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September 1999

DATA ANALYSIS AND RADIONUCLIDE SCALING FACTOR FOR THE B-CELL WASTE STREAM

RL Hill

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B&W Hanford Company, Richland, WA 99352

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Abstract: This report documents statistical data analysis of radiological data obtained to characterized the 324 Facility B-Cell decontamination and decommissioning waste stream.

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ACRONYMS/ABBREVIATIONS

³ H	Tritium
¹⁴ C	Carbon-14
³⁶ Cl	Chlorine-36
⁶⁰ Co	Cobalt-60
⁷⁹ Se	Selenium-79
⁹⁰ Sr	Strontium-90
⁹⁰ Y	Yttrium-90
⁹³ Mo	Molybdenum-93
⁹⁹ Tc	Technetium-99
¹²⁵ Sb	Antimony-125
¹²⁹ I	Iodine-129
¹³⁷ Cs	Cesium-137
^{137m} Ba	Barium-137m
¹⁵⁴ Eu	Europium-154
¹⁵⁵ Eu	Europium-155
¹⁸⁷ Re	Rhenium-187
²³⁷ Np	Neptunium-237
²³⁸ Pu	Plutonium-238
^{239/240} Pu	Plutonium-239 and Plutonium-240
²⁴¹ Am	Americium-241
²⁴³ Cm	Curium-243
²⁴⁴ Cm	Curium-244
AEA	alpha energy analysis
AP	2.5M NaOH and 0.2M KMnO ₄
ALARA	As Low As Reasonable Achievable
BWHC	B&W Hanford Company
CI	confidence interval
Ci	Curie
Citrox	0.3M Oxalic Acid and 0.2M Citric Acid
cc	cubic centimeter
CFR	Code of Federal Regulations
cm	centimeter
cm ²	square centimeter
CRDL	Customer Required Detection Level
CV	Coefficient of Variation
DF	decontamination factor
DL	detection limit
DOE	U.S. Department of Energy
DOE/RL	U.S. Department of Energy, Richland Operations Office
DOT	U.S. Department of Transportation
DQO	data quality objective
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FGE	fissile gram equivalents

FRG	Federal Republic of Germany
g	gram
GEA	gamma energy analysis
GTCC	Greater Than Class C
hr	hour
HCl	hydrochloric acid
HF	hydrofluoric acid
HIC	high integrity container
HLV	high level vault
HNO ₃	nitric acid
HSCRM	Hanford Site Radiological Control Manual
ICP/MS	inductively coupled plasma/mass spectrometry
ID	identification
ISB	interim safety basis
JCS	job control system
KOH	Potassium hydroxide
lb	pound
LCS	laboratory control sample
LLBG	low-level burial grounds
LLW	low-level waste
m	meter
M	Molar (moles per liter)
m ³	cubic meter
mg	milligram
mL	milliliter
mR	milliRoentgen
mRem	millirem
N/A	not applicable
nCi	nanocurie
NL	no (applicable) limit
NOD	Notice of Deficiency
NRC	U.S. Nuclear Regulatory Commission
NWVP	Nuclear Waste Vitrification Project
PAM	Portable alpha meter
ppb	parts per billion
QA	Quality Assurance
QC	Quality Control
R	Roentgen
REC	Radiochemical Engineering Cells
RCA	Radiochemical Analysis
RCRA	Resource Conservation and Recovery Act of 1976
RH-LLW	remote handled low-level waste
RH-TRU	remote handled transuranic
RH-TRUM	remote handled transuranic mixed
RHW	relative half-width
RLFCM	(Pilot-scale) Radioactive Liquid-Fed Ceramic Melter Program

RPD	relative percent difference
SAP	sampling and analysis plan
SEM/EDS	scanning electron microscope/energy dispersive X-ray spectrometry
SCW	Special Case waste
SOP	standard operating procedure
SOW	statement of work
SEPA	State Environmental Policy Act
TLCP	Toxicity Characteristics Leaching Process
TRU	transuranic
TRUM	transuranic mixed
TSD	treatment, storage, and/or disposal
TWD	technical work document
TWP	technical work plan
μCi	microcurie
WAC	waste acceptance criteria
WSEP	Waste Solidification Engineering Prototype Program
WIPP	Waste Isolation Pilot Plant
WMH	Waste Management Federal Services of Hanford, Inc.
WML	Waste Management Laboratories
WMNW	Waste Management Northwest, Inc.
ZVDP	Zeolite Vittrification Demonstration Project

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DATA ANALYSIS AND RADIONUCLIDE SCALING FACTOR FOR THE B-CELL WASTE STREAM

1.0 INTRODUCTION

The 324 Facility is located within the 300 Area of the Hanford Site and is operated by Fluor Daniel Hanford, Inc. for the U.S. Department of Energy through a subcontract with B&W Hanford Company (BWHC). Its purpose was to allow a high degree of versatility in completing complex and varied experimentation on highly radioactive wastes. B-Cell is one of the Radiochemical Engineering Cells (REC) within 324 Facility where various waste solidification work projects have been conducted over the years (DOE/RL 1998a; Hobart 1998). As a result of dispersed residues and internal facility spills during the conduct of these activities, the B-Cell hot cell contains areas of fixed and dispersible (i.e., easily spreadable) waste contamination. The floor dispersible material contains mixed waste (dangerous waste) contaminants (heavy metals). In the mid-1990's, it was determined that dangerous waste and waste residues were being stored for greater than 90 days in the 324 Facility REC (these areas are not Resource Conservation and Recovery Act of 1976 (RCRA) permitted portions of the 324 Facility). Through negotiations between U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and Washington State Department of Ecology (Ecology), it was agreed that a milestone would be added to the Tri-Party Agreement for closure of nonpermitted mixed waste units within the 324 Facility and provided commitments to achieve the highest degree of compliance practicable, given the significant technical difficulties of managing mixed waste that contains high-activity radioactive materials and working remotely in areas within the hot cells (DOE/RL 1998a; Hobart 1998). B-Cell clean-out of both low-level waste (LLW) and mixed wastes is part of the Tri-Party Agreement milestone.

To support the clean-out of LLW from B-Cell, a comprehensive radiological characterization scheme (Figure 1) was developed to obtain statistically reliable and defensible data to support waste classification of the B-Cell dunnage and sifted debris¹ that will be disposed of from B-Cell. Since direct measurement of all of the radionuclides in the waste is not economical or

Figure 1. Overall B-Cell Waste Characterization Document Scheme

¹ Sifted debris is considered items that have fallen to the cell floor and are later collected. The B-Cell floor dispersible material has been found to exhibit mixed (dangerous) waste characteristics (DOE/RL 1998a). All items having the potential for containing floor dispersible or tank heels are required by procedure to be rinsed of visible dispersible or heel material before being placed into the HN-200 grout container (DOE/RL 1998a; 3I-SOP-REC-A-49).

practical (since beta and alpha emitters are present in addition to some gamma emitters), an indirect method coupled with the use of radionuclide scaling factors will be used to generate a radiological profile of grout containers that contain B-Cell dunnage and sifted debris.

Shelor (1999) has published on the method to be used to determine ^{137}Cs content of loaded, ungrouted grout containers using the measured dose rate at a specified distance from the container. Since ^{137}Cs is readily measured and is expected (by process knowledge) to be found in large concentrations in the waste, it was chosen as the radionuclide for direct measurement. The sampling and analysis plan (SAP), coupled with a revised data quality process document, contains a detailed description of the planned sampling and radionuclide analysis strategies (Hobart and Hill 1999). This document serves to document the results of the radionuclide analyses and develop radionuclide scaling factors.

1.1 Purpose

The purpose of this document is to assess whether original project data objectives were met, identify data deficiencies that impact data interpretation, determine whether data is sufficient and of appropriate quality to allow the decisions to be made, and develop radionuclide scaling factors in support of classification of the waste from B-Cell in the 324 Facility.

This data analysis and radionuclide scaling factor document consists of six sections:

- Section 1 provides the purpose, scope, objectives and historical background of this radiological waste characterization effort.
- Section 2 provides documentation of the assessment of analytical data from rack dunnage samples obtained in accordance with the SAP.
- Section 3 provides a discussion of the development of the radionuclide scaling factors.
- Section 4 provides the summary of the data analysis and the radionuclide scaling factors developed for use in classifying the B-Cell dunnage and sifted debris waste.
- Section 5 provides references used in this document.
- Section 6 is a glossary of terms used in this document.

1.2 Scope

This document covers the assessment of the quantitative data on the radionuclide constituents present in rack dunnage waste generated during deactivation activities in B-Cell in the 324 Facility. Sampling and radioisotopic analysis were performed on the fixed layer of contamination present on structural material and process tanks or vessels in accordance with the SAP (Hobart and Hill 1999). Additionally, samples were collected in accordance with the SAP to support studies of potential decontamination methods that are effective in removing the fixed contamination present on the waste.

This document addresses only radionuclide characterization related to metal dunnage waste generated during deactivation activities in B-Cell. Issues related to the

classification of this waste as non-dangerous waste (i.e., not mixed waste) have been discussed elsewhere (Shelor 1999, Rasmussen 1999a-1999h). This document does not address other issues associated with closure of B-Cell.

1.3 Brief B-Cell Description

Historical operations in the 324 Facility B-Cell between 1965 and 1992 have generated a large volume of legacy radioactive waste. During these operations, approximately 70 million of curies of radioactive material, primarily ^{137}Cs (and $^{137\text{m}}\text{Ba}$) and ^{90}Sr (and ^{90}Y), were processed in B-Cell. It is estimated that thousands of Ci of radioactive contamination, both in dispersible and fixed form, reside in B-Cell (Greenborg 1999). The structural materials remaining in B-Cell which are to be disposed of in HN-200 grout containers are the 1A, 1B, and 2A racks and their associated vessels and tanks.

A B-Cell waste package consists of a HN-200 grout container containing the waste and grout (to reduce residual, removable contamination, to fill void spaces, and to lower the external dose rate) and a liner that reduces the amount of contamination introduced into the shipping cask from the grout container. A waste package is generated by size-reducing the stainless steel racks (including Racks 1A, 1B, 2A, and 2B) or vessels, placing the rack material into grout containers, adding grout to the containers, loading the grout container into a liner in a relatively low-contamination area (the REC Airlock), loading the liner into an 3-82B shipping cask, and shipping the sealed cask to the Hanford burial grounds. The dose rates at the surface of the grout container waste packages originating from B-Cell are sufficiently high that they must be handled remotely.

The current method for designating B-Cell waste is based on analytical characterization of residual removable contamination on rinsed surfaces of B-Cell. However, process knowledge indicates that most of the contamination in B-Cell is fixed and that the isotopic distribution of radionuclides in the fixed layers may be significantly different from that of the residual removable contamination. Although analytical information of radionuclides present in process solutions used as feedstock during vitrification projects is available, no radionuclide characterization of fixed contamination present on external surfaces of the equipment racks or process vessels had been obtained as of October 1998. Also, no radionuclide characterization of process residuals present as fixed contamination inside auxiliary vessels has been performed. Radioanalytical information from smears of removable contamination present in the cell taken in March 1998 is the only direct information currently available to estimate the radionuclide makeup of grout containers from external dose rates.

Data on the radionuclide content of removable and fixed contamination on metal surfaces in the waste stream must be collected to validate the classification of the B-Cell waste stream as LLW or transuranic (TRU) waste. The data will be used to establish the relationship between ^{137}Cs , which will be used as a tracer radionuclide, and the alpha-emitting radionuclides present in the waste stream. This relationship will be used to determine the TRU content of individual waste packages generated from this waste stream.

For a more detailed description of B-Cell, see the SAP (Hobart and Hill 1999).

1.4 Waste Characterization Study Background

The objective of sampling and analysis activities is to provide radionuclide characterization data on the fixed contamination layer of metal structures to support decisions related to classifying the B-Cell wastes to meet Hanford solid waste acceptance criteria (WAC) as defined in HNF-EP-0063, Rev. 5 (WMH 1998).

Designation of B-Cell waste to date has previously relied on process knowledge and limited data on the removable contamination on the structural metal material (Webb 1997). The prior basis for shipping B-Cell waste to the Hanford burial grounds was based on a limited number of smear samples obtained from rinsed surfaces of B-Cell waste and non-waste material (Durham 1998). These samples, representing the removable contamination present, were used to establish the ratio of ^{90}Sr to ^{137}Cs . The alpha content was not explicitly determined. Upon review of that data, it was determined that a more in-depth study of the B-Cell waste characterization was needed. Process knowledge indicates that most of the nondispersible B-Cell contamination is fixed and the isotopic distribution of radionuclides in the fixed contamination layer may be significantly different than that of the residual removable contamination. The radionuclides of concern for this waste characterization work are ^{137}Cs , ^{90}Sr , and transuranic radionuclides (such as $^{239/240}\text{Pu}$, ^{238}Pu , ^{241}Am , and ^{243}Cm) based on previous data on B-Cell constituents (Webb 1997; Durham 1998).

As the current waste contractor, Waste Management Hanford has imposed the criteria that the TRU content of the loaded grout containers must be known with 85% assurance that the determined TRU value is equal to or less than the 100 nCi/g limit for the containers to be accepted as LLW. For analytical data, the reporting will be required to be at the 95% confidence level. The use of a 95% bounding value on the TRU to ^{137}Cs regression (i.e., the value for which the measurement has 95% assurance that the actual content of the container is equal to or less than the calculated 95% bounding value) will be used in the radiological profiling of a given grout container. This is to ensure that, after errors associated with the various parts of the grout container radiological profiling process are propagated through the entire process, the requirement that the TRU characterization of the container will be known with 85% assurance will be met. The 85% assurance means that the waste is shown to have 100 nCi/g or less of TRU constituents with 85% assurance that the value is repeatable and measurable.

1.5 Background on Laboratory Analyses Performed

1.5.1 Historical Developments

Figure 2, "Analytical Laboratory Work Timeline", shows the history of the decisions to perform sampling and analysis to characterize the waste stream of B-Cell. Prior waste assay and calculations on B-Cell waste were based on a limited set of smears taken from metal surfaces in B-Cell (Durham 1998). Early

assumptions used in the waste processing centered on the smear analysis of removable contamination representing the total deposit on the metal surface. Analysis of smears from B-Cell in March 1998 indicated that the smearable contamination on the metal surface was only a fraction of the total activity on the metal. Most of the activity was in a fixed film firmly attached to the metal substrate. In May 1998, analytical data were also available from a much more comprehensive set of smears taken from all over the 324 facility including B-Cell. Typical dose rates of smears taken at that time ranged in the R/hr range and clearly showed that substantial activity existed on the metal surfaces.

Analysis of TRU constituents in the removable contamination showed that the ratio of TRU isotopes (^{241}Am , ^{238}Pu , $^{239/240}\text{Pu}$, and ^{243}Cm) to ^{137}Cs was approximately 0.003.

Prior analysis of smears of removable contamination taken from B-Cell had provided TRU to ^{137}Cs ratios in the 0.0004 range, which would imply low levels of TRU material (Durham 1998). Prior characterization data were in question and new data were urgently needed to fully characterize nuclides on the metal surfaces of the cell. Valid film data were needed to provide design data for the waste treatment system supporting the decontamination. These samples were also to be used to provide research samples necessary to develop chemical decontamination methods related to B-Cell.

