0.34	0.003	59.260183																	
231 II B	B3	294	201	2000	0.011	5	0.0535	1.4	0.012	4.5170550	0.000	5	0	0.34	0.003	0.0000000																	
231 II B	B10	294	201	2000	0.021	5	0.105	1.4	0.012	8.0052402	0.000	5	0	0.34	0.003	0.0000000																	
231 II B	B17	294	201	2000	0.054	5	0.2605	1.4	0.012	22.0097002	0.000	5	0	0.34	0.003	0.0000000																	
231 II B	B24	294	201	2000	0.095	5	0.475	1.4	0.012	40.1040944	0.040	5	0.2	0.34	0.003	62.379140																	
231 II B	B31	294	201	2000	0.132	5	0.60	1.4	0.012	55.7244174	0.061	5	0.305	0.34	0.003	95.120109																	
231 II B	B38	294	201	2000	0.155	5	0.775	1.4	0.012	65.4339750	0.003	5	0.415	0.34	0.003	129.438716																	
231 II C	C3	296	201	10000	0.025	10	0.25	1.4	0.012	21.1077339	0.012	10	0.12	0.34	0.003	37.427484																	
231 II C	C10	296	201	10000	0.047	10	0.467	1.4	0.012	39.4292409	0.021	10	0.21	0.34	0.003	65.490097																	
231 II C	C17	296	201	10000	0.058	10	0.50	1.4	0.012	40.9090420	0.034	10	0.34	0.34	0.003	100.044539																	
231 II C	C24	296	201	10000	0.060	10	0.603	1.4	0.012	55.9777102	0.052	10	0.52	0.34	0.003	102.105765																	
231 II C	C31	296	201	10000	0.0755	10	0.755	1.4	0.012	63.7453563	0.065	10	0.65	0.34	0.003	202.732200																	
231 II C	C38	296	201	10000	0.0803	10	0.803	1.4	0.012	67.7900412	0.071	10	0.71	0.34	0.003	221.445948																	

CONTINUED. MCC-MOD TEST RESULTS

AI CALCULATIONS										Ca CALCULATIONS									
TEST #	ICP ID#	ICP LAB#	ICP LAB#	SA/V	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. AI	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Ca			
(Leach)	(Leach)	(Leach)	(Glass)	(#)															
231 III A	A4	292	201	50	0.059	1	0.0590	13.10	0.070	0.7007799	0.093	1	0.0930	10.00	0.133	0.6993007			
231 III A	A11	292	201	50	0.110	1	0.1100	13.10	0.070	1.4104031	0.179	1	0.1790	10.00	0.133	1.3459659			
231 III A	A16	292	201	50	0.100	1	0.1000	13.10	0.070	2.4241799	0.329	1	0.3290	10.00	0.133	2.4738702			
231 III A	A25	292	201	50	1.260	1	1.2600	13.10	0.070	10.1102175	2.370	1	2.3700	10.00	0.133	17.0206080			
231 III A	A32	292	201	50	2.700	1	2.7000	13.10	0.070	34.0153497	5.13	1	5.1300	10.00	0.133	30.5733289			
231 III A	A39	292	201	50	3.260	1	3.2600	13.10	0.070	41.0073064	0.67	1	0.6700	10.00	0.133	60.1541409			
231 III B	B4	294	201	2000	0.169	5	0.8450	13.10	0.070	7.0270420	0.133	5	0.6850	10.00	0.133	5.0003760			
231 III B	B11	294	201	2000	0.130	5	0.6900	13.10	0.070	0.0072600	0.224	5	1.1200	10.00	0.133	8.4210658			
231 III B	B16	294	201	2000	0.319	5	1.5950	13.10	0.070	20.6000455	0.070	5	2.0000	10.00	0.133	21.0557036			
231 III B	B25	294	201	2000	0.570	5	2.8500	13.10	0.070	30.7490350	1.090	5	5.4500	10.00	0.133	40.9005249			
231 III B	B32	294	201	2000	0.702	5	3.5100	13.10	0.070	50.4177042	1.52	5	7.6000	10.00	0.133	57.1471539			
231 III B	B39	294	201	2000	0.702	5	3.5100	13.10	0.070	50.4177042	1.02	5	9.1000	10.00	0.133	60.4201975			
231 III C	C4	290	201	10000	0.200	10	2.0000	13.10	0.070	20.6020824	0.314	10	3.1400	10.00	0.133	23.0107070			
231 III C	C11	290	201	10000	0.300	10	3.0000	13.10	0.070	47.1041007	0.034	10	0.3400	10.00	0.133	47.0770754			
231 III C	C16	290	201	10000	0.370	10	3.7000	13.10	0.070	40.4035001	0.090	10	0.9000	10.00	0.133	52.3347020			
231 III C	C25	290	201	10000	0.302	10	3.0200	13.10	0.070	49.2572725	0.003	10	0.0300	10.00	0.133	60.3939000			
231 III C	C32	290	201	10000	0.370	10	3.7000	13.10	0.070	40.4035001	1.09	10	10.9000	10.00	0.133	01.0010407			
231 III C	C39	290	201	10000	0.320	10	3.2000	13.10	0.070	42.4231003	1.11	10	11.1000	10.00	0.133	03.4000222			
-----F-CALCULATIONS-----																			
TEST #	ICP ID#	ICP LAB#	ICP LAB#	SA/V	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Fe	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Mg			
(Leach)	(Leach)	(Leach)	(Glass)	(#)															
231 III A	A4	292	201	50	0.000	1	0.0000	4.41	0.031	0.0000000	0.000	1	0.0000	2.15	0.013	0.0000000			
231 III A	A11	292	201	50	0.000	1	0.0000	4.41	0.031	0.0000000	0.000	1	0.0000	2.15	0.013	0.0000000			
231 III A	A16	292	201	50	0.000	1	0.0000	4.41	0.031	0.0000000	0.000	1	0.0000	2.15	0.013	0.0000000			
231 III A	A25	292	201	50	0.021	1	0.0210	4.41	0.031	0.0012463	0.231	1	0.2310	2.15	0.013	17.0170873			
231 III A	A32	292	201	50	0.327	1	0.3270	4.41	0.031	10.0079026	0.49	1	0.4900	2.15	0.013	37.7956105			
231 III A	A39	292	201	50	0.45	1	0.4500	4.41	0.031	14.5001139	0.330	1	0.3300	2.15	0.013	26.9109270			
231 III B	B4	294	201	2000	0.006	5	0.0275	4.41	0.031	0.0021870	0.000	5	0.0000	2.15	0.013	0.0000000			
231 III B	B11	294	201	2000	0.004	5	0.0105	4.41	0.031	0.0001447	0.000	5	0.0000	2.15	0.013	0.0000000			
231 III B	B16	294	201	2000	0.007	5	0.0335	4.41	0.031	1.0007405	0.052	5	0.2600	2.15	0.013	20.0547040			
231 III B	B25	294	201	2000	0.000	5	0.0405	4.41	0.031	1.5004710	0.101	5	0.5000	2.15	0.013	30.9526242			
231 III B	B32	294	201	2000	0.011	5	0.0550	4.41	0.031	0.7004239	0.075	5	0.3750	2.15	0.013	20.9251417			
231 III B	B39	294	201	2000	0	5	0.0000	4.41	0.031	0.0000000	0	5	0.0000	2.15	0.013	0.0000000			
231 III C	C4	290	201	10000	0.000	10	0.0000	4.41	0.031	1.0404152	0.000	10	0.0000	2.15	0.013	0.0000000			
231 III C	C11	290	201	10000	0.000	10	0.0010	4.41	0.031	1.9700054	0.051	10	0.5100	2.15	0.013	39.3301920			
231 III C	C16	290	201	10000	0.000	10	0.0000	4.41	0.031	0.0000000	0.053	10	0.5300	2.15	0.013	40.0000000			
231 III C	C25	290	201	10000	0.030	10	0.3000	4.41	0.031	12.0010007	0.000	10	0.0000	2.15	0.013	0.0000000			
231 III C	C32	290	201	10000	0.000	10	0.0000	4.41	0.031	0.0000000	0.000	10	0.0000	2.15	0.013	0.0000000			
231 III C	C39	290	201	10000	0.000	10	0.0000	4.41	0.031	0.0000000	0.000	10	0.0000	2.15	0.013	0.0000000			

CONTINUED. MCC-MOD TEST RESULTS

TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	Na CALCULATIONS				Si CALCULATIONS							
					LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Na	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Si
231 III A	A4	292	201	50	0.030	1	0.0300	1.38	0.010	3.5157023	0.140	1	0.1400	51.50	0.241	0.6057589
231 III A	A11	292	201	50	0.050	1	0.0500	1.38	0.010	5.6642830	0.304	1	0.3040	51.50	0.241	1.2613061
231 III A	A18	292	201	50	0.085	1	0.0850	1.38	0.010	8.3011055	0.559	1	0.5590	51.50	0.241	2.3193096
231 III A	A26	292	201	50	0.160	1	0.1600	1.38	0.010	15.6256104	4.240	1	4.2400	51.50	0.241	17.5919011
231 III A	A32	292	201	50	0.300	1	0.3000	1.38	0.010	37.6067050	9.49	1	9.4900	51.50	0.241	39.3743258
231 III A	A39	292	201	50	0.510	1	0.5100	1.38	0.010	50.6055737	12	1	12.0000	51.50	0.241	49.7883993
231 III B	B4	294	201	2000	0.141	5	0.7050	1.38	0.010	68.6503457	0.204	5	1.0200	51.50	0.241	4.2320139
231 III B	B11	294	201	2000	0.160	5	0.8450	1.38	0.010	82.5227648	0.390	5	1.9800	51.50	0.241	8.2150859
231 III B	B18	294	201	2000	0.227	5	1.1350	1.38	0.010	110.844174	1.000	5	5.4000	51.50	0.241	22.4047797
231 III B	B25	294	201	2000	0.267	5	1.3350	1.38	0.010	130.370187	2.140	5	10.7000	51.50	0.241	44.3946560
231 III B	B32	294	201	2000	0.301	5	1.5050	1.38	0.010	170.270417	3.05	5	15.2500	51.50	0.241	63.2727674
231 III B	B39	294	201	2000	0.422	5	2.1100	1.38	0.010	206.002737	3.47	5	17.3500	51.50	0.241	71.9657273
231 III C	C4	296	201	10000	0.054	10	0.5400	1.38	0.010	52.738435	0.649	10	6.4900	51.50	0.241	26.9272260
231 III C	C11	296	201	10000	0.141	10	1.4100	1.38	0.010	137.700001	1.370	10	13.7000	51.50	0.241	50.8417559
231 III C	C18	296	201	10000	0.180	10	1.8000	1.38	0.010	175.780117	1.400	10	14.8000	51.50	0.241	61.4056925
231 III C	C25	296	201	10000	0.260	10	2.6000	1.38	0.010	259.775772	1.780	10	17.8000	51.50	0.241	73.8527923
231 III C	C32	296	201	10000	0.341	10	3.4100	1.38	0.010	333.020821	2.270	10	22.7000	51.50	0.241	94.1830553
231 III C	C39	296	201	10000	0.430	10	4.3000	1.38	0.010	425.797083	2.240	10	22.4000	51.50	0.241	92.9383454

TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	Sr CALCULATIONS				Cs CALCULATIONS							
					LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Sr	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Cs
231 III A	A4	292	201	50	0.008	1	0.0075	1.40	0.012	0.6332320	0.000	1	0.000	0.34	0.003	0.0000000
231 III A	A11	292	201	50	0.010	1	0.0157	1.40	0.012	1.3255857	0.000	1	0.000	0.34	0.003	0.0000000
231 III A	A18	292	201	50	0.020	1	0.0282	1.40	0.012	2.3800524	0.000	1	0.000	0.34	0.003	0.0000000
231 III A	A26	292	201	50	0.215	1	0.2150	1.40	0.012	18.1626511	0.000	1	0.000	0.34	0.003	0.0000000
231 III A	A32	292	201	50	0.472	1	0.4720	1.40	0.012	39.0514010	0.150	1	0.150	0.34	0.003	48.784355
231 III A	A39	292	201	50	0.614	1	0.6140	1.40	0.012	51.8405944	0.200	1	0.200	0.34	0.003	62.379140
231 III B	B4	294	201	2000	0.011	5	0.0525	1.40	0.012	4.4320241	0.000	5	0.000	0.34	0.003	0.0000000
231 III B	B11	294	201	2000	0.019	5	0.0950	1.40	0.012	8.0209389	0.000	5	0.000	0.34	0.003	0.0000000
231 III B	B18	294	201	2000	0.050	5	0.2500	1.40	0.012	21.1077339	0.000	5	0.000	0.34	0.003	0.0000000
231 III B	B25	294	201	2000	0.095	5	0.4750	1.40	0.012	40.1040944	0.038	5	0.190	0.34	0.003	59.280183
231 III B	B32	294	201	2000	0.132	5	0.6600	1.40	0.012	55.7244174	0.061	5	0.305	0.34	0.003	95.120189
231 III B	B39	294	201	2000	0.152	5	0.7600	1.40	0.012	64.1675110	0.083	5	0.415	0.34	0.003	129.436716
231 III C	C4	296	201	10000	0.027	10	0.2700	1.40	0.012	22.7963528	0.012	10	0.120	0.34	0.003	37.427484
231 III C	C11	296	201	10000	0.054	10	0.5400	1.40	0.012	45.5927052	0.028	10	0.280	0.34	0.003	87.330797
231 III C	C18	296	201	10000	0.057	10	0.5700	1.40	0.012	48.1258332	0.033	10	0.330	0.34	0.003	102.925582
231 III C	C25	296	201	10000	0.067	10	0.6650	1.40	0.012	50.1465721	0.049	10	0.490	0.34	0.003	152.828894
231 III C	C32	296	201	10000	0.0831	10	0.8310	1.40	0.012	70.1821074	0.07	10	0.700	0.34	0.003	218.326991
231 III C	C39	296	201	10000	0.0810	10	0.8100	1.40	0.012	69.0845052	0.072	10	0.720	0.34	0.003	224.564905

CONTINUED. MCC-MOD TEST RESULTS

D.1

TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	Al CALCULATIONS				Ca CALCULATIONS							
					LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Al	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Ca
231 IV A	A5	292	201	50	0.040	1	0.040	13.10	0.070	0.5031504	0.052	1	0.052	10.60	0.133	0.3910068
231 IV A	A12	292	201	50	0.060	1	0.060	13.10	0.070	0.8760310	0.093	1	0.093	10.60	0.133	0.6993007
231 IV A	A19	292	201	50	0.103	1	0.103	13.10	0.070	2.3597070	0.310	1	0.310	10.60	0.133	2.3310023
231 IV A	A26	292	201	50	0.509	1	0.509	13.10	0.070	7.3370120	1.070	1	1.070	10.60	0.133	8.0457177
231 IV A	A33	292	201	50	1.94	1	1.940	13.10	0.070	25.0154735	3.65	1	3.650	10.60	0.133	27.4456720
231 IV A	A40	292	201	50	3.22	1	3.220	13.10	0.070	41.5205282	5.74	1	5.740	10.60	0.133	50.6805023
231 IV B	B5	294	201	2000	0.131	5	0.655	13.10	0.070	0.4459459	0.155	5	0.775	10.60	0.133	5.0275058
231 IV B	B12	294	201	2000	0.150	5	0.780	13.10	0.070	10.0577677	0.301	5	1.505	10.60	0.133	14.3243053
231 IV B	B19	294	201	2000	0.338	5	1.690	13.10	0.070	21.7918300	0.611	5	3.055	10.60	0.133	22.9716520
231 IV B	B26	294	201	2000	0.594	5	2.970	13.10	0.070	38.2908847	1.130	5	5.650	10.60	0.133	42.4043973
231 IV B	B33	294	201	2000	0.709	5	3.545	13.10	0.070	50.8090943	1.53	5	7.650	10.60	0.133	57.6231220
231 IV B	B40	294	201	2000	0.702	5	3.510	13.10	0.070	50.4177842	1.01	5	5.050	10.60	0.133	50.0502293
231 IV C	C5	296	201	10000	0.201	10	2.010	13.10	0.070	25.0180937	0.335	10	3.350	10.60	0.133	25.1898639
231 IV C	C12	296	201	10000	0.336	10	3.360	13.10	0.070	43.3257685	0.552	10	5.520	10.60	0.133	41.5006802
231 IV C	C19	296	201	10000	0.403	10	4.030	13.10	0.070	51.9051331	0.754	10	7.540	10.60	0.133	50.0959922
231 IV C	C26	296	201	10000	0.370	10	3.700	13.10	0.070	47.7099237	0.847	10	8.470	10.60	0.133	63.6809992
231 IV C	C33	296	201	10000	0.343	10	3.430	13.10	0.070	44.2283807	0.989	10	9.890	10.60	0.133	74.3604937
231 IV C	C40	296	201	10000	0.302	10	3.020	13.10	0.070	38.9418134	1.05	10	10.500	10.60	0.133	78.9533048

D.19

TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	Fe CALCULATIONS				Mg CALCULATIONS							
					LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Fe	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Mg
231 IV A	A5	292	201	50	0.000	1	0.000	4.41	0.031	0.0000000	0.000	1	0.000	2.15	0.013	0.0000000
231 IV A	A12	292	201	50	0.000	1	0.000	4.41	0.031	0.0000000	0.000	1	0.000	2.15	0.013	0.0000000
231 IV A	A19	292	201	50	0.000	1	0.000	4.41	0.031	0.0000000	0.000	1	0.000	2.15	0.013	0.0000000
231 IV A	A26	292	201	50	0.004	1	0.004	4.41	0.031	0.1232730	0.107	1	0.107	2.15	0.013	0.2533071
231 IV A	A33	292	201	50	0.007	1	0.007	4.41	0.031	2.8223020	0.353	1	0.353	2.15	0.013	27.2282001
231 IV A	A40	292	201	50	0.290	1	0.290	4.41	0.031	9.6023149	0.299	1	0.299	2.15	0.013	23.0629797
231 IV B	B5	294	201	2000	0.005	5	0.020	4.41	0.031	0.0434400	0.000	5	0.000	2.15	0.013	0.0000000
231 IV B	B12	294	201	2000	0.004	5	0.010	4.41	0.031	0.0163840	0.000	5	0.000	2.15	0.013	0.0000000
231 IV B	B19	294	201	2000	0.000	5	0.000	4.41	0.031	1.2813900	0.054	5	0.270	2.15	0.013	20.8261020
231 IV B	B26	294	201	2000	0.011	5	0.053	4.41	0.031	1.7031133	0.105	5	0.525	2.15	0.013	40.4951984
231 IV B	B33	294	201	2000	0.012	5	0.060	4.41	0.031	1.9484152	0.083	5	0.415	2.15	0.013	32.0104902
231 IV B	B40	294	201	2000	0.0043	5	0.022	4.41	0.031	0.0974054	0	5	0.000	2.15	0.013	0.0000000
231 IV C	C5	296	201	10000	0.023	10	0.230	4.41	0.031	7.4812582	0.000	10	0.000	2.15	0.013	0.0000000
231 IV C	C12	296	201	10000	0.007	10	0.060	4.41	0.031	2.1410567	0.041	10	0.410	2.15	0.013	31.6248210
231 IV C	C19	296	201	10000	0.008	10	0.082	4.41	0.031	2.6001000	0.002	10	0.020	2.15	0.013	47.0229010
231 IV C	C26	296	201	10000	0.000	10	0.000	4.41	0.031	0.0000000	0.000	10	0.000	2.15	0.013	0.0000000
231 IV C	C33	296	201	10000	0.000	10	0.000	4.41	0.031	0.0000000	0.000	10	0.000	2.15	0.013	0.0000000
231 IV C	C40	296	201	10000	0.000	10	0.000	4.41	0.031	0.0000000	0.000	10	0.000	2.15	0.013	0.0000000

CONTINUED. MCC-MOD TEST RESULTS

Na CALCULATIONS																	Si CALCULATIONS																
TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Na	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Si																	
231 IV A	A5	292	291	50	0.030	1	0.030	1.300	0.010	3.515702	0.077	1	0.077	51.50	0.241	0.3207203																	
231 IV A	A12	292	291	50	0.009	1	0.009	1.300	0.010	0.878941	0.150	1	0.150	51.50	0.241	0.6472492																	
231 IV A	A19	292	291	50	0.102	1	0.102	1.300	0.010	9.901327	0.530	1	0.530	51.50	0.241	2.2230818																	
231 IV A	A26	292	291	50	0.002	1	0.002	1.300	0.010	0.054924	1.000	1	1.000	51.50	0.241	7.0031832																	
231 IV A	A33	292	291	50	0.202	1	0.202	1.300	0.010	27.540130	0.8	1	0.800	51.50	0.241	20.2134203																	
231 IV A	A40	292	291	50	0.530	1	0.530	1.300	0.010	52.345795	12	1	12.000	51.50	0.241	49.7883993																	
231 IV B	B5	294	291	2000	0.049	5	0.245	1.300	0.010	23.926710	0.262	5	1.260	51.50	0.241	5.2277819																	
231 IV B	B12	294	291	2000	0.049	5	0.245	1.300	0.010	23.926710	0.471	5	2.355	51.50	0.241	9.7709734																	
231 IV B	B19	294	291	2000	0.098	5	0.490	1.300	0.010	47.053432	1.150	5	5.750	51.50	0.241	23.0509413																	
231 IV B	B26	294	291	2000	0.134	5	0.670	1.300	0.010	65.432243	2.190	5	10.950	51.50	0.241	45.4319144																	
231 IV B	B33	294	291	2000	0.239	5	1.195	1.300	0.010	110.703777	3.00	5	15.300	51.50	0.241	63.4002091																	
231 IV B	B40	294	291	2000	0.315	5	1.575	1.300	0.010	153.014002	3.44	5	17.200	51.50	0.241	71.3033723																	
231 IV C	C5	296	291	10000	0.003	10	0.030	1.300	0.010	0.057054	0.630	10	0.300	51.50	0.241	20.1309090																	
231 IV C	C12	296	291	10000	0.117	10	1.170	1.300	0.010	114.202270	1.200	10	12.000	51.50	0.241	49.7883993																	
231 IV C	C19	296	291	10000	0.247	10	2.470	1.300	0.010	241.220300	1.010	10	10.100	51.50	0.241	60.7994357																	
231 IV C	C26	296	291	10000	0.329	10	3.290	1.300	0.010	321.301513	1.700	10	17.000	51.50	0.241	73.0229050																	
231 IV C	C33	296	291	10000	0.321	10	3.210	1.300	0.010	313.400000	2.090	10	20.900	51.50	0.241	80.7147955																	
231 IV C	C40	296	291	10000	0.424	10	4.240	1.300	0.010	414.070075	2.100	10	21.000	51.50	0.241	87.1290000																	