Because the effort to get samples was substantial and because the analysis of the same was a new process with a high analytical cost, the sampling had to be limited. Pieces of metal were cut from the rack structural material and the rack vessels (Table 1) with a plasma arc torch, water washed and were taken into the REC Airlock. Within the REC Airlock, the samples were placed in a vice and smaller specimens cut from these pieces to eliminate the plasma-influenced zones on the metal coupons. Subsequently the specimens were packaged and shipped to the 222S Laboratory (henceforth referred to in this document as the "Laboratory"). The first specimens were shipped to the Laboratory in October 1998.

9-1-99
ground

Figure 2. Analytical Laboratory Work Timeline

Table 1. 324 B -Cell Process Rack and Vessel Listing

RACK	TANK
1B	Vessel 112 Vitrifaction feed tank and HLV cleanout transfer tank
	Vessel 114 Vitrifaction feed tank for RLFCM
1A	Vessel 113 Process concentrator for melter feed and offgas recovery
	Vessel 115 Nitric Acid Fractionator
2B	Vessel 116 Fractionator overheads (distillate)
	Vessel 118 Offgas vent scrubber solution tank

When sampling and analyzing specimens from a heterogeneous environment, the first concerns are clearly how representative samples are obtained, and, secondly, how the specimens are to be analyzed. The chosen path was to take specimens from the rack as the rack was being subdivided, in accordance with the guidance of a statistician experienced in site processes (Jensen and Wilmarth 1998). The second issue involved destructive removal of the total fixed radioactive film deposit on the metal surface. When the fixed layer was removed from the metal sample, the extent of removal required verification and the subsequent analysis of the solutions had to assure that all of the alpha activity was accounted for (i.e., either in the etching solution or remaining on the surface of the sample).

The number of waste types or populations in the cell was unknown at the time of sampling. Only after the analytical data are reviewed, can decisions be made regarding the number of populations present. If more than one population is present, then waste should be segregated accordingly to take advantage of the different compositions. If only one population is present then the data range will undoubtedly be larger; this requires that a conservative interpretation of composition must be used to develop the assay.

Many questions arose with respect to how representative the samples were and what degree of cross contamination occurred from all of the diverse handling actions. An experienced site statistician was consulted to assist with establishing an optimum sampling approach and subsequently assisted in the interpretation of the analytical data (Jensen and Wilmarth 1998). Sites to be sampled were judgmentally chosen and formalized in the sampling and analysis plan (Hobart and Hill 1999) and the governing technical work plan (3I-SOP-REC-A-49). The overall goal of the process was to obtain randomly selected samples from the rack and perform a total fixed contamination layer or film removal with subsequent analysis of the resultant solutions. Radioactive film analysis is not formalized and therefore some method development was required. In all technical investigative processes, there are always unknowns that arise that require changes in course. This characterization study was typical in that regard. Figure 2 shows the major items along the timeline and the alterations required in the analytical process. After the initial analyses were done, it was determined that the alpha nuclide analyses had been compromised by two major factors: (1) excessive base metal concentrations (including precipitation) in the matrix solution after etching, and

(2) beta crosstalk in the alpha analyzer. A recovery action (or path forward) plan was developed to salvage the samples containing the excessive dissolved iron concentrations. The most significant revision to the analytical method was to optimize the procedure for dissolution of the radioactive film using the mixed acid. Film removal was based on using 3M nitric and 3M hydrochloric mixed acids, which is a dilute form of Aqua Regia. Metal sample exposure to the acid etch solution was limited to marginally remove 99% of the radioisotopes and no more. This was to achieve near complete removal of the fixed contamination layer without causing excessive iron dissolution, which interferes with a number of the analytical procedures. As the analytical data were available, other studies were needed to analyze residual solids (silaceous) with trapped activity and to remove the oxide film on the titanium specimens. A portion of the first residual solids from sample 1A-1g was analyzed using SEM (scanning electron microscope (SEM)/energy dispersive X-ray spectrometry (EDS)) to identify the primary constituents. Complete analytical data sets were not available until early August 1999. An in-depth appraisal of these data is presented in this document.

The Table 2 lists the figures used in this section to illustrate the flow of various sample sets through the analytical processes.

Table 2. Listing of B-Cell Sample Process Flow Diagrams

FIGURE	TITLE
1	Laboratory Work Timeline
2	1B Rack Analysis
3	1A Rack Analysis-Initial 5 Samples
4	Sample 1A-1g Analysis
5	1A Rack Analysis-Second Set (no Titanium)
6	1A Rack Analysis- Titanium Samples Only

1.5.2 Brief Overview of the B-Cell Sample Analytical and Data Process

1.5.2.1 Initial Laboratory Work on 1B Rack Samples and First Batch of 1A Rack Samples

The process for analysis of these samples involved destructively removing the fixed radioactive contamination layer from the 304 stainless steel sample surface with diluted Aqua Regia (3M nitric acid [HNO₃] and 3M hydrochloric acid [HCl]) mixture. The statement of work (SOW) for this analytical work was Hooper 1998. Mixed acid etching times for the 1B Rack samples were variable, i.e., 1/2 hr, 1 hr, and 2 hr and were not optimized in this initial work. Mixed acid etching times for the initial 1A Rack samples (Riddelle 1999a) were unfortunately too long due to multiple causes outside of the scope of this discussion. The resulting solutions had substantial amounts of dissolved iron, chrome and nickel. Partial precipitation occurred after the etching solutions cooled. During

March 1999, data review concerns were raised regarding the solubility of the actinide metals, and thus, the alpha analytical data. Both the 1B Rack sample set and the initial 1A sample set results were put in question. Details of these sequences are in the following sections.

1.5.2.2 Laboratory Recovery Plan

After considerable discussion, a recovery, or path forward plan (WMH 1999), was developed which incorporated dissolution of the solid phase of the 1B Rack and initial five 1A Rack samples, acidification of the water washes and re-analysis of the resulting liquid and small amount of solids. Sample or vessel surfaces that had potential depositions of precipitated solids, from sitting after the previous etching, were rinsed with acid and the rinses combined with the final liquid analyzed. The resulting plan involved the input of numerous individuals within the Laboratory, 324 Facility, and elsewhere on Site. The final SOW paperwork and test procedures were completed and the lab work started in June 1999.

1.5.2.3 Remaining 1A Rack Specimens

After the initial 1B Rack samples and the first set of 1A Rack samples were reanalyzed, the lessons learned from the initial analytical work were applied to the remaining 1A Rack samples which included both structural metals and vessel metals. Subsequent analyses of the metal coupons utilized optimized film removal chemistry to minimize the metals content of the liquids being assayed. A new analytical approach was developed and a new SOW (Riddelle 1999b) was written for this set. After some of the analytical work was done, alterations in the analyses were required to deal with solid phases, and the inert titanium dioxide film on the titanium specimens. An amendment was written to the SOW to cover this added work (Riddelle 1999c).

1.5.2.4 Analytical Procedures Used

Analytical procedures and test plans used by the Laboratory for both the fixed contamination layer characterization study and the decontamination reagent/film removal study are listed in Table 3.

Table 3. Sample Preparation and Analytical Procedures

PROCEDURE No.	REV. No.	RELEASE DATE	TITLE
Sample Preparation by Laboratory			
---	---	6/16/99	Test Procedure for 324 B-Cell Sample Preparation
---	---	1/4/99	Test Procedure for 324 B-Cell Film Removal Studies
---	---	7/15/99	Test Procedure for 324 B-Cell Sample Preparation of Titanium Specimens
Laboratory Analytical Procedures			
LA-220-101	E-4	3/16/99	High Level Strontium-89, 90 in Aqueous Samples
LA-505-161	C-3 C-4	7/15/98 (Orig. Analysis) 6/30/99 (Path Forward)	Inductively Coupled Plasma (ICP) Emission Spectrometric Method for the Thermo Jarrell Ash Type 61E
LA-505-166	A-0 B-0	5/27/99 6/23/99 (Filtered Solids)	Treatment Of B-Cell Samples
LA-506-101	A-1	3/10/99	Determination Of Trace Elements And Radionuclides By ICP/MS Using TJA POEMS
LA-508-002	B-0	8/21/95	Detection Limits and Uncertainty Calculations for Radioisotopic Counting
LA-508-101	G-0	3/25/97	Alpha And Beta In Liquid Samples
LA-508-161	A-1	5/23/94	Alpha Energy Analysis Using the GENIE System
LA-519-151	G-1	3/17/99	Visual Check and Over-The-Top Reading (to record the sample appearance information)
LA-548-121	F-0	2/27/97	Preparation of Sample Mounts for GEA
LA-549-141	G-0	3/23/98	Fusion by Alkali Metal Hydroxide
LA-953-104	B-1	12/16/98	Determination Of Plutonium And Americium By Extraction By TRU-SPEC Resin
LA-925-009	C-0	3/6/98	Determination of Uranium by Kinetic Phosphorescence

1.5.2.5 Analytical Data

Table 4 provides a complete listing of the analytical reports generated by the Laboratory on the analysis of the 1B Rack, 1A Rack, and 2B Rack samples. They are internal WMH reports and are not circulated as site documents.

Table 4. Laboratory Reports on Analysis of 1B Rack, 1A Rack, and 2B Rack Samples

TITLE	DATE	DOCUMENT NUMBER
<i>Results for the Phase I Waste Characterization Analysis of 324 B-Cell Samples (Esch 1998)</i>	November 18, 1998	WMH-9859923
<i>Results for the Waste Characterization Analysis of 324 B-Cell 1A Samples (Esch 1999a)</i>	March 31, 1999	WMH-9952154
<i>Results for the Path Forward Plan Characterization Analysis of 324 B-Cell Rack 1A/2B and 1B Samples (Esch 1999b)</i>	July 14, 1999	WMH-9954826
<i>Results for the Characterization Analysis of the Second Batch of 324 B-Cell Rack 1A/2B Metal Sample (Esch 1999c)</i>	July 20, 1999	WMH-9954972
<i>Results for the Additional Requested Analyses of the 324 B-Cell Rack 1A/2B and Rack 1B Metal Samples (Esch 1999d)</i>	August 5, 1999	WMH-9955401
<i>REVISION: Results for the Path Forward Plan Characterization Analysis of 324 B-Cell Rack 1A/2B and 1B Samples (Esch 1999e)</i>	August 16, 1999	WMH-9954826 - Reissue
<i>REVISION: Results for the Characterization Analysis of the Second Batch of 324 B-Cell Rack 1A/2B Metal Samples (Esch 1999f)</i>	September 2, 1999	WMH-9954972 - Reissue
<i>REVISION: Results for the Additional Requested Analyses of the 324 B-Cell Rack 1A/2B and Rack 1B Metal Samples (Esch 1999g)</i>	September 2, 1999	WMH-9955401 - Reissue

The final documentation of the grout container waste radiological profiling process will be given in HNF-4905 (Hill, et. al. 1999).

1.5.3 Details of Laboratory Analyses Segregated by Sample Type or Sample Set

1.5.3.1 1B Rack Nozzle Panel Samples

Figure 3 gives a flow diagram of the first set of 1B Rack specimens including the original sample treatment and the modifications to the analytical process to recover the solutions. The 1B Rack specimens were unlike the subsequent metal specimens in that they were recovered from the grout containers after the rack had been subdivided for disposal. The rack has three horizontal 1" x 4" channel pieces that support the liquid connector nozzle array. These pieces occur only at this location on the rack and no other. No definitive data are available on exactly where the pieces were cut (one of three elevations) on the horizontal channel members of the nozzle panel.

Random pieces of 1B Rack nozzle rack support channels were taken to the REC Airlock and 1" slices were cut from the channel sections. These "macro samples" were taken to the Laboratory and cut into approximately 1" square pieces for analyses with a hydraulic bar cutter² (see Test Plan for 324 B-Cell Sample Preparation). Specimens were paper wrapped prior to cutting to minimize contamination spread and cutter contamination. Video dimensional records were made of the samples using rulers and 1 inch and 1 foot. Dose rates were taken window open/window closed with an Eberline RO-3B portable dose rate meter. The Eberline RO-3B, commonly called the Hanford Cutie Pie (CP), is a portable pistol-shaped air-filled ionization chamber rate meter used to detect beta, gamma and x-ray radiation. The first step for the coupon analysis was to measure any loosely bound activity by agitation in an ultrasonic water bath. Bath water was analyzed initially and after the data review/recovery, the water bath was acidified, digested and re-analyzed. After the initial cleaning with water the sample was masked on the edges with epoxy resin to suppress cross-contamination effects on the cut areas. The coupon was then etched at 40°C to 70°C with a solution of three parts 3M HCl and one part 3M HNO₃. Removal of the radionuclide film occurred in approximately 20 minutes in the heated mixed acid. The metal samples were documented with video and rulers to allow calculation of the effective area etched and corresponding mass. Following the acid etch, the dose rate of the sample was measured with a RO-7 portable dose rate instrument at 1" distance from the sample, and with a PAM survey instrument for residual alpha contamination.

A high percentage removal was desired, therefore, the later specimens were left in the acid slightly longer i.e., 1 hr and 2 hr. The mixed acid aggressively removed the base metal during this time so the solution became dark from the dissolved iron, chrome and nickel. Aliquots were taken from this solution for alpha isotopic analysis and for gamma energy analysis. Radionuclide film analyses and heavy metal analyses were generated from these aliquots. Although suspended solids were not initially observed in the group of 1B Rack samples, the samples became cloudy after sitting for a few weeks implying colloids or precipitation of some type had occurred. Heavy precipitation occurred after etching the initial 1A Rack samples, as discussed in the following section. Questions arose concerning the validity of the transuranic assay work. At that time (late March 1999), the results for both 1B Rack samples and initial 1A Rack samples were in question.

² Hydraulic cutter from H. K. Porter, Model HKJ02.

RACK1Ba1

Figure 3. 1B Rack Analysis Flow Diagram

1.5.3.2 Recovery Actions for the 1B Samples

During the review process, concern was raised about the possibility that the insoluble transuranic radionuclides may have precipitated in the water bath. Therefore, the water bath solutions were acidified and reanalyzed. All sample storage glassware surfaces and the metal specimen surfaces were triple rinsed with half strength Aqua Regia (approximately 6M) and added to the new volumetric flask for the recovery plan efforts. The mixed acid etching solutions with precipitated iron were processed with a revised EPA digest procedure that utilized concentrated HNO₃ additions, 90°C heating and finally a concentrated HCl addition (Lab Procedure LA-505-166). After dissolution, the mixture was added to the new recovery volumetric flask. In several cases, small traces of solids were visible in the bottom of the new volumetric flask. The clear solution phase was decanted to a certified clean storage bottle and the trace solids and remainder of the solution were filtered. The trace material was measured by dry weight, gamma energy analysis, and portable alpha survey probe (PAM). Two solids samples of the subsequent 1A Rack set were processed by fusion analysis to determine the actual alpha content. Solids sample details are discussed in the next section. PAM assessment was approximately 1/3 to 1/4 of the actual due to masking (Table 5 in Esch 1999d and Esch 1999f).

1.5.3.3 Liquid Analyses Requirements

To provide sufficient data quality for analyses on liquid samples, a table of QC requirements on the analyses was developed during the recovery plan formulation (WMH 1999). The QA/QC table and associated footnotes specify modified limits of detection to assure that the final analytical data will meet the 95% confidence criteria.

The single phase liquid resulting from this separation was analyzed according to the criteria in the following discussion. Footnote four in the Recovery Plan QC table (WMH 1999) specifies the new analytical data criteria for all subsequent B-Cell sample analyses performed by the Laboratory. Laboratory analyses were to be a factor of 10 above the Laboratory detection limit to ensure that at least a 95% confidence level result was achieved. Some analyses, such as some of the low-level alpha constituents and minor gamma nuclides, were not able to meet this criteria. The customer required detection levels (CRDL) used were 0.01 nCi/g for beta gamma and 0.001 nCi/g for alpha emitters, except for ¹⁵⁵Eu, which was 0.001 nCi/g. These limits were driven by the WHC-EP-0063-4 Waste Acceptance Criteria document (WMH 1998), where the gamma analysis requirements for minor constituents are <1% major activity and <1% of the Category 1 isotope limit. Alpha nuclide limits are given as 1 nCi/g for TRU constituents. By mutual agreement, if the CRDL could

not be met, then the technical reasons why were to be documented in the appropriate Laboratory report. In most cases, this problem was due to the significant ^{137}Cs activity present, and /or the interference from the significant dissolved iron concentration.

1.5.3.4 1A Rack - Initial Five Samples

Changes in the analysis, see Figure 4, were made during the processing of the next five samples from the 1A rack nozzle zone. The method for minimizing the cut edge cross contamination was changed from epoxy mask to edge surface removal by electrobath (Riddelle 1999a). Also the coupon preparation was different in that the coupon shape and size were changed to approximately 1-1/2" squares at the Portaband cutting stage in the REC Airlock.

Sample preparation from this group of samples was derived from the experience with the 1B Rack set. Analyses of the initial 1B Rack samples were partially successful in terms of the goals of the analytical process. Epoxy resin masking of the edges was only partially successful because the mixed acids dislodged some of the epoxy. Also, a final coupon survey was not possible because the residual activity beneath the resin prevented monitoring the other surfaces. To improve the method, the activity on the cut edges was removed by electropolishing before analysis. This action removes the cross-contamination transferred from specimen to specimen during the cutting process. Preparation of the coupons started with cutting the metal specimen with the hydraulic bar cutter followed by the same water wash step used in the 1B sample procedure. Next the coupon was electrochemically cleaned in a concentrated phosphoric acid bath by submerging one edge at a time until the specimen edges were clean. After 1 or 2 minutes of current transmission each edge was smooth and clean. After cleaning all edges, the coupon at this stage, was ready for de-filming

RACK1A1a

* SPL 1A-1g (solids) on separate DWG
SEM analysis run on 1A-1g

Figure 4. 1A Rack-Initial Five Samples Analysis Flow Diagram

(etching) in the mixed acid. Removal of the radioactive film for this set of coupons was done with the same 3 molar mixed HCl/HNO₃ acid solution. The coupons were surveyed with an RO-7 portable dose rate instrument at 1 inch and 1 foot distance and with a PAM survey instrument for alpha contamination. In this case, the radionuclide removal was directly verifiable because the coupon should have been clean after film removal.

One significant difference in the procedure for this set was the 3-hr acid etch time. Since the etching step had not been quantitatively evaluated, the intent at this stage was to achieve a maximum removal of radionuclides; however, this lengthy exposure in mixed acid resulted in excessive removal of base metal which caused problems with the following analysis. Solids were noted in the etch solution after the reactions were complete. Unfortunately, corrective actions were not done at this time and subsequent analysis was performed only on the supernatant liquid. After the extent of precipitation was clearly understood, it was believed that the iron precipitation had biased the actinide data.

1.5.3.5 Recovery Actions for the Rack1A First Set Samples

During the review process, concern about precipitated alpha nuclides in the water bath was raised; therefore, the water bath solutions were acidified and reanalyzed. All sample storage glassware surfaces and the metal coupon surfaces were triple rinsed with half strength Aqua Regia and added to the new volumetric flask for the recovery. The mixed acid bath with precipitated iron was processed with a revised EPA digest procedure that utilized concentrated nitric additions, 90°C heating and finally a concentrated HCl addition. After dissolution, the mixture was added to the new recovery volumetric flask. The only case of residual solids found in the first batch of 1A samples was the 1A-1g sample, in which trace solids were noted on the bottom of the new volumetric flask. The clear solution phase was decanted to a certified clean storage bottle and the trace solids and remainder of the solution were filtered. The trace material was measured by dry weight, gamma energy analysis, and portable alpha survey probe (PAM). Two solids samples of a subsequent 1A set, (1A-1d and 1A-14) were processed by fusion analysis to determine the actual alpha content. PAM assessment was approximately 1/3 to 1/4 of the actual total alpha due to masking. A portion of the 1A-1g solid sample (30 mg) was sent in for SEM/EDS analysis. From this analysis, it was determined that the solid phase was partially crystalline and partly amorphous, with mostly silica composition (Esch 1999b). There were traces (1% to 2% by weight) of chromium, iron and aluminum. When measured by gamma spectroscopy, the solid phase retained 9 µCi (2%) of ¹³⁷Cs and 1,200 dpm alpha by PAM. The ¹³⁷Cs activity in the etching extract solution was 430 µCi. The solid phase alpha counted by PAM

amounted to approximately 0.01% of the total alpha activity; however the actual would be 3 to 4 times greater. It should be noted that this material was subjected to leaching by 3M HCl and 3M HNO₃ mixed acid etching solution, which normally does not leave nuclides in an undissolved state.

1.5.3.6 1A-1g Sample

Figure 5 shows the special treatment that was given to the 1A-1g sample. This sample received the same treatment as the other samples shown on Figure 4. Significant differences occurred when the solid fraction was separated from the other material. A portion of the sample went to the SEM instrument and the remainder was sent in for fusion analysis. The data from the precipitate and the fusion were discounted later when it was found that sample weight data were not taken prior to fusion so the quantity of material removed for SEM was not known. Two other 1A Rack samples were selected as shown on Figure 6 and fusion analysis was conducted on those to determine the extent of alpha isotope retention.

1.5.3.7 1A Rack - Second Set of Samples

Figure 6 shows the second set of 1A Rack samples. This group does not include the titanium samples because they are covered on a special analysis flow diagram (Figure 7).

After the 1B Rack samples and the first set of 1A Rack samples were completed using the recovery plan, a revised approach (Riddelle 1999b) was used to complete the remaining 1A Rack samples which included both structural (Figure 6) and titanium vessel samples (Figure 7).

Coupon preparation up to the point of mixed acid etching was the same as the earlier 1A samples. Several revisions were made to simplify the analytical process.

1. By far, the most significant change was the optimization of the acid etching process. When the first three coupons were processed, the coupon dose rate vs. time was plotted to determine when the 99% removal criteria was met. In most cases, it was 15 minutes to 30 minutes. At this point, the acid etch process was halted to minimize the base-metal dissolution. Subsequent coupons were processed with this dissolution time with the qualifier that the final survey of the coupon would determine if further etching were required.

Figure 5. Sample 1A-1g Analysis Flow Diagram

RACK1A31

Figure 6. 1A Rack-Second Set of Stainless Steel Samples Analysis Flow Diagram

2. The 324 Hot Cell Operators noted that cutting the titanium metal samples was difficult; therefore, the titanium coupon saw cutting was minimized. The titanium coupons had both plasma cut edges and saw cut edges. Plasma cut zones will confuse the final survey somewhat because of occluded activity in the plasma areas. Also the plasma cut zone (a narrow band adjacent to the cut) is altered from the high temperature process. Results from these specimens will have a slightly larger uncertainty due to plasma cut edges.
3. Because of Laboratory difficulties in applying the electropolish technique for cleaning coupon cut areas, it was decided to delete this step in the process. The Laboratory personnel had difficulty in suspending the coupon in the phosphoric bath at the proper height. Apparently, the substantial contact dose rates on the coupons complicated the Laboratory procedure. Edge activity will be included in the sample activity.

After incorporating these changes in procedure as documented in a new analysis plan and a new SOW (Riddelle 1999b), all of the remaining coupons were etched with the 3M mixed acid solution and the resulting solution was analyzed as shown on Figure 6. One significant finding was that the four titanium vessel samples performed differently than the 300 alloy stainless steel. Approximately 70% to 90% of the activity was removed in the mixed acid etch solution. Because the amount of residual alpha contamination was not known, the specimens required further processing. Discussions were held with Laboratory personnel and various chemistry schemes were considered for removal of the titanium dioxide film holding the remaining activity. An amendment was written for the SOW and a new analytical plan was written to cover the titanium specimen subsequent processing (Riddelle 1999c). This is covered in the following section.

The remaining 1A Rack metal samples (not including the titanium specimens) were processed similar to the earlier 1B Rack and 1A samples. After the 3M mixed acid was applied to the coupon, the final volumetric flask had some residual solids (range 10 to 130 mg) similar to the 1B Rack runs. These were separated by decanting and filtration and analyzed by gamma energy analysis and PAM instrument count.

Most of the solids contained less than 1% of the alpha activity with a few in the 1% to 5% range. Gamma activity in the solids in most cases was less than 5% with a few samples in the 10% to 15% range. The coupons were surveyed after the acid etch process to assure that most of the contamination of the film had been removed (preferably >99%).

The single phase solution was analyzed in accordance with the recovery plan QA specified in footnote four of the Recovery Plan QC requirements (Page 5 of WMH 1999).

1.5.3.8 Titanium Samples in Second Batch of 1A Rack Specimens

Figure 7 shows the special treatment that the titanium vessel samples received. There were four samples taken, one lower vessel wall sample and one tower specimen from the 113 concentrator and from the Tank 115 nitric acid fractionator. Samples taken from the fractionator indicated that the major activity was on the exterior surface of the metal; however, the inner surface of the tower had a higher alpha nuclide level. These observations tend to confirm that the vessels were flushed following processing. One benefit of the similar contamination characteristics for the process vessel is that these samples tend to merge with the structural steel sample population. When the sample plan was formulated, the possibility of a separate process vessel sample population was considered likely because the process nuclide concentrations were considerably different from the cell environment.

The titanium vessel samples are somewhat different from the stainless steel structural samples in that mechanical cutting was difficult to accomplish in the REC Airlock. Because the REC Airlock does not have the accessory equipment necessary to cut titanium, the amount of titanium cutting was minimized and the specimens have some saw cut edges and some plasma cut edges. The specimens will differ because the plasma melt zone will have occluded activity and it will have a heat affected zone adjacent to the cut.

The most significant difference associated with the titanium is the inert character of the dioxide film on the metal. This film is inert to most chemical attack and therefore is difficult to remove.

These specimens were given the same mixed acid etch as the others however some of the activity remained on the surface (10% to 34% ^{137}Cs and 16% to 37% alpha). Removal of the remainder of the activity can be accomplished with sulfuric acid, concentrated HCl and a HNO_3 -hydrofluoric acid (HF) mixture. Because this process is analytical in nature, only certain chemistry is acceptable. The HNO_3 -HF chemistry is very efficient in removal. However, implementation in the lab was considered difficult because of safety concerns. Therefore, the concentrated HCl reagent was used. All of the titanium specimens were less than 1% residual alpha after HCl etching, except the 1A-5, which was

RACK1A21

Figure 7. Titanium Samples Analysis Flow Diagram

the Tank 115 acid fractionator tower. The PAM count rate was about 1.5% of the etch solution alpha count rate. Therefore, it was concluded that the concentrated HCl etching was effective and removed all but a trivial percentage of the original alpha activity. Residual activity on the specimen after the concentrated HCl etch was in the range of 1% to 3%, indicating that the titanium dioxide film was effectively removed.

Some solid material remained after the hydrochloric acid etch this was analyzed by gamma energy spectroscopy and portable alpha survey. The Tank 113 concentrator vessel had high solids i.e., 50 mg and 100 mg amounts relative to the Tank 115 nitric acid fractionator (10 to 15mg). This is not uncommon for concentrator equipment. Residual ^{137}Cs activity on the trace solids material (post etch solution) was 3% to 10 % for the Tank 115 vessel samples and 7% to 19% for the Tank 113 vessel samples. This retention, which is higher than preferred, does not present a problem for gamma analyses, because it is evaluated by gamma spectroscopy that is not masked by the solid phase. The solids residual alpha values were less than 1% for the Tank 113 concentrator specimens but were higher for the Tank 115 fractionator specimens (5% to 6%). If the solid material is silaceous material it probably contains three or four times as much alpha based on the fusion work on samples 1A-1d and 1A-14. If the solid phase is titanium dioxide (most likely), the ratio of PAM reading to actual activity is not known. Based on these data, it appears that the fractionator had elevated alpha nuclide concentrations internally.

2.0 DATA ASSESSMENT

All analytical data obtained from the above-mentioned analyses will be used to determine the radionuclide constituents of the fixed contamination layer on rack metal dunnage, with the following exceptions. Initial data reported on 1B rack samples and the first batch of 1A/2B rack samples were not used since the analyses were found to suffer from two major sources of systemic error: (1) excessive base metal concentrations (including precipitation) in the matrix solution after etching, and (2) beta crosstalk in alpha analyzer. Both of these sources of error were minimized or eliminated for the all subsequent analyses.

2.1 Review of Objectives

The key decision regarding the B-Cell dunnage and sifted debris is, "*Do the radionuclide characteristics of the dunnage wastes from B-Cell exceed the LLW waste acceptance criteria?*". The key inputs to answering this question have been identified as the following (see Appendix A of HNF-2804; Hobart and Hill 1999):

- Sampling of the rack, tank, and vessel metal structures in B-Cell
- Laboratory analysis of the fixed radioactive contamination layer on the metal samples
 - ⇒ TRU content (plutonium, americium, curium)
 - ⇒ ^{137}Cs

- ⇒ ^{90}Sr
- ⇒ Other gamma emitters.

The primary objective of this work was to perform radioassay at a quality level that assures compliance with transportation and WAC. The radionuclides of concern for this waste characterization work are ^{137}Cs , ^{90}Sr , and transuranic radionuclides (such as $^{239/240}\text{Pu}$, ^{238}Pu , ^{241}Am , and ^{243}Cm) based on previous data on B-Cell constituents (Webb 1997; Durham 1998). Analysis for other radionuclides may be performed if the stated radioassays fail to identify all alpha-emitting radionuclides present in the fixed layer of the metal samples.

As the current waste contractor, Waste Management Hanford has imposed the criteria that the TRU content of the loaded grout containers must be known with 85% assurance that the determined value is equal to or less than 100 nCi/g for the containers to be accepted as LLW. For analytical data, the reporting will be required to be at the 95% confidence level. The QA/QC requirements given in Table 5 provide further requirements in order to overcome any matrix effects in the radiochemical/analytical portion of the study and still meet the established WAC (WMH 1998).

The use of a 95% bounding value (i.e., the value for which the measurement has 95% assurance that the actual content of the container is equal to or less than the calculated 95% bounding value) on the TRU to ^{137}Cs regression is necessary for the radiological profiling of a given grout container. This is to ensure that after errors associated with the various parts of the grout container radiological profiling process are propagated through the entire process, the requirement that the TRU characterization of the container will be known with at least 85% assurance (The 85% assurance means that the waste is shown to have 100 nCi/g or less of TRU constituents with 85% assurance that the value is repeatable and measurable).