Sr CALCULATIONS										Ca CALCULATIONS						
TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Sr	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Ca
231 IV A	A5	292	291	50	0.004	1	0.004	1.40	0.012	0.3200370	0.000	1	0.000	0.34	0.003	0.0000000
231 IV A	A12	292	291	50	0.000	1	0.000	1.40	0.012	0.0501182	0.000	1	0.000	0.34	0.003	0.0000000
231 IV A	A19	292	291	50	0.027	1	0.027	1.40	0.012	2.2700353	0.000	1	0.000	0.34	0.003	0.0000000
231 IV A	A26	292	291	50	0.090	1	0.090	1.40	0.012	0.1053090	0.000	1	0.000	0.34	0.003	0.0000000
231 IV A	A33	292	291	50	0.337	1	0.337	1.40	0.012	20.4532253	0.100	1	0.100	0.34	0.003	31.1895700
231 IV A	A40	292	291	50	0.611	1	0.611	1.40	0.012	51.5073010	0.200	1	0.200	0.34	0.003	82.3791400
231 IV B	B5	294	291	2000	0.013	5	0.004	1.40	0.012	5.4035799	0.000	5	0.000	0.34	0.003	0.0000000
231 IV B	B12	294	291	2000	0.022	5	0.112	1.40	0.012	9.4502040	0.000	5	0.000	0.34	0.003	0.0000000
231 IV B	B19	294	291	2000	0.054	5	0.269	1.40	0.012	22.0097062	0.000	5	0.000	0.34	0.003	0.0000000
231 IV B	B26	294	291	2000	0.097	5	0.485	1.40	0.012	40.9400037	0.039	5	0.195	0.34	0.003	60.0190620
231 IV B	B33	294	291	2000	0.134	5	0.670	1.40	0.012	50.5007200	0.06	5	0.300	0.34	0.003	93.5007110
231 IV B	B40	294	291	2000	0.152	5	0.760	1.40	0.012	64.1075110	0.081	5	0.405	0.34	0.003	120.3177590
231 IV C	C5	296	291	10000	0.027	10	0.270	1.40	0.012	22.7903520	0.012	10	0.120	0.34	0.003	37.4274840
231 IV C	C12	296	291	10000	0.040	10	0.400	1.40	0.012	40.5200400	0.023	10	0.230	0.34	0.003	71.7300110
231 IV C	C19	296	291	10000	0.062	10	0.620	1.40	0.012	52.3471000	0.037	10	0.370	0.34	0.003	115.4014100
231 IV C	C26	296	291	10000	0.068	10	0.657	1.40	0.012	55.4711240	0.040	10	0.400	0.34	0.003	149.7099370
231 IV C	C33	296	291	10000	0.076	10	0.760	1.40	0.012	64.1075110	0.005	10	0.050	0.34	0.003	202.7322000
231 IV C	C40	296	291	10000	0.0707	10	0.707	1.40	0.012	64.7000275	0.009	10	0.090	0.34	0.003	215.2000340

D.20

CONTINUED. MCC-MDD TEST RESULTS

Al CALCULATIONS											Ca CALCULATIONS					
TEST #	ICP ID#	ICP LAB#	ICP LAB#	SA/V	LEACH DATA	DILUTION FACTOR	C	Oxide Wt%	F	Normalized Conc. Al	LEACH DATA	ICP DILUTION FACTOR	C	Oxide Wt%	F	Normalized Conc. Ca
		(Leach)	(Leach)	(/m)				(glass ICP)						(glass ICP)		
232 A	A8	292	282	50	0.084	1	0.084	13.2	0.078	0.8190008	0.090	1	0.09	18.700	0.134	0.6731237
232 A	A13	292	282	50	0.097	1	0.097	13.2	0.078	1.2412981	0.140	1	0.14	18.700	0.134	1.0470813
232 A	A20	292	282	50	0.174	1	0.174	13.2	0.078	2.2266585	0.279	1	0.279	18.700	0.134	2.0868834
232 A	A27	292	282	50	0.614	1	0.614	13.2	0.078	7.0572891	1.139	1	1.139	18.700	0.134	8.5187540
232 A	A34	292	282	50	2.35	1	2.35	13.2	0.078	30.0720063	4.47	1	4.47	18.700	0.134	33.4310008
232 A	A41	292	282	50	3.66	1	3.66	13.2	0.078	48.8366093	7.6	1	7.6	18.700	0.134	58.8415542
232 B	B6	294	282	2000	0.122	5	0.61	13.2	0.078	7.8061018	0.334	5	1.669	18.700	0.134	12.4827045
232 B	B13	294	282	2000	0.152	5	0.76	13.2	0.078	9.7256347	0.419	5	2.095	18.700	0.134	15.6888232
232 B	B20	294	282	2000	0.332	5	1.66	13.2	0.078	21.2428337	0.600	5	3.04	18.700	0.134	22.7388217
232 B	B27	294	282	2000	0.599	5	2.995	13.2	0.078	38.3268790	1.160	5	5.8	18.700	0.134	43.8790000
232 B	B34	294	282	2000	0.784	5	3.92	13.2	0.078	50.1638002	1.52	5	7.6	18.700	0.134	58.8415542
232 B	B41	294	282	2000	0.79	5	3.95	13.2	0.078	50.5477000	1.85	5	9.25	18.700	0.134	69.1821547
232 C	C6	296	282	10000	0.224	10	2.24	13.2	0.078	28.8650287	0.343	10	3.43	18.700	0.134	26.0534909
232 C	C13	296	282	10000	0.332	10	3.32	13.2	0.078	42.4056875	0.577	10	5.77	18.700	0.134	43.1547083
232 C	C20	296	282	10000	0.392	10	3.92	13.2	0.078	50.1638002	0.745	10	7.45	18.700	0.134	55.7198814
232 C	C27	296	282	10000	0.390	10	3.9	13.2	0.078	49.9078824	0.898	10	8.98	18.700	0.134	67.0132007
232 C	C34	296	282	10000	0.352	10	3.52	13.2	0.078	45.0450450	0.977	10	9.77	18.700	0.134	73.0713137
232 C	C41	296	282	10000	0.307	10	3.07	13.2	0.078	39.2864455	1.1	10	11	18.700	0.134	82.2708705

Fe CALCULATIONS											Mg CALCULATIONS						
TEST #	ICP ID#	ICP LAB#	ICP LAB#	SA/V	LEACH DATA	DILUTION FACTOR	C	Oxide Wt%	F	Normalized Conc. Fe	LEACH DATA	ICP DILUTION FACTOR	C	Oxide Wt%	F	Normalized Conc. Mg	
	(Leach)	(Leach)	(Glass)	(/m)				(glass ICP)						(glass ICP)			
232 A	A8	292	282	50	0.000	1	0	4.460	0.031	0.0000000	0.000	1	0	2.160	0.013	0.0000000	
232 A	A13	292	282	50	0.000	1	0	4.460	0.031	0.0000000	0.000	1	0	2.160	0.013	0.0000000	
232 A	A20	292	282	50	0.000	1	0	4.460	0.031	0.0000000	0.000	1	0	2.160	0.013	0.0000000	
232 A	A27	292	282	50	0.000	1	0.0004	4.460	0.031	0.2052901	0.119	1	0.119	2.160	0.013	9.1384187	
232 A	A34	292	282	50	0.366	1	0.366	4.460	0.031	11.7400250	0.431	1	0.431	2.160	0.013	33.0907192	
232 A	A41	292	282	50	0.602	1	0.602	4.460	0.031	19.3100971	0.324	1	0.324	2.160	0.013	24.8756219	
232 B	B6	294	282	2000	0.007	5	0.036	4.460	0.031	1.1547506	0.054	5	0.27	2.160	0.013	20.7296849	
232 B	B13	294	282	2000	0.005	5	0.0245	4.460	0.031	0.7058760	0.000	5	0	2.160	0.013	0.0000000	
232 B	B20	294	282	2000	0.008	5	0.042	4.460	0.031	1.3472161	0.053	5	0.265	2.160	0.013	20.3450019	
232 B	B27	294	282	2000	0.002	5	0.009	4.460	0.031	0.2000002	0.109	5	0.545	2.160	0.013	41.0432529	
232 B	B34	294	282	2000	0.012	5	0.06	4.460	0.031	1.9245944	0.06	5	0.3	2.160	0.013	23.0329032	
232 B	B41	294	282	2000	0.0074	5	0.037	4.460	0.031	1.1800332	0	5	0	2.160	0.013	0.0000000	
232 C	C6	296	282	10000	0.011	10	0.11	4.460	0.031	3.5284231	0.000	10	0	2.160	0.013	0.0000000	
232 C	C13	296	282	10000	0.012	10	0.12	4.460	0.031	3.0491000	0.040	10	0.4	2.160	0.013	30.7108443	
232 C	C20	296	282	10000	0.011	10	0.11	4.460	0.031	3.5284231	0.053	10	0.53	2.160	0.013	40.6916037	
232 C	C27	296	282	10000	0.000	10	0	4.460	0.031	0.0000000	0.000	10	0	2.160	0.013	0.0000000	
232 C	C34	296	282	10000	0.011	10	0.11	4.460	0.031	3.5284231	0.000	10	0	2.160	0.013	0.0000000	
232 C	C41	296	282	10000	0.000	10	0	4.460	0.031	0.0000000	0.000	10	0	2.160	0.013	0.0000000	