Table 5. Analytical and Quality Control (QC) Requirements

ANALYTE	ANALYTICAL METHOD ^(1,2)	LIMITING CRDL ⁽³⁾ ($\mu\text{Ci/g}$ metal etched)	QC ACCEPTANCE CRITERIA		
			LCS (% Recovery)	SPIKE (% Recovery)	DUPLICATE (RPD)
^{137}Cs	GEA	1×10^{-5}	80 – 120%	N/A	$\leq 20\%$
^{154}Eu	GEA	1×10^{-5}	N/A	N/A	$\leq 20\%$
^{155}Eu	GEA	2×10^{-6}	N/A	N/A	$\leq 20\%$
^{60}Co	GEA	1×10^{-5}	80 – 120%	N/A	$\leq 20\%$
All detectable gamma emitters not listed above	GEA	1×10^{-5}	N/A	N/A	$\leq 20\%$
^{90}Sr	Radiochemical separation and beta counting	1×10^{-5}	80 – 120%	N/A	$\leq 20\%$
Gross alpha	Proportional Counter	5×10^{-6}	80 – 120%	70 - 130%	$\leq 20\%$

ANALYTE	ANALYTICAL METHOD ^(1,2)	LIMITING CRDL ⁽³⁾ ($\mu\text{Ci/g}$ metal etched)	QC ACCEPTANCE CRITERIA		
			LCS (% Recovery)	SPIKE (% Recovery)	DUPLICATE (RPD)
^{238}Pu	Radiochemical separation and AEA	2×10^{-6}	N/A	N/A	$\leq 20\%$
$^{239/240}\text{Pu}$	Radiochemical separation and AEA	2×10^{-6}	70 – 125%	N/A	$\leq 20\%$
^{241}Am	Radiochemical separation and AEA	2×10^{-6}	70 – 125%	N/A	$\leq 20\%$
$^{243/244}\text{Cm}$	Radiochemical separation and AEA	2×10^{-6}	N/A	N/A	$\leq 20\%$
^{243}Cm	ICP/MS ⁽³⁾	N/A	N/A	N/A	$\leq 20\%$
^{244}Cm	ICP/MS ⁽³⁾	N/A	N/A	N/A	$\leq 20\%$
Total Uranium (supplemental)	Laser kinetic phosphorescence	1 ppb	79 – 125%	N/A	$\leq 20\%$

GEA = Gamma Energy Analysis

AEA = Alpha Energy Analysis

ICP/MS = Inductively Coupled Plasma/Mass Spectrometry

N/A = Not applicable for this method

- (1) All samples must be in a homogeneous solution prior to analysis.
- (2) Sample sizes and counting techniques shall be employed that limit counting error to <5%. In the event that <5% counting error cannot be attained, the counting error attained shall be reported and the technical basis for the inability to reach the desired maximum counting error shall be included in the report.
- (3) This supplemental analysis is to be performed only on one acid etch solution (Sample No. S99BW00063) after the recovery dissolution is completed. This determination is for calculating the ratio of the two isotopes only and CRDLs are not applicable.
- (4) Use of detection levels greater than the limiting customer required detection level (CRDL) listed is permissible as long as the analytical result attained to the analysis is at least 10 times the detection level used for that analysis.

Interference from the high ^{137}Cs content in this waste matrix will make reaching the listed limiting CRDL difficult for some gamma emitters (such as ^{154}Eu , ^{155}Eu and ^{60}Co) and gross alpha. Detection levels will be minimized as much as possible in an attempt to reach the limiting CRDL specified.

If ^{154}Eu , ^{155}Eu , ^{60}Co or gross alpha are detected and the analytical result is less than 10 times the detection level used for the analysis, then the technical basis for the inability to reach the required detection level will be reported in the letter report.

If ^{154}Eu , ^{155}Eu and ^{60}Co are not detected; the detection limit must be less than 1% of the Cs result and less than 1% of the respective Category 1 limit. If either of these criteria (< 1% of the Cs result or < 1% of the respective category 1 limit) are not met, the isotope must be reported as < the detection limit used and the technical basis for the lack of ability to reach a lower detection limit must be included in the report of results.

Water wash sample Limiting CRDLs can be a factor of 10 higher than those listed, when restricted by sample volume.

2.2 Data Quality Review

All analytical data were verified and validated in accordance with the 222-S Laboratory Quality Assurance Plan (Markel 1999) and/or the Hanford Analytical Services Quality Assurance Requirements Document (HASQARD) (DOE/RL 1998b) prior to reporting to BWHC. Upon receipt of the Laboratory reports, the data were verified to ensure that the Laboratory completed all analyses required by the applicable SOW. All SOWs and work plans used for this work are given in Table 6.

Table 6. Statements of Work (SOW) Associated with B-Cell Metal Sample Analysis

TITLE	DATE	DOCUMENT NUMBER
324 B-Cell Waste Characterization and Film Removal Samples (Hoover 1998)	11/6/98	WAH-98-003
324 B-Cell 1A Rack Sample Analysis (Riddelle 1999a)	2/16/99	JGR-99-003
Transmittal of the Path Forward Plan for 324 B-Cell Rack 1A/2B and 1B Samples (WMH 1999)	6/1/99	WMH-9953670
324 B-Cell 1A/2B Rack Sample Analysis (2nd Batch) (Riddelle 1999b)	6/14/99	JGR-99-009
Amendment #1 to 324 B-Cell 1A/2B Rack Sample Analysis (2nd Batch) (Riddelle 1999c)	7/14/99	JGR-99-011

The deliverables noted in the SOWs were compared with the information provided in the reports. In all cases, the required analyses were performed to the level of quality requested, except where noted below. In several cases, clerical errors were noted and the Laboratory reports were revised to reflect these changes (Esch 1999e; Esch 1999f; Esch 1999g).

2.2.1 Evaluation of Results of Method Blanks, Laboratory Control Samples, Tracers, and Laboratory Duplicates

The QA and QC samples are used to provide an assessment of the kinds and amounts of bias and/or imprecision in the data (Keith 1998). The ideal situation is when the analyte is reported to be present when it is actually present and absent when it is absent (Figure 8). False positives are decision errors that occur when wrong analytes are concluded to be present. Blanks are used to demonstrate the absence of false positives in the data. False negatives are decision errors that occur when analytes are concluded not to be present when they really are present. False negatives can occur from poor recovery of analytes, matrix effects, or other interferences. Matrix spikes are used to demonstrate the absence of false

		"TRUTH"	
		PRESENT	ABSENT
SAMPLE CONCLUSION	PRESENT	No Error	False Positive Type I error
	ABSENT	False Negative Type II error	No Error

Figure 8. False Positives/False Negatives

negatives. The blanks and matrix spikes cover all sources of laboratory error. Other QC samples are needed to distinguish between sources of laboratory errors and sampling errors (Keith 1998).

2.2.1.1 Path Forward Samples

The recovery of the samples from the 1B rack and the first batch of 1A/2B rack samples were reported in Laboratory Reports Esch 1999b and Esch 1999e. The samples were analyzed in four analytical batches: (1) 1A/2B water washes; (2) 1B water washes; (3) 1A/2B acid etch solutions; (4) 1B acid etch solutions. For all 4 batches, the standard recovery, spike recovery, and the relative percent difference (RPD) between duplicate analyses all met the QC criteria given in the SOW (duplicated in Table 5). Upon reacidification of the acid etch solutions, no iron precipitates were seen. Residual alpha on the metal samples was found to be <1% for all samples.

⁹⁰Sr contamination was found in the preparation blanks for batches 1 and 2 (was <0.15% of sample results for all samples in each batch). ¹³⁷Cs contamination was found in the preparation blank for batch 3 (was <0.02% of sample results). Since activity of blank contaminants was <5% of sample results, it was considered insignificant and no reanalysis was done.

The Laboratory attempted to achieve <5% counting error for all listed radionuclides. This criterion was not met for any of the total alpha analyses. For the acidified water samples (batches 1 and 2), many of the alpha emitters also had counting errors >5%. In batch 3, ¹⁵⁴Eu and ¹⁵⁵Eu had counting errors >5%. In all cases where the counting error criterion was not met, the analyte activity was low or non-detectable above the detection limit. Technical justifications for not meeting these criteria are given in Esch 1999b and Esch 1999e.

According to the Path Forward Plan (WMH 1999), if ^{60}Co , ^{154}Eu , or ^{155}Eu are not detected in the sample, then the detection limit must be less than 1% of the ^{137}Cs and 1% of the respective Category 1 limit for waste acceptance. Preliminary results indicated that batch 3 and 4 samples did not meet the latter criterion. Following reanalysis, all the samples in batch 3 met the 1% of Category 1 criterion. Batch 4 samples were not reanalyzed - the required sample size would cause an ALARA concern due to the high ^{137}Cs activity.

A comparison was done between the results of the total alpha analysis and the summation of the results for all alpha emitters present in the samples. This comparison was done since it was the same such comparison which help identify that systematic errors had occurred during the initial analysis of the 1B rack samples and the first batch of 1A/2B rack samples. For the acid etch solutions (batches 3 and 4), the resulting ratio of the total alpha results to the summation of alpha results ranged from 81% to 118%. Larger discrepancies were found for the water wash solutions (batches 1 and 2). Batch 2 samples were chosen for additional analysis. Total uranium analysis by the phosphorescence method was performed. No uranium was detected at the detection limits of 30 to 70 ppb. Subsequent mass scan of actinide masses between 190 to 260 atomic mass units was performed using ICP/MS. This test also indicated that an insignificant uranium amount was present to account for differences in alpha balance. And, no other peaks were detected in the actinide mass range, i.e., neptunium and thorium were not detected in these samples. A broad spectrum AEA showed no unexpected alpha emitters. Thus, there are no previously unknown alpha emitters found to be present in the samples. Since the activity in the water wash solutions is a small portion of the total activity for any given sample, reanalysis was not done.

The quest to analytically determine the ^{243}Cm to ^{244}Cm ratio was not successful. Curium, a +3 ion, is eluted with the americium fraction and is reported as $^{243}\text{Cm}/^{244}\text{Cm}$. It is suspected that ^{243}Am was present in the 1A-1g sample tested at levels that were far below the levels that can be detected using AEA, but were readily detected using ICP/MS. The interference of ^{243}Am with the ^{243}Cm prevented any conclusions being reached regarding its proportion relative to ^{244}Cm . The Laboratory has indicated that additional analyses for separating the curium from the americium are not currently available. Thus, for this study, the 1:70 ratio of ^{243}Cm (TRU) to ^{244}Cm (non-TRU), previously estimated using process knowledge of the fuel that was added to B-Cell during its operational history (Guenther et. al. 1991), will be used.

2.2.1.2 Second Batch of 1A/2B Samples

The results of the analysis of the second batch of 1A/2B rack samples were reported in Laboratory Reports Esch 1999c and Esch 1999f.

These samples were analyzed in two analytical batches. The standard recovery, spike recovery, and RPD between sample and duplicate results all met the criteria specified in the SOW (Riddelle 1999b).

The mixed acid etching of all stainless steel samples achieved >99% removal of alpha activity from the metal samples. Two of the four titanium samples had >10% of the alpha remaining on the metal samples after mixed acid etching. Further etching was required for the titanium samples (see Section 2.2.1.3).

The criterion of achieving <5% counting error was not met for any of the total alpha analyses. In batch 2, two ^{239}Pu , three ^{154}Eu and, one $^{243/244}\text{Cm}$ had counting errors greater than 5%. In batch 3, only one ^{154}Eu had a counting error greater than 5%. Technical justification for not reanalyzing the samples are given in Esch 1999c and Esch 1999f. For all samples where ^{60}Co , ^{154}Eu , or ^{155}Eu are not detected in the sample, the criteria to be less than 1% of the ^{137}Cs value and less than 1% of the Category 1 limit for waste acceptance was met.

For the test of alpha balance, the resulting ratio of the total alpha results to the summation of alpha results ranged from 72% to 120%.

2.2.1.3 Analysis of the Titanium Samples and Siliceous Solids

The results of further analysis of the titanium samples and analysis of the siliceous solids were reported in Laboratory Reports Esch 1999d and Esch 1999g.

Since the mixed acid etching of the four titanium samples was only partially successful, concentrated HCl was used for additional etching. On all samples, the beta-gamma activity removal from the metal sample was >99% and the alpha activity removal was <99%. For Sample 1A-5, the residual alpha was 1.3%. These samples were analyzed in one analytical batch. The standard recovery, spike recovery, and RPD between sample and duplicate results all met the criteria specified in the SOW (Riddelle 1999c). No contamination was found in the preparation blanks.

A sand-like solid was found in the majority of the mixed acid solutions. These solids were filtered and analyzed in accordance with the SOW (Riddelle 1999c). Three samples underwent KOH fusion in order to obtain information of its radionuclide constituents. The fusion appeared to

be successful on all three samples. The results of one sample were determined to be inconclusive since the mass of the sample had not been determined prior to fusion. This was the 1A-1g sample, which was also used to perform the SEM/EDS analysis. For the fusion of the solids, a standard and preparation blank were included in the batch. For this batch, the duplicates are really replicate aliquots removed from a single digestion, since the entire filter was digested. Standard recoveries met the criteria in the SOW and no contamination was found in the preparation blanks. The RPD for the total alpha analysis of one sample was 39%. The counting uncertainty for that sample was approximately 40% due to low alpha counts. No reanalysis was done.

A portion of the 1A-1g solid sample (30 mg) was sent in for SEM/EDS analysis. From this analysis, it was determined that the solid phase was partially crystalline and partly amorphous, with mainly silica, SiO_2 , composition (Esch 1999b). From the semi-quantitative analysis, traces (1% to 2% by weight) of chromium, iron and aluminum were reported in the sample. Neither cesium nor strontium were observed in the SEM/EDS spectra for the sample. However, as radioactive atoms, they would be present in very low mass quantities and would not be expected to be observed using this method.

The criterion that the counting errors be limited to <5% was not met for ^{238}Pu , $^{239/240}\text{Pu}$, total alpha, and GEA analytes for many of the samples because of low concentrations of these constituents being present. The technical justification for not reanalyzing the samples are given in Esch 1999d and Esch 1999g. For all samples where ^{60}Co , ^{154}Eu , or ^{155}Eu are not detected in the sample, the criteria to be less than 1% of the ^{137}Cs value and less than 1% of the Category 1 limit for waste acceptance was met.

Also, the acid etch solution from sample 1-2A from the 1B rack was chosen to perform additional actinide screening. The previous sample used for actinide screening was a 1B water wash sample. It was felt that since the water wash samples were found to have low concentrations of all radionuclides, it would be prudent to also test acid etch solutions, which were found to have higher radioactivity concentrations than the water washes. A qualitative total uranium and mass scan by ICP/MS were performed. In the mass range of 230 to 260 for actinides, only two small peaks were observed. It is not known to what these peaks are attributed to. No thorium or ^{237}Np was determined to be present.

For the test of alpha balance associated with the titanium samples, the resulting ratio of the total alpha results to the summation of alpha results ranged from 85% to 98%.

2.2.2 Non-Detect and Less-Than Values

Non-detect values are measurements reported by the Laboratory as being less than the defined detection limit for the given analysis method, e.g. $< 3.6\text{E-}04 \mu\text{Ci/ml}$.

There are two general ways to analyze data that contain less-than values (Gilbert 1996):

- Replace the less-than value with a replacement value; commonly used replacement values are "0", 1/2 the detection limit, or the detection limit.
- Employ statistical techniques.

A subset of the first method is to set the less-than values to "0" if there are no detected analytes in the sample set, and to set the less-than values to the detection limit if one or more of the samples have the analyte above the detection limit. For this study, the subset method will be used. This means that for ^{60}Co , ^{155}Eu , and uranium which all had 100% less-than values, the reported mean of the B-Cell samples will be "0". For $^{239/240}\text{Pu}$, ^{154}Eu and ^{125}Sb , the less-than values will be reported at the respective detection limits since each had at least one sample that was reported to have detectable analyte present.

It should be noted that the numerical value of sample statistics, such as the mean and standard error, can be misleading when numerical values are substituted for less-than values. The replacement of less-than values by the respective detection limit is generally regarded as conservative when estimating the true mean since it will give an estimate that is greater than or equal to the estimated mean that would be obtained if the less-than values were replaced by actual measurements (Gilbert 1996).

2.2.3 Missing, Incomplete, or Inadequate Data

Three of the 21 samples scheduled for analysis from the 1A rack (Hobart and Hill 1999) were not shipped to the Laboratory. Sample 1A-6 had radioactivity levels that exceeded the transportation limits for shipping the sample from the 324 Facility to the Laboratory. Samples 1A-4 and 1A-13 were lost prior to shipping. Data that did not meet the specified QC criteria were discussed in Section 2.2.1.

For Sample 1A-1g, the KOH fusion data was determined to be inconclusive and was not used. One contributing factor was that this sample was also used for other analyses. Prior to beginning the fusion of this sample, the mass of the sample to be fused was not determined. The data from the fusion of the other two samples was used to infer the radionuclide constituent composition of the small amounts of siliceous solids left behind in the acid etching solutions.

As mentioned above, the initial data reported for the 1B rack samples and the first batch of the 1A/2B samples will not be used or reported. Those analyses were found to suffer from two major sources of systemic error: (1) excessive base

metal concentrations (including precipitation) in the matrix solution after etching, and (2) beta crosstalk in the alpha analyzer. These problems were remedied before any additional samples were analyzed.

2.3 Data Review

All of the data obtained from the multitude of analyses performed will be used. The contributions to each data set are discussed below.

For the 1B rack samples, the unique features are the following:

- The metal samples were cut by the Laboratory using hydraulic cutters.
- The edges of the specimens were covered with epoxy in an effort to limit cross-contamination (equipment for electropolishing the edges was not yet available).
- The samples underwent ultrasonic water wash in an effort to remove any contamination that may have resulted from handling.
- Mixed acid etching was conducted from 20 minutes to 2 hours
- The initial analytical data was not used due to systematic error found in the process. Data generated from the Path Forward Plan were used.
- The summary data for each sample represents the mathematical addition of the results from the water wash, from mixed acid etching, and any siliceous solids that were found.

For first batch of 1A/2B rack samples, the unique features are the following:

- The 2B sample was taken to represent the 2A rack.
- The metal samples were cut by the Laboratory using hydraulic cutters.
- The edges of the specimens were electropolished in an effort to limit cross-contamination
- The samples underwent ultrasonic water wash in an effort to remove any contamination that may have resulted from handling
- Mixed acid etching was conducted up to 3 hours
- The initial analytical data was not used due to systematic error found in the process. Data generated from the Path Forward Plan were used.
- The summary data for each sample represents the mathematical addition of the results from the water wash and from mixed acid etching.
- No siliceous solids were found in any of these samples, except for 1A-1g.
- For the 1A-1g sample, the siliceous solids found were analyzed and later fused.
 - ⇒ Fusion results were equivocal and were not added into the sample summary.
 - ⇒ SEM/EDS analysis of this solid material found it to be primarily SiO₂.

For the second batch of 1A/2B rack samples, the unique features are the following:

- The 2B sample was taken to represent the 2A rack.
- The metal samples were not cut by the Laboratory.
- The edges of the specimens were not treated.
- The samples did not undergo ultrasonic water washing.
- Mixed acid etching was conducted from 20 minutes to 1 hour.

- The summary data for each stainless steel sample represents the mathematical addition of the results from mixed acid etching and any siliceous solids that were found.
- The summary data for each titanium sample represents the mathematical addition of the results from mixed acid etching, from the HCl etching, and any siliceous solids that were found.
- The siliceous solids from two samples, 1A-1d and 1A-14, were subjected to KOH fusion.
 - ⇒ For these two samples the summary data represents mathematical addition of the results from mixed acid etching and the results from the analysis of the fusion solutions.

Data on removable contamination in B-Cell are included in this data review. The data were obtained in March 1998 in accordance with 324 Facility standard operating procedure, 3I-SOP-G-23, "Radioactive Holdup Sampling Procedure".

2.3.1 Numerical Distributions

To obtain the magnitude of the radionuclide constituents in the fixed radioactive contamination layer, it was necessary to combine the results from analysis of several different components found during the analysis process. The data presented in Table 7 represent a compilation of data from all components for a given sample of B-Cell rack metal. See Appendix A for a breakdown of results for each sample component. As part of the quality control process, duplicate samples were analyzed. In Table 7, the results for each duplicate are shown as the mean of the duplicate results. This applies specifically to samples 1-1A, 1A-1c, 1A-1d, 1A-3, and the HCl etching for sample 1A-5.

Table 8 presents the mean, standard deviation, % total activity, and proportion relative to the ^{137}Cs average value. The radionuclides detected in the radioactive fixed contamination layer of the metal samples were ^{137}Cs , ^{90}Sr , $^{239/240}\text{Pu}$, ^{238}Pu , ^{241}Am , ^{243}Cm , ^{244}Cm , ^{154}Eu . Those not detectable were ^{60}Co , ^{155}Eu , uranium, and neptunium. For two of the four titanium samples, ^{125}Sb was detectable in the HCl etching solution, but not in the initial mixed acid etching. As mentioned above, it was not possible to analytically arrive at a measured ratio between ^{243}Cm and ^{244}Cm . Using process knowledge of the fuel that was used as a source of material added to B-Cell during its operational history, it can be estimated that ^{243}Cm (TRU) and ^{244}Cm (non-TRU) are present in a 1:70 ratio (Guenther et. al. 1991).

Table 7. Summary of Radiochemical Analysis of B-Cell Rack Metal Samples (nCi/g)

RACK	SAMPLE	WEIGHT OF ETCHED AREA (g)	^{239,240} Pu	²⁴⁰ Pu	²⁴⁰ Am	CALC'D ²⁴³ Cm	CALC'D ²⁴⁴ Cm	TRU	CALC'D ALPHA TOTAL	RPT'D TOTAL ALPHA	¹³⁷ Cs	⁹⁰ Sr	⁶⁰ Co	¹⁵⁴ Eu	¹⁵⁵ Eu	¹²⁵ Sb	Total Uranium (ppb)	
1B Rack	1-1a	5.39	3.41	6.33	253.20	1.558	107.517	264.52	372.0	373.5	42,847	29,432	<48.4	186.7	<222.4	---	<66.8	
	1-1b	8.83	1.05	1.90	71.72	0.330	22.786	75.03	97.8	93.0	12,533	10,960	<25.6	83.08	<93.5	---	<53.2	
	1-2a	6.62	2.99	5.18	222.22	1.366	94.279	231.77	326.0	314.4	30,756	25,149	<42.4	127.7	<174.8	---	<38.2	
	1-2b	6.64	1.45	2.98	101.20	0.374	25.808	106.01	131.8	121.5	23,714	14,798	<31.8	114.9	<127.8	---	<72.4	
	3-1a	6.54	2.46	3.76	54.46	0.280	19.340	60.99	80.3	66.5	17,773	27,210	<35.6	123.7	<135.6	---	<57.5	
	3-1b	7.57	1.43	2.28	30.37	0.138	9.556	34.24	43.8	35.6	15,901	8,000	<18.5	62.00	<59.8	---	<54.4	
	3-2a	10.12	1.99	3.02	57.71	0.285	19.663	63.11	82.7	72.4	16,497	25,290	<17.5	61.41	<81.0	---	<33.7	
	3-2b	5.33	1.83	2.83	33.37	0.169	11.681	38.26	49.9	50.4	10,704	15,290	<0.59	19.31	<9.4	---	<65.7	
	1A-1a	57.65	0.22	0.47	5.72	0.026	1.784	6.46	8.21	6.56	3,116	5,450	<0.52	4.44	<5.2	---	---	
	1A-1b	23.00	0.27	0.48	10.30	0.048	3.292	11.13	14.4	11.5	3,462	9,480	<0.66	9.35	<6.4	---	---	
1A Rack	1A-1c	9.81	0.16	0.33	10.99	0.049	3.390	11.53	14.9	14.9	1,927	1,589	<0.15	7.46	<3.9	---	---	
	1A-1d	22.21	0.74	0.69	15.80	0.077	5.323	17.36	22.6	20.6	6,669	10,500	<0.14	9.86	<3.7	---	---	
	1A-1e	19.29	0.17	0.37	3.51	0.015	1.008	4.06	5.07	5.44	1,766	4,494	<0.31	2.98	<2.5	---	---	
	1A-1f	18.65	0.60	0.75	3.90	0.016	1.115	5.27	6.38	6.94	4,967	7,615	<0.36	3.36	<5.3	---	---	
	1A-1g	29.46	2.08	2.16	11.27	0.043	2.988	15.55	18.5	19.4	14,873	15,082	<0.28	7.38	<8.9	---	---	
	1A-1h	8.90	0.09	0.14	0.99	0.005	0.341	1.23	1.57	1.86	1,847	1,364	<0.38	1.41	<2.8	---	---	
	1A-2	25.26	0.24	0.50	1.98	0.011	0.735	2.74	3.46	4.04	2,377	1,959	<1.03	3.29	<3.3	81.1	---	
	1A-3	54.83	0.04	0.09	0.37	0.002	0.129	0.53	0.64	0.54	918	233	<0.05	0.19	<0.8	---	---	
	1A-5	53.86	0.22	0.45	2.27	0.012	0.796	2.96	3.74	3.48	500	749	<0.13	1.55	<0.9	<0.29	---	
	1A-7	39.41	0.97	2.25	22.74	0.117	8.090	26.10	34.2	33.4	3,089	1,616	<0.49	9.63	<2.5	<34.8	---	
2B Rack	1A-8	19.09	0.15	0.39	2.75	0.011	0.748	3.33	4.04	4.33	1,937	2,226	<0.58	4.06	<2.7	2.01	---	
	1A-9	81.11	0.30	0.62	2.96	0.015	1.005	3.96	4.90	3.55	1,595	1,640	<0.40	1.30	<3.0	---	---	
	1A-10	39.78	0.19	0.42	1.71	0.008	0.573	2.35	2.90	2.92	1,510	518	<0.32	1.36	<2.9	---	---	
	1A-11	50.21	0.04	0.08	0.59	0.003	0.223	0.74	0.94	0.86	646	339	<0.54	1.66	<2.7	---	---	
	1A-12	43.40	0.69	0.71	5.18	0.023	1.567	6.63	8.17	7.95	4,051	4,220	<0.12	3.27	<2.8	---	---	
	1A-14	106.70	0.53	0.93	4.65	0.030	2.070	6.19	8.21	6.94	904	1,660	<2.3	7.31	<4.5	---	---	
	2B-1a	60.86	1.13	1.51	1.77	0.003	0.203	4.42	4.62	4.34	424	184	<0.35	1.16	<0.8	---	---	
	2B-1b	88.41	0.49	0.66	1.00	0.002	0.155	2.16	2.31	2.34	390	139	<0.02	0.25	<0.3	---	---	
	a Calculated Alpha is the summation of the values for all alpha emitting radionuclides (^{239,240} Pu, ²⁴⁰ Pu, ²⁴⁰ Am, ²⁴³ Cm, ²⁴⁴ Cm).																	

Table 7. Summary of Radiochemical Analysis of B-Cell Rack Metal Samples (nCi/g) (continued)

RACK	SAMPLE	RPT'D ALPHA/Cs RATIO	CALC'D ALPHA/Cs RATIO	TRU/Cs RATIO	Sr/Cs RATIO	RPT'D ALPHA/ CALC'D ALPHA RATIO	TOTAL ACTIVITY (nCi/g)
1B Rack	1-1a	0.00872	0.00868	0.00617	0.687	1.004	72,837
	1-1b	0.00742	0.00780	0.00599	0.874	0.951	23,674
	1-2a	0.01022	0.01060	0.00754	0.818	0.964	56,358
	1-2b	0.00512	0.00556	0.00447	0.624	0.921	38,759
	3-1a	0.00374	0.00452	0.00343	1.531	0.828	45,187
	3-1b	0.00224	0.00275	0.00215	0.503	0.813	24,007
	3-2a	0.00440	0.00501	0.00383	1.533	0.876	41,932
	3-2b	0.00471	0.00466	0.00357	1.428	1.010	26,064
1A Rack	1A-1a	0.00211	0.00264	0.00207	1.749	0.799	8,518
	1A-1b	0.00332	0.00415	0.00322	2.738	0.799	12,821
	1A-1c	0.00775	0.00774	0.00598	0.825	1.001	3,542
	1A-1d	0.00309	0.00339	0.00260	1.574	0.910	16,976
	1A-1e	0.00308	0.00287	0.00230	2.545	1.073	6,271
	1A-1f	0.00140	0.00129	0.00106	1.533	1.087	12,597
	1A-1g	0.00130	0.00125	0.00105	1.014	1.046	29,990
	1A-1h	0.00101	0.00085	0.00067	0.738	1.186	3,217
	1A-2	0.00170	0.00146	0.00115	0.824	1.168	4,404
	1A-3	0.00058	0.00069	0.00058	0.254	0.843	1,078
	1A-5	0.00695	0.00747	0.00593	1.497	0.930	1,250
	1A-7	0.01081	0.01106	0.00845	0.523	0.977	4,775
2B Rack	1A-8	0.00224	0.00209	0.00172	1.149	1.073	4,138
	1A-9	0.00223	0.00307	0.00248	1.028	0.724	3,150
	1A-10	0.00193	0.00192	0.00155	0.343	1.007	1,995
	1A-11	0.00133	0.00146	0.00115	0.525	0.911	958
	1A-12	0.00196	0.00202	0.00164	1.042	0.973	8,034
	1A-14	0.00768	0.00908	0.00685	1.837	0.845	2,490
	2B-1a	0.01048	0.01115	0.01043	0.444	0.940	605
	2B-1b	0.00601	0.00593	0.00553	0.356	1.014	532

Table 8. B-Cell Metal Rack Sample Data Analysis Results

Radionuclide	Average Conc. (nCi/g)	Std. Dev. (nCi/g)	Lower 95% CI ^a	Upper 95% CI ^a	CV ^b	% Total Activity	Relative to ¹³⁷ Cs
^{239/240} Pu	0.93	0.94	0.62	1.23	102%	0.0057%	0.00011
²³⁸ Pu	1.51	1.59	1.00	2.02	106%	0.0093%	0.00019
²⁴¹ Am	33.4	63.0	13.1	53.7	189%	0.205%	0.0041
CALC'D ²⁴⁰ Cm	0.179	0.379	0.057	0.301	212%	0.0011%	0.000022
CALC'D ²⁴⁴ Cm	12.4	26.2	3.9	20.8	212%	0.0758%	0.0015
¹³⁷ Cs	8,132	10,488	4,756	11,507	129%	49.9%	1.00
⁹⁰ Sr	8,114	9,124	5,177	11,050	112%	49.8%	0.998
⁶⁰ Co ^c	0	N/A	N/A	N/A	N/A	0.0%	0
¹⁵⁴ Eu	30.7	50.4	14.5	47.0	164%	0.188%	0.0038
¹⁵⁵ Eu ^c	0	N/A	N/A	N/A	N/A	0.0%	0
¹²⁵ Sb ^d	29.6	37.9	19.8	61.8	128%	0.181%	0.0036
TRU	36.0	65.6	14.9	57.1	182%	0.221%	0.0044
Uranium	0	N/A	N/A	N/A	N/A	0.0%	0
CALC'D ALPHA TOTAL	48.4	91.6	18.9	77.9	189%	0.297%	0.0060
RPT'D TOTAL ALPHA	46.0	90.0	17.1	75.0	195%	0.282%	0.0057
TRU/ ¹³⁷ Cs RATIO	0.00371	0.00265	0.00286	0.00457	71%	---	---
⁹⁰ Sr/ ¹³⁷ Cs RATIO	1.092	0.636	0.888	1.297	58%	---	---
RPT'D ALPHA/ CALC'D ALPHA	0.953	0.112	0.916	0.989	12%	---	---
TOTAL ACTIVITY (nCi/g)	16,347	19,234	10,157	22,537	118%	---	---

a CI = (Statistical) Confidence Interval. 95% CI = Average $\pm$ t_{0.05,n-1} *Std. Dev./(# Observations)^{0.5}.

b CV = Coefficient of Variation = Std. Dev./Average, expressed as a percentage of the mean or average value.

c See Section 2.2.2 for explanation of substituting "0" when a radionuclide has 100% less-than values reported.

d ¹²⁵Sb was only observed in the siliceous solids found for titanium samples 1A-2, 1A-5, 1A-7, and 1A-8.