CONTINUED. MCC-MOD TEST RESULTS

Na CALCULATIONS											Si CALCULATIONS						
TEST #	ICP ID#	ICP LAB#	ICP LAB#	SA/V	LEACH DATA	ICP DILUTION FACTOR	C	Oxide Wt%	F	Normalized Conc. Na	LEACH DATA	ICP DILUTION FACTOR	C	Oxide Wt%	F	Normalized Conc. Si	
	(Leach)	(Leach)	(Glass)	(/m)				(glass ICP)						(glass ICP)			
232 A	A6	292	202	50	0.036	1	0.030	1.470	0.011	3.300512	0.140	1	0.14	52	0.243	0.6752794	
232 A	A13	292	202	50	0.010	1	0.010	1.470	0.011	1.850256	0.242	1	0.242	52	0.243	0.9944116	
232 A	A20	292	202	50	0.000	1	0.00	1.470	0.011	7.334470	0.405	1	0.405	52	0.243	1.9929323	
232 A	A27	292	202	50	0.150	1	0.150	1.470	0.011	14.302217	2.020	1	2.02	52	0.243	8.3004602	
232 A	A34	292	202	50	0.354	1	0.354	1.470	0.011	32.455031	0.23	1	0.23	52	0.243	33.6182117	
232 A	A41	292	202	50	0.615	1	0.615	1.470	0.011	56.303739	13.7	1	13.7	52	0.243	56.2952005	
232 B	B6	294	202	2000	0.058	5	0.2905	1.470	0.011	20.633295	0.180	5	0.93	52	0.243	8.8214990	
232 B	B13	294	202	2000	0.002	5	0.31	1.470	0.011	20.421072	0.402	5	2.31	52	0.243	9.4921105	
232 B	B20	294	202	2000	0.185	5	0.025	1.470	0.011	75.630724	1.150	5	5.75	52	0.243	23.6275477	
232 B	B27	294	202	2000	0.191	5	0.955	1.470	0.011	87.555238	2.240	5	11.2	52	0.243	40.0223537	
232 B	B34	294	202	2000	0.239	5	1.195	1.470	0.011	109.550048	3.07	5	15.35	52	0.243	63.0752794	
232 B	B41	294	202	2000	0.317	5	1.505	1.470	0.011	145.314190	3.40	5	17.4	52	0.243	71.4990130	
232 C	C6	290	202	10000	0.003	10	0.03	1.470	0.011	70.095120	0.074	10	0.74	52	0.243	27.6955950	
232 C	C13	290	202	10000	0.161	10	1.51	1.470	0.011	130.430125	1.250	10	12.5	52	0.243	51.3042341	
232 C	C20	290	202	10000	0.223	10	2.23	1.470	0.011	204.448355	1.570	10	15.7	52	0.243	64.5134780	
232 C	C27	290	202	10000	0.270	10	2.70	1.470	0.011	253.039221	1.840	10	18.4	52	0.243	75.6081525	
232 C	C34	290	202	10000	0.335	10	3.35	1.470	0.011	307.130939	2.050	10	20.5	52	0.243	84.2373439	
232 C	C41	290	202	10000	0.437	10	4.37	1.470	0.011	400.645433	2.190	10	21.9	52	0.243	89.9901301	

Sr CALCULATIONS											Cs CALCULATIONS						
TEST #	ICP ID#	ICP LAB#	ICP LAB#	SA/V	LEACH DATA	DILUTION FACTOR	C	Oxide Wt%	F	Normalized	LEACH DATA	ICP DILUTION	C	Oxide Wt%	F	Normalized	
	(Leach)	(Leach)	(Glass)	(/m)				(glass ICP)		Conc. Sr		FACTOR		(glass ICP)		Conc. Cs	
232 A	A6	292	202	50	0.007	1	0.0067	1.4	0.012	0.5050873	0.000	1	0	0.34	0.003	0.0000000	
232 A	A13	292	202	50	0.012	1	0.012	1.4	0.012	1.0131712	0.000	1	0	0.34	0.003	0.0000000	
232 A	A20	292	202	50	0.024	1	0.0244	1.4	0.012	2.0001148	0.000	1	0	0.34	0.003	0.0000000	
232 A	A27	292	202	50	0.102	1	0.102	1.4	0.012	8.0119554	0.000	1	0	0.34	0.003	0.0000000	
232 A	A34	292	202	50	0.411	1	0.411	1.4	0.012	34.7011145	0.130	1	0.13	0.34	0.003	40.548441	
232 A	A41	292	202	50	0.690	1	0.690	1.4	0.012	59.0172230	0.230	1	0.23	0.34	0.003	71.736011	
232 B	B6	294	202	2000	0.012	5	0.061	1.4	0.012	5.1502071	0.000	5	0	0.34	0.003	0.0000000	
232 B	B13	294	202	2000	0.021	5	0.107	1.4	0.012	9.0341101	0.000	5	0	0.34	0.003	0.0000000	
232 B	B20	294	202	2000	0.052	5	0.2616	1.4	0.012	22.0700000	0.000	5	0	0.34	0.003	0.0000000	
232 B	B27	294	202	2000	0.090	5	0.4905	1.4	0.012	41.4133739	0.041	5	0.205	0.34	0.003	63.930019	
232 B	B34	294	202	2000	0.132	5	0.68	1.4	0.012	55.7244174	0.061	5	0.305	0.34	0.003	95.128189	
232 B	B41	294	202	2000	0.152	5	0.70	1.4	0.012	64.1075110	0.082	5	0.41	0.34	0.003	127.077238	
232 C	C6	290	202	10000	0.029	10	0.29	1.4	0.012	24.4049713	0.015	10	0.15	0.34	0.003	40.704355	
232 C	C13	290	202	10000	0.040	10	0.40	1.4	0.012	40.5260490	0.025	10	0.25	0.34	0.003	77.973926	
232 C	C20	290	202	10000	0.050	10	0.50	1.4	0.012	40.0009420	0.030	10	0.30	0.34	0.003	110.520367	
232 C	C27	290	202	10000	0.067	10	0.672	1.4	0.012	56.7375007	0.052	10	0.52	0.34	0.003	102.105705	
232 C	C34	290	202	10000	0.075	10	0.75	1.4	0.012	63.3232010	0.060	10	0.60	0.34	0.003	205.051103	
232 C	C41	290	202	10000	0.0804	10	0.804	1.4	0.012	67.0024721	0.061	10	0.61	0.34	0.003	190.250378	

CONTINUED. MCC-MOD TEST RESULTS

Al CALCULATIONS											Ca CALCULATIONS						
TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Al	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Ca	
233 A	A7	292	203	50	0.000	1	0.000	13.2	0.078	0.7878133	0.147	1	0.147	18.7	0.134	1.0994353	
233 A	A14	292	203	50	0.000	1	0.000	13.2	0.078	1.1389230	0.240	1	0.24	18.7	0.134	1.7949964	
233 A	A21	292	203	50	0.100	1	0.100	13.2	0.078	2.3834308	0.615	1	0.615	18.7	0.134	4.5998784	
233 A	A28	292	203	50	0.504	1	0.504	13.2	0.078	6.4496314	1.640	1	1.64	18.7	0.134	12.2658091	
233 A	A35	292	203	50	1.000	1	1.000	13.2	0.078	13.8206300	2.8	1	2.8	18.7	0.134	20.9416252	
233 A	A42	292	203	50	1.000	1	1.000	13.2	0.078	29.8022113	3.77	1	3.77	18.7	0.134	28.1964025	
233 B	B7	294	203	2000	0.150	5	0.700	13.2	0.078	9.9615725	0.411	5	2.055	18.7	0.134	15.3696571	
233 B	B14	294	203	2000	0.202	5	1.010	13.2	0.078	12.9240587	0.582	5	2.91	18.7	0.134	21.7643319	
233 B	B21	294	203	2000	0.302	5	1.010	13.2	0.078	23.1823609	0.750	5	3.75	18.7	0.134	28.0468195	
233 B	B28	294	203	2000	0.505	5	2.925	13.2	0.078	37.4300908	0.968	5	4.84	18.7	0.134	36.1990950	
233 B	B35	294	203	2000	0.812	5	4.060	13.2	0.078	51.9553845	1.09	5	5.45	18.7	0.134	46.7813777	
233 B	B42	294	203	2000	0.801	5	4.305	13.2	0.078	55.0906020	1.17	5	5.85	18.7	0.134	48.7630384	
233 C	C7	296	203	10000	0.262	10	2.620	13.2	0.078	33.5278400	0.703	10	7.03	18.7	0.134	57.0659287	
233 C	C14	296	203	10000	0.357	10	3.570	13.2	0.078	45.6848894	0.825	10	8.25	18.7	0.134	61.7030029	
233 C	C21	296	203	10000	0.422	10	4.220	13.2	0.078	54.8028665	0.940	10	9.40	18.7	0.134	70.7527766	
233 C	C28	296	203	10000	0.384	10	3.840	13.2	0.078	49.1400491	0.843	10	8.43	18.7	0.134	63.0492502	
233 C	C35	296	203	10000	0.411	10	4.110	13.2	0.078	52.5952088	0.994	10	9.94	18.7	0.134	74.3427695	
233 C	C42	296	203	10000	0.342	10	3.420	13.2	0.078	43.7653563	1.04	10	10.4	18.7	0.134	77.7831794	

Fe CALCULATIONS											Mg CALCULATIONS						
TEST #	ICP ID# (Leach)	ICP LAB# (Leach)	ICP LAB# (Glass)	SA/V (/m)	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Fe	LEACH ICP DATA	DILUTION FACTOR	C	Oxide Wt% (glass ICP)	F	Normalized Conc. Mg	
233 A	A7	292	203	50	0.005	1	0.005	4.52	0.032	0.1502539	0.000	1	0	2.10	0.013	0.0000000	
233 A	A14	292	203	50	0.005	1	0.0048	4.52	0.032	0.1519237	0.000	1	0	2.10	0.013	0.0000000	
233 A	A21	292	203	50	0.015	1	0.015	4.52	0.032	0.4747617	0.050	1	0.05	2.10	0.013	3.8386305	
233 A	A28	292	203	50	0.013	1	0.013	4.52	0.032	0.4114001	0.134	1	0.134	2.10	0.013	10.2880658	
233 A	A35	292	203	50	0.062	1	0.062	4.52	0.032	1.9823482	0.218	1	0.218	2.10	0.013	16.7373011	
233 A	A42	292	203	50	0.140	1	0.140	4.52	0.032	4.8210136	0.286	1	0.286	2.10	0.013	21.9581107	
233 B	B7	294	203	2000	0.033	5	0.1645	4.52	0.032	5.2065530	0.000	5	0	2.10	0.013	0.0000000	
233 B	B14	294	203	2000	0.031	5	0.1535	4.52	0.032	4.8583944	0.000	5	0	2.10	0.013	0.0000000	
233 B	B21	294	203	2000	0.025	5	0.124	4.52	0.032	8.9248905	0.050	5	0.25	2.10	0.013	19.1941527	
233 B	B28	294	203	2000	0.011	5	0.057	4.52	0.032	1.8040943	0.050	5	0.20	2.10	0.013	21.4974510	
233 B	B35	294	203	2000	0.013	5	0.065	4.52	0.032	2.0573000	0.057	5	0.205	2.10	0.013	21.8813341	
233 B	B42	294	203	2000	0.0040	5	0.023	4.52	0.032	0.7279879	0	5	0	2.10	0.013	0.0000000	
233 C	C7	296	203	10000	0.011	10	0.11	4.52	0.032	3.4815058	0.000	10	0	2.10	0.013	0.0000000	
233 C	C14	296	203	10000	0.044	10	0.44	4.52	0.032	13.9283423	0.000	10	0	2.10	0.013	0.0000000	
233 C	C21	296	203	10000	0.050	10	0.5	4.52	0.032	15.8253800	0.054	10	0.54	2.10	0.013	41.4593698	
233 C	C28	296	203	10000	0.053	10	0.53	4.52	0.032	10.7749123	0.000	10	0	2.10	0.013	0.0000000	
233 C	C35	296	203	10000	0.048	10	0.48	4.52	0.032	15.1923734	0	10	0	2.10	0.013	0.0000000	
233 C	C42	296	203	10000	0.048	10	0.48	4.52	0.032	15.1923734	0	10	0	2.10	0.013	0.0000000	