The major radionuclides present in the fixed contamination layer are ^{137}Cs (49.9%) and ^{90}Sr (48.8%). Each of the remaining detectable radionuclides were found to represent less than 0.3% of the total radioactivity.

Table 9 presents data for the technical smears³ of B-Cell to measure removable contamination levels and radionuclide constituents. Table 10 presents the mean, standard deviation, % total activity, and proportion relative to the ^{137}Cs average value for the B-Cell removable smears. The radionuclides detected on the smear samples were ^{137}Cs , ^{90}Sr , $^{239/240}\text{Pu}$, ^{238}Pu , ^{241}Am , ^{243}Cm , ^{244}Cm , and ^{154}Eu . And, as with the metal rack samples, ^{60}Co and ^{155}Eu were not found in detectable quantities. No ^{125}Sb was detectable on the smear samples.

2.3.2 Mobile Radionuclides

Most of the 10 site-designated mobile radionuclides can be discounted for B-Cell wastes through process knowledge. Due to the use of high temperature processes within the cell, such as calcination and various vitrification processes, any volatile radionuclides are not expected to be present in concentrations greater than the mobile radionuclide reporting limit. Tritium (^3H), which is generated from ^6Li , is not expected to have been present in fuel used in B-Cell. ^{14}C is generated from ^{14}N by an (n,p) reaction and should not have been present in B-Cell. ^{36}Cl and ^{93}Mo are activation products and are not expected to be present in B-Cell. ^{187}Re is not normally present in fuel material, and thus, is not expected to be present in B-Cell. Uranium and ^{237}Np were not found to be present in the B-Cell samples.

Two of the designated mobile radionuclides that cannot be entirely dismissed are ^{79}Se and ^{99}Tc . Since both of these radionuclides are pure beta emitters, and the cost and timing of the associated analytical procedures may be prohibitively restrictive, a ratioing method using ORIGEN data will be used to estimate potential concentrations of these site-designated mobile radionuclides. Ratioing will be done with ^{241}Am . ^{137}Cs or ^{90}Sr are not acceptable for use in a ratioing method for mobile radionuclides since high activities of these separated radionuclides were added to B-Cell for use in the FRG program.

The ORIGEN data is based on expected yields for reactor fuel having 20,000 megawatt-days per ton (MWD/T) exposure and 10 years of cooling, which is the type of reactor fuel most similar to that in B-Cell. The expected yields are as follows:

- ^{79}Se yield is $2.5\text{E-}7$ Ci/g U
- ^{99}Tc yield is $8.3\text{E-}6$ Ci/g U
- ^{241}Am yield is $1.06\text{E-}3$ Ci/g U.

³ In this context, technical smear is considered a smear that is taken of 100 cm² of a surface.

Table 9. Summary of Radiochemical Analysis of B-Cell Smears of Removable Contamination (nCi/smear or nCi/100 cm²)*

SAMPLE	^{239/240} Pu	²³⁹ Pu/ ²⁴¹ Am	CALC'D ²³⁹ Cm	CALC'D ²⁴⁰ Cm	TRU	CALC'D ALPHA TOTAL	RPT'D TOTAL ALPHA	¹³⁷ Cs	⁹⁰ Sr	⁶⁰ Co	¹⁵⁴ Eu	¹⁵³ Eu
39b	17.3	106	0.761	52.5	124	177	178	167,582	72,428	<18.5	284	<195.6
40b	1.16	6.63	0.037	2.54	7.83	10.4	12.0	7,042	3,068	<3.5	14.6	<35.6
42a	19.4	253	1.174	81.0	274	355	336	42,862	42,228	<4.5	164	<85.6
43a	1.51	4.77	0.029	1.97	6.31	8.3	9.9	1,502	1,798	<2.5	3.30	<15.6
44b	4.16	13.7	0.048	3.31	17.9	21.2	22.9	4,782	1,118	<2.5	8.90	<15.6
45a	7.83	75.5	0.343	23.7	83.7	107	109	53,302	28,128	<8.5	81.4	<85.6

SAMPLE	RPT'D ALPHA/Cs	CALC'D ALPHA/Cs	TRU/Cs	Sr/Cs	RPT'DALPHA/ CALC'D ALPHA	TOTAL ACTIVITY (Bq/g)
39b	0.00106	0.00105	0.00074	0.432	1.007	240,686
40b	0.00170	0.00147	0.00111	0.436	1.157	10,175
42a	0.00784	0.00827	0.00638	0.985	0.947	85,680
43a	0.00659	0.00551	0.00420	1.197	1.196	3,331
44b	0.00479	0.00444	0.00375	0.234	1.078	5,949
45a	0.00204	0.00201	0.00157	0.528	1.015	81,714

* Note that the analysis of the B-Cell smears were performed in 1998 by the Analytical Chemistry Laboratory (ACL) of Pacific Northwest National Laboratory. The ACL reports a combined ²³⁹Pu/²⁴¹Am instead of reporting values for each of these radionuclides.

Table 10. B-Cell Removable Smear Data Analysis Results

Radionuclide	Average Conc. (nCi/g)	Std. Dev. (nCi/g)	Lower 95% CI*	Upper 95% CI*	CV*	% Total Activity	Relative to ¹³⁷ Cs
^{239/240} Pu	8.54	7.96	2.01	14.08	93%	0.0120%	0.00018
²³⁸ Pu/ ²⁴¹ Am	76.7	96.0	9.94	143.37	125%	0.1076%	0.00166
CALC'D ²⁴³ Cm	0.399	0.475	0.069	0.729	119%	0.0006%	0.00001
CALC'D ²⁴⁴ Cm	27.5	32.8	4.73	50.3	119%	0.0386%	0.00060
¹³⁷ Cs	46,178	63,312	2,161	90,196	115%	64.81%	1
⁹⁰ Sr	24,794	28,794	4,775	44,813	116%	34.80%	0.537
⁶⁰ Co ^c	0	N/A	N/A	N/A	N/A	N/A	N/A
¹⁵⁴ Eu	92.80	112.32	14.7	171	121%	0.13%	0.00201
¹⁵⁵ Eu ^c	0	N/A	N/A	N/A	N/A	N/A	N/A
TRU	85.6	104	13.5	158	121%	0.12%	0.00185
CALC'D ALPHA TOTAL	113	136	18.6	207.6	120%	0.16%	0.00245
RPT'D TOTAL ALPHA	111	129	21.8	201	116%	0.16%	0.00241
TRU/ ¹³⁷ Cs RATIO	0.00296	0.00220	0.00143	0.00449	74%	---	---
⁹⁰ Sr/ ¹³⁷ Cs RATIO	0.635	0.372	0.377	0.894	59%	---	---
RPT'D ALPHA/ CALC'D ALPHA	1.07	0.10	1.001	1.113	8.9%	---	---
TOTAL ACTIVITY (nCi/g)	71,256	91,251	7,814	134,698	128%	---	---

a CI = (Statistical) Confidence Interval. 95% CI = Average $\pm$ $t_{0.05,n-1}$ *Std. Dev./(# Observations)^{0.5}.

b CV = Coefficient of Variation = Std. Dev./Average, expressed as a percentage of the mean or average value.

c See Section 2.2.2 for explanation of substituting "0" when a radionuclide has 100% less-than values reported.

The associated ratios to be used to estimate potential concentrations of the two mobile radionuclides in B-Cell waste are:

- ⁷⁹Se to ²⁴¹Am ratio is 0.000236
- ⁹⁹Tc to ²⁴¹Am ratio is 0.007830.

Procedurally (324 Facility SOP 3I-SOP-REC-A-49), only 2,500 lbs of metal waste can be loaded into a given grout container. That results in 1.13E6 g rack metal per grout container. The volume of a grout container is 1.43 m³, from Hanford engineering drawing, H-3-49415. Thus, the maximum density of rack material in a grout container would be 1.14E7 g/m³. This value multiplied by the average concentration of ²⁴¹Am reported (in nCi/g) for the fixed contamination layer of the B-Cell metal samples multiplied by the conversion factor of 1Ci/1E9 nCi will be the estimated concentration of the given mobile radionuclide (in units of Ci/m³). The estimated concentrations of ⁷⁹Se and ⁹⁹Tc will then be compared to the associated mobile radionuclide reporting limits in HNF-EP-0063 (WMH 1998). If the estimated concentrations are greater than the mobile radionuclide

reporting limits, then an evaluation of the disposal conditions to ensure disposal is compliant with burial ground performance objectives is performed by the waste contractor.

2.3.3 Spatial Distributions

In addition to the numerical variability of the samples, there is also a spatial variability of the distribution of the radionuclides within B-Cell. See Figures 9 through 13 for distributions of ^{137}Cs and TRU concentrations on the racks in B-Cell. Slight variations in the radionuclide distribution are seen in B-Cell. The sampling and analysis plan (Hobart and Hill 1999) was not designed to allow a quantitative assessment of the spatial variability of radioactive contamination within B-Cell. Thus, only a qualitative assessment can be made.

In general, the activity decreases as you go from top of the cell to the floor, south to north (from the 1B rack to the 2A rack), and rack front to rack back. Based on process knowledge of the uses of the B-Cell racks, this is not an unexpected result. The 1B rack, in the southeast corner of B-Cell, dealt with the high-activity feed materials. The 1A rack, which was farther north on the east wall of B-Cell, was used for high concentration/high activity process functions. The 2A rack is in the northeast corner of B-Cell and was separated from high-activity process functions. Its function was to scrub vent off-gases from the various processes performed in B-Cell.

It should be noted that there is a lack of data on the exact location where the 1B samples were taken on the horizontal support channels. They are shown graphically in Figure 10 at randomly selected locations. See Section 1.5.3.1 for information.

B-Cell - View toward East Wall

Figure 9. Spatial Distribution of ^{137}Cs and TRU Concentration (nCi/g) on Racks in B-Cell

Rack 1B - Front View

Figure 10. Spatial Distribution of ^{137}Cs and TRU Concentration (nCi/g) on 1B Rack (Front View)

Rack 1A - Front View

Figure 11. Spatial Distribution of ^{137}Cs and TRU Concentration (nCi/g) on 1A Rack Nozzle Rack (Front View)

Rack 1A - Side View

Figure 12. Spatial Distribution of ^{137}Cs and TRU Concentration (nCi/g) on 1A Rack in B-Cell (Side View)

RACK 2B - Front View (attached to 2A Rack)

Figure 13. Spatial Distribution of ^{137}Cs and TRU Concentration (nCi/g) on 2A/2B Racks in B-Cell (Front View)

3.0 RADIOLOGICAL SCALING FACTORS

As discussed below, the TRU to ^{137}Cs scaling factor has a very important part in the radiological profiling of B-Cell grout containers.

3.1 Background of Process to Radiological Profile B-Cell Grout Containers

Since TRU nuclides that are present in the waste can not be directly determined, measurement of the dose rate from the ^{137}Cs in the waste will be used as an indicator to the TRU present in the waste (Figure 14). It is the TRU: ^{137}Cs scaling factor that relates the measured ^{137}Cs content of a grout container to the content of TRU radionuclides. For B-Cell, the radionuclides that make up the TRU component of the waste are $^{239/240}\text{Pu}$, ^{238}Pu , and ^{243}Cm . By definition in the Hanford solid WAC, ^{244}Cm is not considered a TRU radionuclide since its half-life is less than 20 years (WMH 1998).

Figure 14. General Scheme for Radiological Profiling B-Cell Grout Container Wastes

HNF-4799 (Shelor 1999) provides the technical basis for determining the ^{137}Cs content of a loaded B-Cell grout container from dose rates measured at a specified distance from the grout container. Information reported in this document provides the results of the radioanalytical look at the fixed contamination layer of the metal structures in B-Cell. This analytical data is used to develop the TRU: ^{137}Cs scaling factor. The scaling factor, used in conjunction with the ^{137}Cs content determined for a given grout container, is used to estimate the TRU concentration of the waste. The estimated TRU concentration then can be compared to the WAC in order to classify the waste as LLW or TRU waste.

3.2 Development of TRU:Cs Radiological Scaling Factor

The ^{137}Cs and TRU data pairs from Table 7 for the B-Cell metal rack samples are used to develop the scaling factor.

The TRU: ^{137}Cs scaling factor is obtained by plotting TRU data against the ^{137}Cs data (from Table 7). As can be seen in Figure 15, there is a definite linear relationship between TRU and ^{137}Cs as evidenced by having a linear regression line with a non-zero slope. Table 11 contains the statistical results of a linear regression analysis of the data run using the Data Analysis Tools of Excel®. A line is fit through the data using the least squares method. R^2 is the percent of the variability in the data that can be explained by the straight line, e.g., 87.6% of the data variability accounted for.

Table 11. Summary Output of TRU: ^{137}Cs Regression Statistics

Regression Statistics				
R^2	0.876362			
Standard Error	23.5153			
Observations	28			
	<i>Coefficients</i>	<i>Standard Error</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	-11.610095	5.662176	-23.248872	0.028681
Slope	0.0058575	0.000432	0.0049706	0.006744

Figure 15: TRU: ¹³⁷Cs Scaling Factor Determination

Since the value "zero" is included in the 95% confidence interval for the intercept, it is valid to redo the regression analysis and force the regression line through the origin (i.e., force the intercept to "0"). The results of this reanalysis are shown in Figure 16 and Table 12.

Table 12. Summary Output of TRU:¹³⁷Cs Regression Statistics When Regression Forced Through Origin

Regression Statistics				
R ²	0.856369			
Standard Error	24.8716			
Observations	28			
	Coefficients	Standard Error	Lower 95%	Upper 95%
Intercept	0	N/A	N/A	N/A
Slope	0.005309	0.000358	0.004574	0.006044

For this analysis, the R² value is 0.856. The slope of the regression line, which is the TRU:¹³⁷Cs scaling factor, is **0.00531**. To determine the 95% confidence band on the regression equation, the following version of Equation 10.31 from Ostle and Malone 1988 is used:

$$(L,U) = \hat{Y} \pm t_{0.05} s_{\hat{Y}}$$

where:

$$s_{\hat{Y}}^2 = SE^2 \left[\frac{X^2}{\sum X_i^2} \right]$$

$\hat{Y}$ = The predicted Y value (TRU value) on the regression line at a given X value (¹³⁷Cs value), where $\hat{Y} = bX$ and b is the estimated slope at X = ¹³⁷Cs value.

$s_{\hat{Y}}^2$ = The estimated variance of $\hat{Y}$ regression line.

$t_{0.05}$ = The quantile from Student's t distribution with n-1 = 28-1 = 27 degrees of freedom for a 2-sided 95% confidence bound on the regression equation.

SE = The standard error associated with the regression data = 24.87.

n = Number of observations = 28.

L = Lower confidence interval.

U = Upper confidence interval.

Figure 16: TRU:¹³⁷Cs Scaling Factor Determination When Regression Forced Through Origin

In order to meet the 85% assurance criteria set by the waste contractor for determining the TRU concentration in the waste using the radiological profiling scheme depicted in Figure 14, the upper 95% bounding value (i.e., upper confidence interval) on the analytical data will be used. The upper 95% bounding value will be taken as the upper

limit to the regression line, $(95\% BV) = \hat{Y} + t_{0.05} s_{\hat{Y}}$, where $t_{0.05}$ is the quantile from

Student's t distribution, with n-1 degrees of freedom, for a 1-sided 95% confidence statement. Using the 95% BV = 100 nCi TRU/g, the resulting ^{137}Cs concentration is 17,062 nCi/g. Therefore, in order to have 95% assurance that 100 nCi/g or less of TRU constituents are in the waste, the ^{137}Cs concentration must be less than or equal to 17,062 nCi/g. This is equivalent to 19.4 Ci ^{137}Cs (assuming the net weight of the waste is 2,500 lbs and the volume of a grout container is 1.43 m³) which would give a gross dose rate of 0.314 R/hr at 10 feet from the ungrouted grout container. These threshold values will change with the changes in either net weight of the waste or the distance from the grout container used to obtain the dose rate measurements.

3.3 Sr:Cs Radiological Scaling Factor

The relationship between ^{90}Sr and ^{137}Cs seen for both the removable and fixed contamination is different than that previously reported by Durham (1998). Durham reported that the ^{90}Sr : ^{137}Cs ratio was 2.2:1 for the three smears taken in 1993 and was 0.18:1 for the three 1998 smears. Upon further analysis, the general ratio suggested for use was 2.5:1 (Durham 1998). As reported in Table 10, analysis of the smears of removable contamination in B-Cell obtained under controlled conditions shows that the ratio for removable contamination is approximately 0.6:1. The average ^{90}Sr : ^{137}Cs ratio in the fixed contamination layer was 1.1:1 (Table 8).

The ^{90}Sr : ^{137}Cs scaling factor is obtained by plotting ^{90}Sr data against the ^{137}Cs data (from Table 7). As can be seen in Figure 17, there is a linear relationship between ^{90}Sr and ^{137}Cs as evidenced by having a linear regression line with a non-zero slope. Table 13 contains the statistical results of a linear regression analysis of the data run using the Data Analysis Tools of Excel[®] for both with and without forcing the regression line through zero. Since the value "zero" is included in the 95% confidence interval for the intercept for the original regression line, it is valid to have the regression analysis force the regression line through the origin. The resultant ^{90}Sr : ^{137}Cs scaling factor is 0.860, where $^{90}\text{Sr} = 0.860 \cdot ^{137}\text{Cs}$.

Figure 17. ^{90}Sr : ^{137}Cs Scaling Factor Determination

Table 13. Summary Output of ^{90}Sr : ^{137}Cs Regression Statistics

Regression Statistics				
R^2	0.791958			
Standard Error	4241			
Observations	28			
	<i>Coefficients</i>	<i>Standard Error</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	1818.226	1021.177	-280.834	3917.286
Slope	0.774177	0.077818	0.614221	0.934134
Regression Statistics - Through Origin				
R^2	0.766591			
Standard Error	4408.151			
Observations	28			
	<i>Coefficients</i>	<i>Standard Error</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	0	N/A	N/A	N/A
Slope	0.860038	0.063483	0.729783	0.990293

3.4 Other Radiological Scaling Factors

For the other radionuclides ($^{239/240}\text{Pu}$, ^{238}Pu , ^{241}Am , ^{243}Cm , ^{244}Cm , and ^{154}Eu) present in the fixed contamination layer on the rack samples, the mean value for each radionuclide relative to ^{137}Cs will be used as the scaling factor. As mentioned in Section 2.3.1, none of the radionuclides besides ^{137}Cs and ^{90}Sr amount to more than 0.3% of the total radioactivity present. See the last column of Table 8 for the scaling factors for $^{239/240}\text{Pu}$, ^{238}Pu , ^{241}Am , ^{243}Cm , ^{244}Cm , and ^{154}Eu .

4.0 CONCLUSIONS

4.1 Waste Classification Data

The collection of B-Cell structural metal samples for analysis of the fixed contamination layer was successful. Thus far, 31 samples of the 39 samples planned (Hobart and Hill 1999) have been collected. Schedule delays have prevented the collection of the eight samples from the 2A rack. Of the 31 samples collected from the 1B, 1A, and 2B racks, 28 were analyzed. Two samples were misplaced prior to shipping and one sample had activity too high to meet shipping requirements. Additional metal samples from Rack 2A, as prescribed in HNF-2804, have been determine to not be required since they are expected to have low activity (Jensen and Hobart 1999). Additional samples, with low activity, would produce data that would not influence the slope of the regression equation given in Section 3.2 of HNF-4904.

Even though the process by which the fixed contamination layer was removed varied from batch to batch, and even though analysis was required from multiple constituents

resulting from the acid etching process (e.g., water wash and acid etch solutions, and a siliceous precipitate), the data met the high level of quality requirements placed upon it in the sampling and analysis plan (Hobart and Hill 1999). The analytical results were able to reach the 95% confidence level for most radionuclides. The high level of ^{137}Cs in the samples interfered with achieving this goal for certain of the radionuclides. The initial problem of not having the total alpha results equal the summation of the results for each of the alpha emitters was solved. The interference of matrix effects from dissolution of iron from the metal samples were minimized through a high level of diligence from the Laboratory staff. The unexpected occurrence of siliceous precipitates in the majority of acid etch solutions and the tenacious binding of the radioactive constituents in an oxide layer on the titanium samples were amply handled by the Laboratory staff. Based on the results of the various quality control samples performed, the analytical results met the high level of quality required.

The radionuclides detected in the radioactive fixed contamination layer of the metal samples were ^{137}Cs , ^{90}Sr , $^{239/240}\text{Pu}$, ^{238}Pu , ^{241}Am , ^{243}Cm , ^{244}Cm , ^{154}Eu . Those not detectable were ^{60}Co , ^{155}Eu , uranium, thorium and neptunium. For two of the four titanium samples, ^{125}Sb was detectable in the HCl etching solution, but not in the initial mixed acid etching. It was not possible to analytically arrive at a measured ratio between ^{243}Cm (TRU) and ^{244}Cm (non-TRU). Therefore, a 1:70 ratio between the two radionuclides was adopted using process knowledge of B-Cell activities.

The linear regression analysis of the data indicated that a linear relationship between ^{137}Cs concentration and TRU concentration could be described with 95% confidence. Therefore, a TRU: ^{137}Cs scaling factor ($\text{TRU} = 0.00531 * ^{137}\text{Cs}$) was developed for use in the radiological profiling of B-Cell waste that is loaded in grout containers to use to predict TRU content from the ^{137}Cs content. Use of the scaling factor will produce estimates of TRU concentrations at the 95% confidence level. A ^{90}Sr : ^{137}Cs scaling factor was developed from the fixed contamination layer results, where $^{90}\text{Sr} = 0.860 * ^{137}\text{Cs}$. Scaling factors for other detectable radionuclides are presented in Table 8 for fixed contamination and Table 10 for removable contamination.

Upon review of the results of the TRU: ^{137}Cs scaling factors for fixed and removable contamination in B-Cell, it is seen that the scaling factor of the fixed contamination is more conservative (i.e., predicts a higher concentration of TRU) than that for removable contamination. The scaling factor for fixed contamination is 0.00531 and for removable it is 0.003. For most, if not all, non-rack material placed in grout containers, the removable contamination results would most likely apply. This conclusion can be reached since this type of materials are high turnover items, such as manipulator boots, which mostly likely would not have been present in B-Cell during the time of the high-activity processing which is thought to have resulted in the fixed contamination layer. To avert costly expense (of time and money) from obtaining and analyzing additional samples of all these materials, the conservative assumption will be made that the scaling factor for fixed contamination (0.00531) applies to all waste placed in B-Cell grout containers.

4.2 Results of Fixed Contamination Layer Removal Study

During mid-1998, a development study was done in the Laboratory to investigate what reagents would perform well to chemically decontaminate the metal and other surfaces within B-Cell. Metal samples from the 1B Rack were taken late in the year to characterize rack metal being disposed to the low-level burial ground (LLBG). Parts of these specimens were used to test various reagents including mineral acid, organic acids, bases and alkaline permanganate. Several reagents provided good removal of the radionuclides from the metal coupon surface. Two reagents were chosen for further analysis; they are AP-Nitric and AP-Citrox (AP is a mixture of sodium hydroxide and potassium permanganate; Citrox is a mixture of oxalic and citric acids). The testing results are given in HNF-4298 (O'Rourke 1999). Further alpha radionuclide analysis will be done to verify chemical performance for these reagents before use.

The present project management plan (PMP) for 324 Facility (BWHC 1998) is formulated based on chemical cleaning for most contaminated surfaces in the hot cells, etc. Present plans are to modify the techniques to emphasize use of physical methods, specifically, high-pressure water to clean surfaces. The benefits of this approach are threefold, namely, the waste streams are much easier to process, the volume of solid waste is significantly reduced, and the rate of cleaning is much faster. Some planned decontamination will require chemical cleaning, such as pipe cleaning and possibly some tank internal surfaces. These volumes will be minimized to agree with the change in overall approach noted above.

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6.0 GLOSSARY

These definitions were obtained from ASTM 1998, EPA 1994, EPA 1998, and WMH 1999.

action level—the numerical value that causes the decision-maker to choose one of the alternative actions (e.g., compliance or noncompliance). It may be a regulatory threshold standard, such as a Maximum Contaminant Level for drinking water; a risk-based concentration level; a technological limitation; or a reference-based standard. [NOTE: the action level is specified during the planning phase of a data collection activity; it is not calculated from the sampling data.]

bias—A systematic error that is consistently negative or consistently positive (i.e., the expected sample measurement is different than the sample's true value).

boundaries—the spatial and temporal conditions and practical constraints under which environmental data are collected. Boundaries specify the area or volume (spatial boundary) and the time period (temporal boundary) to which the decision will apply. Samples are then collected within these boundaries.

carrier – A known amount of the naturally occurring element of interest added to the sample. The carrier demonstrates the same chemical behavior as the isotope of interest. The recovery is not reported, but is used to correct results for losses incurred during separation (used in ⁹⁰Sr analysis).

characteristic—A property of items in a sample or population which can be measured, counted, or otherwise observed.

confidence limit—An upper and/or lower limit(s) within which the true value is likely to be contained with a stated probability or confidence.

data validation—Examination of available laboratory data to determine whether an analyte is present or absent in a sample and the degree of overall uncertainty associated with the reported value.

data verification—Determination whether the laboratory carried out all steps required by the sampling and analysis plan, contract, or statement of work.

Data Quality Assessment (DQA) Process—Statistical and scientific evaluation of the data set to assess the validity and performance of the data collection design and statistical test, and to establish whether a data set is adequate for its intended use.

Data Quality Objective (DQO)—Qualitative and quantitative statements derived from the DQO Process that clarify study objectives, define the appropriate type of data, and specify the tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.

decision error—An error made when drawing an inference from data in the context of hypothesis testing, such that variability or bias in the data mislead the decision maker to draw a conclusion that is inconsistent with the true or actual state of the population under study. See also false negative decision error, false positive decision error.

defensible—The ability to withstand any reasonable challenge related to the veracity, integrity, or quality of the logical, technical, or scientific approach taken in a decision-making process.

DQO Process—A quality management tool based on the scientific method, developed by the U.S. Environmental Protection Agency to facilitate the planning of environmental data collection activities. The DQO Process enables planners to focus their planning efforts by specifying the intended use of the data (the decision), the decision criteria (action level) and the decision maker's tolerable decision error rates. The products of the DQO Process are the DQOs.

duplicate – A second aliquot of a sample that is carried through the analytical process. A relative percent difference (RPD) between the sample and duplicate results will be determined. Acceptable sample precision is usually $\leq 20\%$ RPD. RPD is dependent upon counting error.

dunnage— Rack and vessel metal waste material generated during clean out of B-Cell.

false negative decision error—A false negative decision error occurs when the decision-maker does not reject the null hypothesis when the null hypothesis actually is false. In statistical terminology, a false negative decision error is also called a Type II error. The measure of the size of the error is expressed as a probability, usually referred to as "beta"; this probability is also called the complement of power.

false positive decision error—A false positive decision error occurs when a decision-maker rejects the null hypothesis when the null hypothesis actually is true. In statistical terminology, a false positive decision error is also called a Type I error. The measure of the size of the error is expressed as a probability, usually referred to as "alpha", the "level of significance," or "size of the critical region."

heterogeneity—The condition of the population under which all items of the population are not identical with respect to the parameter of interest.

homogeneity—The condition of the population under which all items of the population are identical with respect to the parameter of interest.

laboratory control sample (LCS) – A known amount of analyte in a known matrix that is carried through the analytical method. This sample provides an indication of analytical method and instrument performance. Control limits for LCS recoveries are governed by historical method performance at a 95% confidence level.

less-than value—Non-detect measurements reported by the laboratory in the form of being less than a some reporting limit or some defined detection limit for individual samples, e.g., < 1.2 , where 1.2 is the detection limit of the sample.

linear regression—A statistical method to describe the linear relationship of one variable to another variable.

mean— (i) A measure of central tendency of the population (population mean), or (ii) the arithmetic average of a set of values (sample mean).

measurement error—The difference between the true or actual state and that which is reported from measurements.

natural variability—The variability that is inherent or natural to the media, objects, or people being studied.

non-detect value—Measurements reported by the analytical laboratory as being less than some reporting limit or some defined detection limit for individual samples.

population—The total collection of objects, media, or people to be studied and from which a sample is to be drawn.

preparation blank – A blank that has been carried through the entire dissolution and analytical process. The blank will consist of all reagents used during the dissolution of the samples. Blank values should be less than the minimum detectable activity or less than 5% of the sample result.