CONTINUED. MCC-MOD TEST RESULTS

Na CALCULATIONS										Si CALCULATIONS						
TEST #	ICP ID#	ICP LAB#	ICP LAB#	SA/V	LEACH ICP	DILUTION	C	Oxide Wt%	F	Normalized	LEACH ICP	DILUTION	C	Oxide Wt%	F	Normalized
(Leach)	(Leach)	(Glass)	(/m)	DATA	FACTOR	(glass ICP)	Conc. Na				DATA	FACTOR	(glass ICP)	Conc. Si		
233 A	A7	292	203	50	0.054	1	0.054	1.74	0.013	4.102545	0.165	1	0.165	52.4	0.245	0.672832
233 A	A14	292	203	50	0.010	1	0.010	1.74	0.013	1.394182	0.279	1	0.279	52.4	0.245	1.137698
233 A	A21	292	203	50	0.111	1	0.111	1.74	0.013	0.597463	0.799	1	0.799	52.4	0.245	3.258139
233 A	A28	292	203	50	0.120	1	0.12	1.74	0.013	9.294544	2.480	1	2.48	52.4	0.245	10.031317
233 A	A36	292	203	50	0.177	1	0.177	1.74	0.013	13.709453	5.29	1	5.29	52.4	0.245	21.571410
233 A	A42	292	203	50	0.32	1	0.32	1.74	0.013	24.785451	8.99	1	8.99	52.4	0.245	38.059164
233 B	B7	294	203	2000	0.107	5	0.535	1.74	0.013	41.438170	0.332	5	1.66	52.4	0.245	0.769100
233 B	B14	294	203	2000	0.080	5	0.4	1.74	0.013	30.981814	0.682	5	3.31	52.4	0.245	13.497423
233 B	B21	294	203	2000	0.147	5	0.735	1.74	0.013	58.929083	1.310	5	6.55	52.4	0.245	20.709402
233 B	B28	294	203	2000	0.200	5	1	1.74	0.013	77.454534	2.175	5	10.875	52.4	0.245	44.345762
233 B	B36	294	203	2000	0.271	5	1.355	1.74	0.013	104.950894	2.92	5	14.6	52.4	0.245	59.535460
233 B	B42	294	203	2000	0.394	5	1.97	1.74	0.013	152.585432	3.52	5	17.6	52.4	0.245	71.768774
233 C	C7	296	203	10000	0.003	10	0.03	1.74	0.013	84.287263	0.925	10	9.25	52.4	0.245	37.719384
233 C	C14	296	203	10000	0.213	10	2.13	1.74	0.013	184.978158	1.540	10	15.4	52.4	0.245	62.797677
233 C	C21	296	203	10000	0.307	10	3.07	1.74	0.013	209.740047	2.020	10	20.2	52.4	0.245	82.370979
233 C	C28	296	203	10000	0.370	10	3.70	1.74	0.013	292.778139	2.150	10	21.5	52.4	0.245	87.672082
233 C	C36	296	203	10000	0.434	10	4.34	1.74	0.013	336.152670	2.52	10	25.2	52.4	0.245	102.759838
233 C	C42	296	203	10000	0.53	10	5.3	1.74	0.013	410.509031	2.73	10	27.3	52.4	0.245	111.323155

Sr CALCULATIONS										Ca CALCULATIONS						
TEST #	ICP ID#	ICP LAB#	ICP LAB#	SA/V	LEACH ICP	DILUTION	C	Oxide Wt%	F	Normalized	LEACH ICP	DILUTION	C	Oxide Wt%	F	Normalized
(Leach)	(Leach)	(Glass)	(/m)	DATA	FACTOR	(glass ICP)	Conc. Sr				DATA	FACTOR	(glass ICP)	Conc. Ca		
233 A	A7	292	203	50	0.000	1	0.0002	1.39	0.012	0.5272378	0.000	1	0	0.30	0.003	0.000000
233 A	A14	292	203	50	0.010	1	0.01	1.39	0.012	0.0503835	0.000	1	0	0.30	0.003	0.000000
233 A	A21	292	203	50	0.024	1	0.0241	1.39	0.012	2.0494243	0.000	1	0	0.30	0.003	0.000000
233 A	A28	292	203	50	0.070	1	0.0701	1.39	0.012	5.9611885	0.000	1	0	0.30	0.003	0.000000
233 A	A36	292	203	50	0.131	1	0.131	1.39	0.012	11.1400242	0.180	1	0.18	0.30	0.003	53.022269
233 A	A42	292	203	50	0.181	1	0.181	1.39	0.012	15.3919410	0.410	1	0.41	0.30	0.003	120.772947
233 B	B7	294	203	2000	0.021	5	0.104	1.39	0.012	8.0439088	0.000	5	0	0.30	0.003	0.000000
233 B	B14	294	203	2000	0.031	5	0.1545	1.39	0.012	13.1384254	0.000	5	0	0.30	0.003	0.000000
233 B	B21	294	203	2000	0.050	5	0.248	1.39	0.012	21.0095114	0.000	5	0	0.30	0.003	0.000000
233 B	B28	294	203	2000	0.074	5	0.368	1.39	0.012	31.2941136	0.068	5	0.34	0.30	0.003	100.153175
233 B	B36	294	203	2000	0.0809	5	0.4445	1.39	0.012	37.7995476	0.11	5	0.55	0.30	0.003	162.012490
233 B	B42	294	203	2000	0.004	5	0.42	1.39	0.012	35.7181000	0.17	5	0.85	0.30	0.003	250.302939
233 C	C7	296	203	10000	0.040	10	0.4	1.39	0.012	34.0153400	0.032	10	0.32	0.30	0.003	94.261812
233 C	C14	296	203	10000	0.051	10	0.51	1.39	0.012	43.3895597	0.051	10	0.51	0.30	0.003	150.229763
233 C	C21	296	203	10000	0.050	10	0.503	1.39	0.012	47.0785023	0.079	10	0.79	0.30	0.003	232.708849
233 C	C28	296	203	10000	0.047	10	0.468	1.39	0.012	39.7979489	0.110	10	1.1	0.30	0.003	324.024979
233 C	C36	296	203	10000	0.004	10	0.04	1.39	0.012	54.4245455	0.14	10	1.4	0.30	0.003	412.395428
233 C	C42	296	203	10000	0.0577	10	0.577	1.39	0.012	49.0671293	0.10	10	1.0	0.30	0.003	471.309061

D.24

CONTINUED. MCC-MOD TEST RESULTS
Summary of Normalized Concentration Result (g/m³) for MCC-Mod Testing of ORNL Pilot-Scale ISV Products

ISV	(Leach)	SA/V	(days)	TIME	T*SA/V	Al	Ca	Fe	Mg	Na	Si	Sr	Cs
230A	A1	50	0.022	-1.854	0.045	0.62787	0.83425	0.00000	0.00000	3.59389	0.24338	0.31824	0.00000
230A	A8	50	0.003	-1.204	0.495	0.87899	0.76435	0.00000	0.00000	5.57053	0.50325	0.59102	0.00000
230A	A15	50	0.199	-0.701	0.990	2.52059	2.73215	0.00000	0.00000	4.85175	2.09550	2.45499	0.00000
230A	A22	50	0.567	-0.248	1.453	6.12331	7.65978	0.18964	7.55299	9.61386	6.35251	7.14675	0.00000
230A	A29	50	2.017	0.305	2.004	29.62475	35.04635	9.34090	32.92120	30.54807	32.02878	35.46099	38.58185
230A	A36	50	0.285	0.798	2.497	45.26499	57.89559	14.03999	25.12192	53.61851	52.00005	58.48518	70.89636
230A	B1	2000	0.017	-1.777	1.524	9.03980	7.11498	1.11455	0.00000	24.25876	4.45500	5.27309	0.00000
230A	B8	2000	0.050	-1.301	2.000	9.17177	10.48951	0.58223	0.00000	28.05571	8.82751	8.86525	0.00000
230A	B15	2000	0.158	-0.601	2.501	21.90667	25.85788	1.29753	23.39786	53.90836	22.09377	23.27896	0.00000
230A	B22	2000	0.541	-0.207	3.034	38.40268	48.78842	1.92907	44.74328	79.96406	44.55004	43.25513	0.00000
230A	B29	2000	1.322	0.121	3.422	49.88387	64.23009	1.00351	21.75591	90.29650	60.43131	60.01091	100.04454
230A	B36	2000	5.148	0.711	4.012	53.57897	85.78031	0.74868	0.00000	156.58041	73.01267	74.19531	147.81906
230A	C1	10000	0.038	-1.418	2.582	32.99198	32.78958	0.31753	0.00000	83.55795	31.10253	28.18694	51.41553
230A	C8	10000	0.124	-0.900	3.092	41.17399	42.36461	2.99431	0.00000	131.17780	44.13764	37.27951	77.12330
230A	C15	10000	0.360	-0.444	3.550	50.27977	60.00978	2.99431	42.00064	191.37406	80.03750	50.00900	102.83107
230A	C22	10000	1.001	0.020	4.020	49.48796	79.52513	10.04844	0.00000	278.52650	72.00007	61.73850	186.38131
230A	C29	10000	3.199	0.505	4.505	46.30925	104.89510	3.65971	0.00000	327.94250	89.92509	82.48954	247.43726
230A	C36	10000	9.026	0.955	4.955	44.47318	125.22301	3.32701	0.00000	436.85768	95.70010	95.47190	298.85279
231IA	A2	50	0.024	-1.814	0.005	0.83183	1.00000	0.00000	0.00000	1.36724	0.54352	0.58569	0.00000
231IA	A9	50	0.003	-1.199	0.500	1.61182	1.58403	0.00000	0.00000	0.54322	1.40237	1.52820	0.00000
231IA	A16	50	0.201	-0.698	1.003	4.84205	5.14324	0.00000	5.01369	8.93386	4.89508	5.15873	0.00000
231IA	A23	50	0.573	-0.242	1.457	8.88436	9.83533	0.18809	9.71835	12.20751	9.62578	9.92083	0.00000
231IA	A30	50	2.018	0.305	2.004	36.49164	40.00301	9.05083	38.87539	42.38447	41.07543	40.94908	46.78438
231IA	A37	50	0.286	0.798	2.497	43.97050	52.40998	12.52194	25.29986	57.61944	52.00272	53.78251	65.49810
231IB	B2	2000	0.017	-1.759	1.542	8.70516	4.86048	0.51904	0.00000	31.25122	3.50817	3.63053	0.00000
231IB	B9	2000	0.049	-1.308	1.993	9.60646	9.02323	0.87589	0.00000	21.97351	9.23160	8.89039	0.00000
231IB	B16	2000	0.150	-0.603	2.498	22.62998	23.34782	1.55713	22.75444	67.38544	24.47930	23.84905	0.00000
231IB	B23	2000	0.540	-0.267	3.034	39.97318	43.98827	1.08089	42.84778	95.78688	47.92133	42.63762	65.40610
231IB	B30	2000	1.322	0.121	3.422	49.90847	58.01925	2.27062	26.22546	91.80046	61.82006	55.72442	95.12819
231IB	B37	2000	5.148	0.711	4.012	52.28756	71.00991	14.27371	0.00000	197.71631	73.04534	65.65813	123.19880
231IC	C2	10000	0.038	-1.418	2.582	28.49781	26.15954	1.82201	0.00000	52.73644	26.96672	21.95204	37.42748
231IC	C9	10000	0.124	-0.900	3.094	40.74685	37.59081	1.62201	0.00000	132.01709	45.83937	38.80538	85.49810
231IC	C16	10000	0.361	-0.442	3.558	48.99938	52.58034	1.29761	38.56888	200.01594	60.99079	40.12683	102.92558
231IC	C23	10000	1.059	0.025	4.025	47.98782	63.80745	2.82230	0.00000	289.07379	71.30337	54.58011	155.94785
231IC	C30	10000	3.199	0.505	4.505	44.61523	78.88826	0.00000	0.00000	312.51221	65.08499	63.48763	190.49429
231IC	C37	10000	9.024	0.955	4.955	42.03631	82.71299	0.00000	0.00000	417.98508	96.03402	86.22820	221.44595
231IIA	A3	50	0.024	-1.827	0.072	0.78078	0.61659	0.00000	0.00000	0.54322	0.53188	0.55724	0.00000
231IIA	A10	50	0.003	-1.199	0.500	1.39261	1.20810	0.00000	0.00000	0.09175	1.07460	1.18203	0.00000
231IIA	A17	50	0.201	-0.697	1.002	2.79612	2.70216	0.00000	0.00000	9.18005	2.46038	2.60047	0.00000
231IIA	A24	50	0.577	-0.239	1.460	7.64648	8.42109	0.14596	8.17617	10.44963	8.25558	8.52752	0.00000
231IIA	A31	50	2.017	0.305	2.004	21.53894	23.68599	0.52049	23.21725	22.95012	24.06439	24.48497	26.51114
231IIA	A38	50	0.290	0.799	2.498	40.23107	48.84873	13.52759	25.37699	50.19727	47.71386	49.13808	59.26818
231IIB	B3	2000	0.019	-1.726	1.575	7.80122	4.73720	0.64681	0.00000	35.04592	3.87935	4.51706	0.00000
231IIB	B10	2000	0.050	-1.301	2.000	9.54198	9.24882	0.40550	0.00000	19.53201	9.08036	8.86525	0.00000
231IIB	B17	2000	0.150	-0.601	2.501	21.59841	23.31002	1.31383	23.52578	47.85343	24.27184	22.86971	0.00000
231IIB	B24	2000	0.540	-0.267	3.034	37.84557	41.73248	17.03113	41.65220	87.38544	45.01701	48.10409	62.37914
231IIB	B31	2000	1.323	0.122	3.423	49.90200	58.01925	1.78421	24.08279	86.30236	61.82006	55.72442	95.12819
231IIB	B38	2000	5.142	0.711	4.012	50.46228	89.93007	0.97321	0.00000	151.66140	72.40003	65.43398	129.43672
231IIC	C3	10000	0.036	-1.426	2.574	25.01547	21.86134	1.58957	0.00000	69.33865	25.43357	21.10773	37.42748
231IIC	C10	10000	0.124	-0.900	3.092	41.77842	41.13091	1.58957	36.25284	99.61327	48.96859	39.42025	65.49810
231IIC	C17	10000	0.361	-0.442	3.558	49.51516	53.61305	0.00000	47.05150	212.88994	62.23550	48.96994	105.04454
231IIC	C24	10000	1.060	0.025	4.025	50.28684	78.83239	35.03547	0.00000	302.74820	74.26770	55.97771	162.18577
231IIC	C31	10000	3.199	0.505	4.505	44.22839	75.84324	1.02201	0.00000	326.18402	66.71480	63.74530	202.73221
231IIC	C38	10000	9.026	0.955	4.955	39.84423	61.90105	0.00000	0.00000	424.62120	89.61912	87.79804	221.44595
231IIIA	A4	50	0.024	-1.814	0.005	0.78078	0.69930	0.00000	0.00000	3.51570	0.00570	0.63323	0.00000
231IIIA	A11	50	0.004	-1.194	0.504	1.41648	1.34597	0.00000	0.00000	5.68428	1.26131	1.32557	0.00000
231IIIA	A18	50	0.201	-0.690	1.003	2.42410	2.47387	0.00000	0.00000	8.30111	2.31931	2.36095	0.00000
231IIIA	A25	50	0.583	-0.235	1.404	16.11822	17.82089	0.80125	17.81789	15.62561	17.59190	18.15265	0.00000
231IIIA	A32	50	2.015	0.304	2.003	34.81535	38.57433	10.00790	37.79552	37.00679	39.37433	39.85140	46.78436
231IIIA	A39	50	0.292	0.799	2.498	41.90737	50.15416	14.59811	25.91093	50.88557	49.78840	51.84059	62.37914
231IIIB	B4	2000	0.018	-1.801	1.500	7.02754	5.00038	0.89211	0.00000	68.85035	4.23291	4.43282	0.00000
231IIIB	B11	2000	0.051	-1.295	2.000	8.69720	8.42189	0.60014	0.00000	82.52275	8.21509	8.02094	0.00000
231IIIB	B18	2000	0.150	-0.709	2.502	20.58665	21.65570	1.08675	20.05478	110.04417	22.40470	21.10773	0.00000
231IIIB	B25	2000	0.540	-0.267	3.034	36.74954	40.90052	1.50847	38.95252	130.37619	44.39406	40.10409	59.26818
231IIIB	B32	2000	1.324	0.122	3.423	50.41778	57.14715	1.78421	28.92514	176.27842	63.27278	55.72442	95.12819
231IIIB	B39	2000	5.142	0.711	4.012	50.41778	68.42620	0.00000	0.00000	206.06274	71.90573	64.16751	129.43672
231IIIC	C4	10000	0.038	-1.426	2.574	26.56282	23.61880	1.94642	0.00000	52.73644	26.92723	22.70635	37.42748
231IIIC	C11	10000	0.126	-0.901	3.099	47.19414	47.67276	1.97886	39.33819	137.70009	58.84178	45.59271	87.35000
231IIIC	C18	10000	0.362	-0.442	3.558	48.48360	52.33470	0.00000	40.88087	175.78812	61.40509	48.12683	102.92558
231IIIC	C25	10000	1.002	0.020	4.020	49.25727	60.39597	12.05179	0.00000	259.77577	73.85279	50.14067	152.82889
231IIIC	C32	10000	3.200	0.505	4.505	48.48360	81.90105	0.00000	0.00000	333.82082	94.18306	78.18211	218.32699
231IIIC	C39	10000	9.026	0.955	4.955	42.42315	83.46492	0.00000	0.00000	425.79788	92.93835	69.00451	224.50491

CONTINUED. MCC-MOD TEST RESULTS
 CONTINUED. Summary of Normalized Concentration Result (g/m³) for MCC-Mod Testing of DRNL Pilot-Scale ISV Products

ISV	(Leach)	SA/Y	(days)	TIME	T+SA/Y	Al	Ca	Fe	Mg	Na	Si	Sr	Cs
231IVA	A5	50	0.023	-1.648	0.059	0.59316	0.39101	0.00000	0.00000	3.51578	0.32072	0.32084	0.00000
231IVA	A12	50	0.003	-1.204	0.495	0.87083	0.89930	0.00000	0.00000	0.87894	0.84725	0.65012	0.00000
231IVA	A19	50	0.200	-0.899	1.000	2.35971	2.33100	0.00000	0.00000	9.90133	2.22380	2.27064	0.00000
231IVA	A28	50	0.587	-0.232	1.407	7.33781	8.4572	0.12327	0.25331	8.05492	7.88316	8.10537	0.00000
231IVA	A39	50	2.019	0.305	2.004	25.01547	27.44587	2.82230	27.22020	27.54614	28.21343	28.45323	31.18957
231IVA	A40	50	0.292	0.799	2.498	41.52053	50.00050	9.00231	23.00298	52.34579	49.78840	51.58738	82.37914
231IVB	B5	2000	0.018	-1.700	1.505	8.44595	5.82751	0.84845	0.00000	23.92672	5.22770	5.40350	0.00000
231IVB	B12	2000	0.040	-1.320	1.901	10.05777	14.32439	0.61636	0.00000	23.92672	9.77097	9.45820	0.00000
231IVB	B19	2000	0.157	-0.894	2.497	21.79163	22.97105	1.28139	20.02610	47.65349	23.85094	22.00971	0.00000
231IVB	B20	2000	0.537	-0.270	3.031	38.29088	42.48440	1.70311	40.49520	55.43224	45.43191	48.94900	60.81900
231IVB	B33	2000	1.320	0.121	3.422	50.80909	57.52312	1.94042	32.01049	110.70370	83.48021	50.50073	93.50071
231IVB	B40	2000	5.140	0.711	4.012	50.41778	66.05023	0.89747	0.00000	153.81400	71.30337	64.10751	120.31770
231IVC	C5	10000	0.030	-1.417	2.503	25.91000	25.18900	7.40120	0.00000	81.05705	20.13001	22.70035	37.42740
231IVC	C12	10000	0.120	-0.890	3.102	43.32577	41.00000	2.14100	31.02402	114.20220	49.78840	40.52005	71.73001
231IVC	C19	10000	0.303	-0.441	3.559	51.90513	50.89599	2.00010	47.02290	241.22030	60.79944	52.34710	115.40141
231IVC	C20	10000	1.003	0.020	4.020	47.70992	63.00000	0.00000	0.00000	321.30161	73.02209	55.47112	149.70994
231IVC	C33	10000	3.001	0.500	4.500	44.22039	74.30049	0.00000	0.00000	319.40001	80.71400	64.10751	202.73221
231IVC	C40	10000	9.030	0.950	4.950	38.94101	70.95330	0.00000	0.00000	414.07007	87.12970	64.75003	215.20003
232A	A0	50	0.022	-1.054	0.045	0.81900	0.67312	0.00000	0.00000	3.30051	0.57520	0.50509	0.00000
232A	A13	50	0.003	-1.204	0.495	1.24130	1.04700	0.00000	0.00000	1.05020	0.99441	1.01317	0.00000
232A	A20	50	0.199	-0.700	0.998	2.22000	2.00000	0.00000	0.00000	7.33447	1.99293	2.00011	0.00000
232A	A27	50	0.574	-0.241	1.450	7.85729	6.51875	0.20529	9.13042	14.30222	8.30040	8.01190	0.00000
232A	A34	50	2.010	0.305	2.004	30.07209	33.43101	11.74003	33.00072	32.45503	33.81021	34.70111	40.54044
232A	A41	50	0.204	0.790	2.497	40.83001	50.04155	19.31010	24.07502	50.30374	50.29520	50.01722	71.73001
232B	B0	2000	0.010	-1.700	1.505	7.00010	12.40270	1.15470	20.72900	20.03320	3.02150	5.15020	0.00000
232B	B13	2000	0.040	-1.320	1.901	9.72503	15.00000	0.70500	0.00000	20.42107	9.49211	9.03411	0.00000
232B	B20	2000	0.150	-0.802	2.499	21.24203	22.73002	1.34722	20.34500	75.03072	23.02755	22.07000	0.00000
232B	B27	2000	0.530	-0.271	3.030	30.32000	43.97000	0.20000	41.04325	87.05524	40.02235	41.41337	60.93000
232B	B34	2000	1.320	0.121	3.422	50.10300	50.04155	1.92459	23.03290	100.55000	83.07520	55.72442	95.12019
232B	B41	2000	5.130	0.711	4.012	50.54771	69.10215	1.10000	0.00000	145.31419	71.49901	64.10751	127.07724
232C	C0	10000	0.030	-1.420	2.574	20.00503	25.05349	3.52042	0.00000	70.00513	27.09500	24.40497	40.70430
232C	C13	10000	0.120	-0.890	3.102	42.40507	43.15471	3.04919	30.71004	130.43012	51.30423	40.52005	77.97393
232C	C20	10000	0.302	-0.442	3.550	50.10300	55.71900	3.52042	40.09100	204.44000	64.51340	40.00994	110.52037
232C	C27	10000	1.002	0.020	4.020	49.90700	67.01320	0.00000	0.00000	253.03922	75.00015	50.73759	102.10577
232C	C34	10000	3.201	0.500	4.500	45.04500	73.07131	3.52042	0.00000	307.13004	84.23734	63.32320	200.05110
232C	C41	10000	9.029	0.950	4.950	39.20045	82.27007	0.00000	0.00000	400.04549	80.00014	67.00247	100.20030
233A	A7	50	0.024	-1.014	0.005	0.70701	1.09944	0.10020	0.00000	4.10254	0.07203	0.52724	0.00000
233A	A14	50	0.005	-1.190	0.500	1.13002	1.70500	0.15192	0.00000	1.30410	1.13770	0.05030	0.00000
233A	A21	50	0.201	-0.090	1.003	2.30344	4.59900	0.47470	3.03003	0.59745	3.25014	2.04942	0.00000
233A	A20	50	0.590	-0.225	1.474	0.44003	12.20501	0.41140	10.20007	9.29454	10.03102	5.00110	0.00000
233A	A35	50	2.021	0.300	2.004	13.02004	20.94103	1.00235	10.73730	13.70045	21.57141	11.14002	53.02227
233A	A42	50	0.295	0.790	2.498	23.00221	20.10040	4.02101	21.95011	24.70545	30.05010	15.39104	120.77295
233B	B7	2000	0.017	-1.777	1.524	9.90107	15.30000	5.20055	0.00000	41.43010	8.70010	8.04399	0.00000
233B	B14	2000	0.049	-1.313	1.900	12.92400	21.70433	4.05039	0.00000	30.90101	13.49742	13.13043	0.00000
233B	B21	2000	0.150	-0.802	2.499	23.10337	20.04002	3.92470	19.19415	50.92900	20.70940	21.00051	0.00000
233B	B28	2000	0.537	-0.270	3.031	37.43000	38.19910	1.00400	21.40745	77.45453	44.34570	31.29411	100.15310
233B	B35	2000	1.321	0.121	3.422	51.95530	40.70130	2.05730	21.00133	104.95000	59.53540	37.79955	102.01249
233B	B42	2000	5.140	0.711	4.012	55.00000	43.75304	0.72797	0.00000	152.50543	71.70077	35.71011	250.30294
233C	C7	10000	0.030	-1.420	2.574	33.52700	57.00593	3.40159	0.00000	64.20720	37.71930	34.01534	94.20101
233C	C14	10000	0.120	-0.890	3.102	45.00400	61.70300	13.92034	0.00000	164.97010	62.79700	43.30950	150.22970
233C	C21	10000	0.302	-0.442	3.550	54.00207	70.75270	15.02539	41.45937	299.74000	82.37090	47.07059	232.70000
233C	C20	10000	1.003	0.020	4.020	49.14000	63.04925	10.77491	0.00000	292.77014	87.07200	39.79795	324.02490
233C	C35	10000	3.201	0.500	4.500	52.59521	74.34277	15.19237	0.00000	330.15200	102.75904	54.42455	412.39545
233C	C42	10000	9.031	0.950	4.950	43.70530	77.70310	15.19237	0.00000	410.50903	111.32310	49.00713	471.30900

231 NORMALIZED CONCENTRATION VALUES (g/m³): MEAN AND S.D. CALCULATIONS

TEST #	ICP ID#	LOG	AVG LOG	LOG S.D.	Al VALUES	Ca VALUES	Si VALUES	Sr VALUES	Cs VALUES										
	(Leach)	T=SA/Y			Normal []	231 Avg. Stand Dev	Normal []	231 Avg. Stand Dev	Normal []	231 Avg. Stand Dev									
231 I A	A02	0.005	0.075	0.011	0.8310341	0.0660	0.0754	1.0000752	0.0767	0.2101	0.5435234	0.5003	0.1075	0.5650073	0.5193	0.1103	0.0000000	0.0000	0.000
231 II	A03	0.072			0.7607799			0.6165877			0.5310763			0.5572442			0.0000000		
231 III	A04	0.005			0.7607799			0.6093007			0.6057509			0.6332320			0.0000000		
231 IV	A05	0.059			0.5931504			0.3910000			0.3207203			0.3200376			0.0000000		
231 I A	A09	0.500	0.500	0.003	1.0110217	1.3249	0.2722	1.5040274	1.2031	0.3100	1.4023732	1.0064	0.2042	1.5201999	1.1715	0.3252	0.0000000	0.0000	0.000
231 II	A10	0.500			1.3920140			1.2030000			1.0745900			1.1820331			0.0000000		
231 III	A11	0.504			1.4104031			1.3459659			1.2013001			1.3255057			0.0000000		
231 IV	A12	0.495			0.0760310			0.6993007			0.6472492			0.6501102			0.0000000		
231 I A	A16	1.003	1.002	0.001	4.6420460	3.0560	0.9309	5.1432439	3.1020	1.1437	4.0958593	2.9749	1.1123	5.1507302	3.1049	1.1914	0.0000000	0.0000	0.000
231 II	A17	1.002			2.7001220			2.7021041			2.4003707			2.0004720			0.0000000		
231 III	A18	1.003			2.4241799			2.4730702			2.3193090			2.3000524			0.0000000		
231 IV	A19	1.000			2.3597070			2.3310023			2.2230010			2.2706353			0.0000000		
231 I A	A23	1.457	1.402	0.004	0.6043015	9.9905	3.5015	9.0353260	11.0309	3.9700	9.6257572	10.0393	3.9522	9.9206349	11.1705	4.0033	0.0000000	0.0000	0.000
231 II	A24	1.400			7.0404024			0.4210000			0.2505762			0.5275246			0.0000000		
231 III	A25	1.404			10.1102175			17.0200000			17.5919011			18.1520511			0.0000000		
231 IV	A26	1.407			7.3370120			0.0457177			7.0031632			0.1053000			0.0000000		
231 I A	A30	2.004	2.004	0.000	30.4910440	29.4041	0.3304	40.0000000	32.4273	7.0072	41.0754294	33.1019	7.2192	40.9400037	33.4347	7.1100	40.7043000	37.0174	9.110
231 II	A31	2.004			21.5339300			23.0000000			24.0000000			24.0000000			26.5113500		
231 III	A32	2.003			34.0153407			30.5743200			39.3743250			39.0514010			40.7043000		
231 IV	A33	2.004			25.0154735			27.4456720			28.2134203			28.4532253			31.1095700		
231 I A	A37	2.497	2.490	0.000	43.9704972	41.9074	1.3431	52.4099550	50.3233	1.5500	52.0927220	49.9959	1.7725	53.7025059	51.5073	1.0491	0.0000000	62.3791	2.205
231 II	A38	2.490			40.2310700			40.0407255			47.7130027			49.1300045			50.2001000		
231 III	A39	2.490			41.9073054			60.1541400			49.7003993			51.0400044			62.3791400		
231 IV	A40	2.490			41.5205202			50.0000000			49.7003993			51.0400044			62.3791400		
231 I B	B02	1.542	1.530	0.030	0.7001705	7.4950	0.0703	4.0004557	4.9004	0.0320	3.5601000	4.2200	0.0230	3.6305302	4.4059	0.0279	0.0000000	0.0000	0.000
231 II	B03	1.575			7.0012172			4.7371903			3.0793401			4.5170550			0.0000000		
231 III	B04	1.500			7.0275420			5.0000000			4.2320139			4.4320241			0.0000000		
231 IV	B05	1.505			0.4450450			5.0275050			5.2277019			5.4035790			0.0000000		
231 I B	B09	1.993	1.995	0.000	9.0004570	9.0259	0.4130	9.0232340	10.2545	2.3091	9.2315000	9.0700	0.5507	0.0000000	8.7597	0.6114	0.0000000	0.0000	0.000
231 II	B10	2.000			9.5410047			9.2400157			9.0000000			0.0000000			0.0000000		
231 III	B11	2.000			0.0072500			0.4210000			0.2150000			0.0000000			0.0000000		
231 IV	B12	1.901			10.0077077			14.3243000			9.7700734			9.4502040			0.0000000		
231 I B	B16	2.490	2.500	0.002	22.0290773	21.0400	0.7342	23.3470201	22.0213	0.0000	24.4792903	23.7532	0.0101	23.0400454	22.3742	0.7475	0.0000000	0.0000	0.000
231 II	B17	2.501			21.5904114			23.3100233			24.2710447			22.0097002			0.0000000		
231 III	B18	2.502			20.5000455			21.0057030			22.4047797			21.1077339			0.0000000		
231 IV	B19	2.497			21.7910300			22.9710520			23.0509413			22.0007002			0.0000000		
231 I B	B23	3.034	3.033	0.001	39.9731793	30.2103	1.1000	43.9000000	42.2004	1.1121	47.9213343	45.0912	1.3394	42.0370224	40.9490	1.0341	0.0000000	61.9093	2.300
231 II	B24	3.034			37.0455740			41.7324011			45.0170110			40.1040044			62.3791400		
231 III	B25	3.034			30.7495350			40.9000000			44.3940000			40.1040044			59.2001000		
231 IV	B26	3.031			30.2000000			42.4043973			45.4319144			40.9400037			60.8190000		
231 I B	B30	3.422	3.422	0.000	49.9004741	50.2000	0.3095	50.0192490	50.0772	0.0712	01.0200500	02.5000	0.7014	55.7244174	55.9355	0.3050	95.120190	94.730	0.075
231 II	B31	3.423			49.9020012			50.0192490			01.0200500			55.7244174			95.120190		
231 III	B32	3.423			50.4177042			57.1471539			03.2727574			55.7244174			95.120190		
231 IV	B33	3.422			50.0000043			57.5231220			03.4000001			50.5007200			93.500710		
231 I B	B37	4.012	4.012	0.000	52.2074974	50.9013	0.0007	71.0000100	00.5541	1.4002	73.0453400	72.3400	0.0347	05.0501297	04.0003	0.7537	123.100000	110.520	13.004
231 II	B30	4.012			50.4022571			00.9000000			72.4000000			05.4339750			129.430710		
231 III	B39	4.012			50.4177042			00.4261975			71.9057273			04.1075110			95.120190		
231 IV	B40	4.012			50.4177042			00.0502293			71.3033723			04.1075110			120.317700		
231 I C	C02	2.502	2.570	0.004	20.4970000	20.4903	1.2701	23.1500301	23.4004	1.1000	20.0007103	20.3071	0.0323	21.9520432	22.1031	0.7001	37.4274000	37.4275	0.000
231 II	C03	2.574			25.0154735			21.0013445			25.4335740			21.1077339			37.4274000		
231 III	C04	2.574			20.5020224			23.0107970			20.9272200			22.7003520			37.4274000		
231 IV	C05	2.503			25.9100037			25.1000039			20.1300000			22.7003520			37.4274000		

CONTINUED. 231 NORMALIZED CONCENTRATION VALUES (g/m³): MEAN AND S.D. CALCULATIONS

TEST #	ICP ID#	LDG	AVG LDG	LDG S.D.	Al VALUES			Ca VALUES			Si VALUES			Sr VALUES			Ca VALUES		
					Normal []	231 Avg.	Stand Dev	Normal []	231 Avg.	Stand Dev	Normal []	231 Avg.	Stand Dev	Normal []	231 Avg.	Stand Dev	Normal []	231 Avg.	Stand Dev
231 I C	C09	3.094	3.097	0.004	40.7488537	43.2613	2.4491	37.5968118	41.9768	3.6261	45.8399668	50.3070	4.0797	36.3863023	40.4835	3.3419	65.4981000	72.5158	8.924
231 II	C10	3.092			41.7704196			41.1309121			40.9585926			39.4292400			65.4980970		
231 III	C11	3.099			47.1941407			47.8727574			56.8417559			45.5927052			87.3388000		
231 IV	C12	3.102			43.3257685			41.5868802			49.7883993			40.5268490			71.7360100		
231 I C	C16	3.558	3.558	0.001	48.9993811	49.7408	1.3358	52.5603429	53.0010	1.7390	50.9907891	52.8579	2.3194	48.1258332	49.3921	1.7466	102.926	100.824	5.11
231 II	C17	3.558			49.5151840			53.6130630			52.2354991			48.9899426			100.846		
231 III	C18	3.558			48.4835981			52.3347820			51.4850025			48.1258332			102.926		
231 IV	C19	3.559			51.9651331			58.6959922			50.7904357			52.3471000			115.401		
231 I C	C23	4.025	4.026	0.001	47.9678151	48.8866	1.8376	63.8874502	66.0012	3.0550	71.3633723	73.1267	1.1123	54.8801081	55.6189	0.4937	155.948	155.168	4.61
231 II	C24	4.025			50.2888385			70.8323934			74.2670058			55.9777102			162.188		
231 III	C25	4.026			49.2572725			60.3959090			73.8527923			50.1485721			152.829		
231 IV	C26	4.026			47.7099237			63.6889992			73.0229850			55.4711248			149.719		
231 I C	C30	4.505	4.524	0.032	44.6152259	45.3089	1.7937	73.0082021	70.1147	8.4475	85.8649888	88.3744	3.3707	63.4878328	65.3707	2.7794	198.494	205.871	8.06
231 II	C31	4.505			44.2203887			75.0432368			86.7147965			63.7453563			202.732		
231 III	C32	4.505			40.4835981			81.9618497			94.1830553			70.1621074			218.327		
231 IV	C33	4.500			44.2203887			74.3864937			86.7147955			64.1675110			202.732		
231 I C	C37	4.955	4.958	0.000	42.8363111	40.6113	1.4603	82.7129859	81.7731	1.7120	90.0340221	89.9303	2.0015	60.2201959	67.4003	1.6252	221.448	220.600	3.39
231 II	C38	4.955			39.8442335			81.9618497			80.6191187			67.7988412			221.448		
231 III	C39	4.950			42.4231483			83.4849222			92.9383454			69.8645852			224.585		
231 IV	C40	4.950			30.9416134			78.9533848			87.1200988			64.7585275			215.288		

CONTINUED. MCC-MOD TEST RESULTS

231 AVERAGE NORMALIZED CONCENTRATION VALUES (g/m³): MEAN AND S.D. CALCULATIONS

LOG (T+SA/V) (Average)	Al VALUES			Ca VALUES			Si VALUES			Sr VALUES			Cs VALUES		
	MEAN	-2r	+2r	MEAN	-2r	+2r	MEAN	-2r	+2r	MEAN	-2r	+2r	MEAN	-2r	+2r
0.075	0.0866	0.5358	0.8374	0.0767	0.2485	1.1130	0.5003	0.2854	0.7152	0.5193	0.2827	0.7658	0.0000	0.0000	0.0000
0.500	1.3249	0.7805	1.8694	1.2031	0.5671	1.8391	1.0904	0.5288	1.6647	1.1716	0.5212	1.8210	0.0000	0.0000	0.0000
1.002	3.0560	1.1943	4.9178	3.1826	0.8952	5.4899	2.9749	0.7503	5.1994	3.1049	0.7221	5.4878	0.0000	0.0000	0.0000
1.462	9.9965	2.8336	17.1695	11.0309	3.0778	18.9841	10.8393	2.9350	18.7437	11.1765	3.0100	19.3431	0.0000	0.0000	0.0000
2.004	29.4641	10.7874	42.1409	32.4273	18.4120	46.4417	33.1819	18.7435	47.8203	33.4347	19.2026	47.8067	37.8174	19.5814	58.0534
2.498	41.9074	39.2211	44.5930	50.3233	47.2114	53.4352	49.9959	48.4509	53.5400	51.5073	40.2891	54.8856	62.3791	57.9691	66.7891
1.530	7.4950	8.1364	8.8518	4.9084	3.8409	6.1719	4.2268	2.9792	5.4744	4.4959	3.2401	5.7518	0.0000	0.0000	0.0000
1.995	9.5259	0.8983	10.3534	10.2545	5.5163	14.9927	9.0760	7.9587	10.1934	8.7597	7.7369	9.7825	0.0000	0.0000	0.0000
2.500	21.0488	20.1789	23.1152	22.8213	21.4440	24.1988	23.7532	22.1330	25.3795	22.3742	20.8793	23.8691	0.0000	0.0000	0.0000
3.033	38.2163	35.0904	40.5362	42.2984	40.0722	44.5207	45.6912	43.0124	48.3701	40.9490	30.0009	43.0171	61.9893	57.3773	66.0013
3.422	50.2888	49.5098	51.0679	56.8772	55.8347	58.0197	62.5985	61.0358	64.1813	55.9355	55.2043	58.0067	94.7380	93.3080	96.0880
4.012	50.9013	49.2999	52.5028	69.5541	66.5937	72.5145	72.3480	70.6795	74.0181	64.9063	63.3989	66.4137	118.5200	91.1520	145.8880
2.578	26.4903	23.9421	29.0546	23.4604	21.0945	25.8203	26.3071	25.1025	27.6317	22.1631	20.7630	23.5032	37.4275	37.4275	37.4275
3.097	43.2613	38.3831	48.1595	41.9768	34.7207	49.2270	50.3070	42.1470	50.4665	40.4635	33.7797	47.1473	72.5150	54.6670	90.3030
3.558	49.7400	47.0700	52.4100	53.0010	50.3218	57.2803	62.0579	50.2191	67.4906	49.3921	45.9109	52.0733	100.0240	90.5900	117.0500
4.020	48.8080	40.7300	50.0011	60.0012	59.0912	72.1112	73.1267	70.9820	75.3514	55.8189	54.6315	58.0002	155.1680	145.0420	184.3940
4.524	45.3889	41.8016	48.9783	70.1147	69.2195	83.0099	80.3744	81.0330	95.1158	65.3707	59.8118	70.9295	205.0710	180.9410	221.2010
4.950	40.8113	37.8900	43.7319	81.7731	78.3478	85.1903	89.9303	85.0073	94.0533	67.4003	64.2100	70.7100	220.6000	213.8700	227.4020

D.29

APPENDIX E

ANALYTICAL PROCEDURES

APPENDIX E

ANALYTICAL PROCEDURES

1.0 SAMPLE ANALYSIS OF ISV SOLUTIONS AND LEACHATES

Since the samples contained significant amounts of solids, a measured aliquot of the solution aliquot was filtered through a tared 47-mm cellulose acetate membrane filter. The precipitate was air dried for at least 24 hours and reweighed. About 0.25 g of the dried solid was fused with KOH in a zircalloy-2 metal crucible. The fused solid was then leached with demineralized water, transferred into a 250-mL volumetric flask, acidified with hydrochloric acid, and diluted to volume with demineralized water. A 10-mL aliquot was pipetted into a 100-mL volumetric flask and diluted to volume. This solution and the filtrate were analyzed on the ICP/AES for the listed ions.

Cesium in the filtrate was analyzed using the Graphite Furnace/Atomic Adsorption (GFAA) method. Since the fusion of the solid samples were acidified with HCl and since solutions containing significant amounts of HCl cannot be analyzed using the GFAA method, the fused samples were analyzed by flame AA method.

The results of the ions analyzed were reported as mg/L in the filtrate and mg/L in the precipitate, assuming that all the solids solubilized in the volume of the solution filtered.

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