Quality Assurance (QA)—An integrated system of management activities involving planning, quality control, quality assessment, reporting, and quality improvement to ensure that a product or service (e.g., environmental data) meets defined standards of quality with a stated level of confidence.

Quality control (QC)—The overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer.

radionuclide scaling factor—Values used to relate the concentration of a readily-measured radionuclide to more difficult to measure radionuclides.

range—The numerical difference between the minimum and maximum of a set of values.

random error—Errors which affect the data by increasing the imprecision and are often uncontrollable and unobserved.

representative sample—A sample collected in such a manner that it reflects one or more characteristics of interest (as defined by the project objectives) of a population from which it is collected.

sample—A portion of material which is taken from a larger quantity for the purpose of estimating properties or composition of the larger quantity.

sampling—The process of obtaining representative samples and/or measurements of a subset of a population.

sampling design error—The error due to observing only a limited number of the total possible values that make up the population being studied. It should be distinguished from errors due to imperfect selection; bias in response; and errors of observation, measurement, or recording, etc.

sifted debris—Considered to be items that have fallen to the hot cell floor and are later collected. The B-Cell floor dispersible material has been found to exhibit mixed (dangerous) waste characteristics (DOE/RL 1998a). All items having the potential for containing floor dispersible or tank heels are required by procedure to be rinsed of visible dispersible or heel material before being placed into the HN-200 grout container (DOE/RL 1998a; 3I-SOP-REC-A-49).

spike – A known amount of the isotope of interest that is added to a second aliquot of sample. Spike recoveries give an indication of matrix interference (used in gross alpha analysis).

standard deviation—The square root of the variance.

statistic—Function of the sample measurements; e.g., the sample mean or standard deviation.

statistical test—Any statistical method that is used to determine which of several hypotheses are true.

systematic error—Errors which increase the bias of the data. The effect can be either positive or negative but it affects all results in a data set the same way. Examples include, but are not limited to, flaws in the sampling design that result in sampling of inappropriate locations, mismatches between analytical methods and sample matrix, analyzing solutions containing suspended solids, incomplete digestions, insufficient reaction time during sample preparation, improperly calibrated instruments, incorrect standards, and dirty detectors.

subsample—A portion of a sample that is taken for testing or for record purposes.

total study error—The combination of sampling design error and measurement error.

tracer – A known amount of a different radionuclide than the isotope of interest added to the sample. The tracer demonstrates the same chemical behavior as the isotope of interest. The recovery is not reported, but is used to correct results for losses incurred during separation (used in ^{238}Pu , $^{239/240}\text{Pu}$, ^{241}Am , $^{243/244}\text{Cm}$).

Type I error—A Type I error occurs when a decision maker rejects the null hypothesis when it is actually true. See false positive decision error.

Type II error—A Type II error occurs when the decision maker fails to reject the null hypothesis when it is actually false. See *false negative decision error*.

variable—The attribute of the environment that is indeterminate.

variance—A measure of (i) the variability or dispersion in a population (population variance), or (ii) the sum of the squared deviations of the measurements about their mean divided by the degrees of freedom (sample variance).

APPENDIX A

Detailed Data Summary

APPENDIX A - DETAILED DATA SUMMARY

This appendix contains a detailed listing of analytical data from the analysis of the fixed radioactive contamination layer of B-Cell rack metal samples.

1.0 1B RACK SAMPLES

The analytical results reported in Tables 7 and 8 for the 1B rack samples represent a mathematical sum of the results for the various samples shown in Figure A-1. Tables A-1, A-2, A-3, and A-4 contain the results for the various sample portions shown in Figure A-1.

*RCA = Radiochemical Analysis; GEA = Gamma Energy Analysis;
PAM = Portable Alpha Monitor; Si ppt = Siliceous Precipitate*

Figure A-1. Graphical Representation of the 1B Rack Sample Results

2.0 1A/2B RACK SAMPLES

2.1 First Batch of 1A/2B Samples

The analytical results reported in Tables 7 and 8 for the first batch of 1A and 2B rack samples (Samples 1A-1a, 1A-1c, 1A-1e, 1A-1f, 1A-1g, 1A-1h, and 2B-1b) except for sample 1A-1g represent a mathematical sum of the results for the various samples shown in Figure A-2. Tables A-5, A-6, and A-7 contain the results for the various sample portions shown in Figure A-2.

Figure A-2. Graphical Representation of the First Batch of 1A and 2B Rack Sample Results

2.2.1 1A-1g Sample from First Batch of 1A Rack Samples

Sample 1A-1g was the only sample from the first batch of 1A rack samples that showed a siliceous precipitate (Figure A-3). A portion of the residual solids from sample 1A-1g was analyzed using SEM (scanning electron microscope (SEM)/energy dispersive X-ray spectrometry (EDS)) to identify the primary constituents. In addition, the siliceous precipitate underwent KOH fusion to determine the radionuclide constituents. The data from the siliceous precipitate and the fusion of the precipitate were discounted when it was found that sample weight was not measured prior to fusion so the quantity of material removed for SEM was not known. Therefore, the sample portions summed and reported for sample 1A-1g in Tables A-5, A-6, and A-7 are the same as that shown in Figure A-2.

Figure A-3. Graphical Representation of the 1A-1g Sample Results

2.1 Second Batch of 1A/2B Samples

The analytical results reported in Tables 7 and 8 for the second batch of 1A and 2B rack samples (Samples 1A-1a, 1A-1b, 1A-1d, 1A-2, 1A-3, 1A-5, 1A-7, 1A-8, 1A-9, 1A-10, 1A-11, 1A-12, 1A-14, and 2B-1a), represent a mathematical sum of the results for the various samples shown in Figure A-4. Tables A-8, A-9, A-10 and A-11 contain the results for the various sample portions shown in Figure A-4.

Figure A-4. Graphical Representation of the Second Batch of 1A and 2B Rack Sample Results

Table A-1. Water Wash Results for 1B Rack Samples (nCi/g)

SAMPLE	Etched Surface Area (cm ²)	Weight of Etched Area (g)	Pu239/Pu240	Pu238	Am241	Cm243/Cm244	Calc'd Cm243	Calc'd Cm244	Calc'd TRU	Calc'd Alpha Total	RPT'D TOTAL ALPHA	Cu137	Sr90	Co60	Ba154	Ba155	Total Uranium (ppb)	TOTAL ACTIVITY (nCi/g)
1-1A	5.30	5.39	<0.0126	0.0160	0.201	0.0755	0.00108	0.0744	0.231	0.305	0.506	1,410	932	<0.224	<0.764	<2.39	<66.8	2,346
1-1B	8.69	8.83	0.0126	0.0344	0.624	0.2160	0.00309	0.2129	0.674	0.887	0.987	1,300	1,310	<0.185	<0.679	<2.09	<53.2	2,614
1-2A	6.52	6.62	0.0020	0.0054	1.220	0.4450	0.00636	0.4386	1.234	1.672	1.350	1,440	749	<0.139	<0.712	<1.82	<38.2	2,193
1-2B	6.54	6.64	<0.0150	<0.0150	0.198	0.0819	0.00117	0.0807	0.229	0.310	0.452	1,730	798	<0.221	<0.847	<2.75	<72.4	2,532
3-1A	6.44	6.54	0.0219	0.0682	0.563	0.2200	0.00314	0.2169	0.656	0.873	1.120	1,870	2,110	<0.246	<0.737	<2.59	<57.5	3,984
3-1B	7.45	7.57	<0.0119	0.0480	0.169	0.0544	0.00078	0.0536	0.230	0.283	0.285	1,600	770	<0.198	<0.597	<2.25	<54.4	2,373
3-2A	9.97	10.12	<0.00714	<0.0071	0.107	0.0481	0.00069	0.0474	0.122	0.169	0.316	986	1,190	<0.125	<0.405	<1.47	<33.7	2,178
3-2B	5.25	5.33	<0.0142	<0.0142	0.074	<0.0500	<0.00071	<0.0493	0.103	0.152	0.180	1,130	1,190	<0.242	<0.705	<2.18	<65.7	2,323
AVE	7.02	7.13	0.0122	0.0260	0.394	0.1489	0.00213	0.1467	0.435	0.582	0.650	1,433	1,131	<0.198	<0.681	<2.19	<55.2	2,568
SD	1.63	1.65	0.0058	0.0223	0.392	0.1394	0.00199	0.1374	0.393	0.529	0.439	297	451	<0.045	<0.132	<0.41	<13.6	592

SAMPLE	RPT'D ALPHA/Cs	CALC'D ALPHA/Cs	TRU/Cs	Sr90/Cu137	Rpt'd Alpha/Calc'd Alpha
1-1A	0.000359	0.000216	0.000164	0.661	1.66
1-1B	0.000759	0.000682	0.000519	1.008	1.11
1-2A	0.000938	0.001161	0.000857	0.520	0.81
1-2B	0.000261	0.000179	0.000132	0.461	1.46
3-1A	0.000599	0.000467	0.000351	1.128	1.28
3-1B	0.000178	0.000177	0.000144	0.481	1.01
3-2A	0.000320	0.000172	0.000124	1.207	1.87
3-2B	0.000159	0.000135	0.000091	1.053	1.18
AVE	0.000447	0.000399	0.000298	0.815	1.30
SD	0.000286	0.000362	0.000269	0.315	0.35

AVE = Average; SD = Standard Deviation; Calc'd = Calculated; RPT'D = Reported; TRU = Transuranic.

Table A-2. Mixed Acid Etch Results for 1B Rack Samples (nCi/g)

SAMPLE	Etched Surface Area (cm ²)	Weight of Etched Area (g)	Pu239/Pu240	Pu238	Am241	Cm243/Cm244	Calc'd Cm243	Calc'd Cm244	Calc'd TRU	Calc'd Alpha Total	RPT'D TOTAL ALPHA	Cs137	Sr90	Co60	Eu154	Eu155	Total Uranium (ppb)	TOTAL ACTIVITY (nCi/g)
1-1A	5.30	5.39	3.40	6.31	253.0	109.0	1.557	107.4	264.3	371.7	373.0	41,400	28,500	<48.2	<186.0	<220.0	—	70,726
1-1B	8.69	8.83	1.04	1.87	71.1	22.9	0.327	22.6	74.3	96.9	92.0	11,200	9,650	<25.4	<82.4	<91.4	—	21,146
1-2A	6.52	6.62	2.99	5.17	221.0	95.2	1.360	93.8	230.5	324.4	313.0	29,300	24,400	<42.3	<127.0	<173.0	<108	54,367
1-2B	6.54	6.64	1.43	2.96	101.0	26.1	0.373	25.7	105.8	131.5	121.0	21,900	14,000	<31.6	<114.0	<125.0	—	36,302
3-1A	6.44	6.54	2.44	3.69	53.9	19.4	0.277	19.1	60.3	79.4	65.4	15,800	25,100	<35.4	<123.0	<133.0	—	41,271
3-1B	7.45	7.57	1.42	2.23	30.2	9.6	0.138	9.5	34.0	43.5	35.3	14,200	7,230	<18.3	<61.4	<57.5	—	21,611
3-2A	9.97	10.12	1.98	3.01	57.6	19.9	0.284	19.6	62.9	82.5	72.1	15,300	24,100	<17.4	<61.0	<79.5	—	39,640
3-2B	5.25	5.33	1.82	2.82	33.3	11.8	0.169	11.6	38.1	49.7	50.2	9,470	14,100	<0.349	<18.6	<7.22	—	23,646
AVE	7.02	7.13	2.07	3.51	102.6	39.2	0.561	38.7	108.8	147.5	140.3	19,821	18,385	<27.4	<96.7	<110.8	—	38,589
SD	1.63	1.65	0.82	1.51	86.3	39.3	0.562	38.8	88.8	127.4	128.8	10,754	8,058	<15.4	<51.7	<67.0	—	17,366

SAMPLE	RPT'D ALPHA/Cs	CALC'D ALPHA/Cs	TRU/Cs	Sr90/Cs137	Rpt'd Alpha/Calc'd Alpha
1-1A	0.00901	0.00898	0.00638	0.688	1.00
1-1B	0.00821	0.00865	0.00664	0.862	0.95
1-2A	0.01068	0.01107	0.00787	0.833	0.96
1-2B	0.00553	0.00600	0.00483	0.639	0.92
3-1A	0.00414	0.00503	0.00382	1.589	0.82
3-1B	0.00249	0.00306	0.00239	0.509	0.81
3-2A	0.00471	0.00539	0.00411	1.575	0.87
3-2B	0.00530	0.00525	0.00402	1.489	1.01
AVE	0.00626	0.00668	0.00501	1.023	0.92
SD	0.00277	0.00263	0.00180	0.452	0.08

AVE = Average; SD = Standard Deviation; Calc'd = Calculated; RPT'D = Reported; TRU = Transuramic.

Table A-3. Siliceous Solids Results and Revised ^{137}Cs and TRU Concentrations for 1B Rack Samples (nCi/g)

Sample	GEA & PAM Results ($\mu\text{Ci}/\text{Sample}$)							Cs in Solids (nCi/g metal sample)	Cs in Acid (nCi/g)	REVISED Total Cs (nCi/g)
	Dry Wt (g)	Cs137	Co60	Eu154	Alpha*	Cs in acid	Solids (% Acid)	Etched Metal Wt (g)		
1-1a	<0.0100	0.197	<1.21E-5	<4.83E-5	<1%	223	0.088%	5.39	42,810	42,847
1-1b	<0.0100	0.291	<1.19E-5	<5.27E-5	<1%	99	0.294%	8.83	12,500	12,533
1-2a	<0.0100	0.103	<1.23E-5	<4.89E-5	<1%	194	0.053%	6.62	30,740	30,756
1-2b	<0.0100	0.557	<1.03E-5	1.02E-4	<1%	145	0.384%	6.64	23,630	23,714
3-1a	<0.0100	0.672	<1.02E-4	1.18E-4	<1%	103	0.652%	6.54	17,670	17,773
3-1b	<0.0100	0.763	<1.26E-5	<5.21E-5	<1%	108	0.706%	7.57	15,800	15,901
3-2a	<0.0100	2.140	<4.03E-5	<5.95E-4	<1%	155	1.381%	10.12	16,286	16,497
3-2b	<0.0100	0.556	<1.25E-5	1.18E-4	<1%	51	1.101%	5.33	10,600	10,704
Average	<0.0100	0.660	<2.68E-5	1.42E-4	<1%	—	0.582%	—	21,255	21,341
SD	—	0.642	<3.20E-5	1.86E-4	—	—	0.474%	—	10,808	10,779

* (as % of Acid Etch Total Alpha)

From Table 7 of WHM-9955401

Sample	PAM (cpm)	1% Alpha in Mixed Acid (cpm)	100% Alpha Mixed Acid (cpm)	Calc'd % Alpha	Total Alpha- Sol'n (nCi/g)	Solids (nCi/g)	REVISED Total Alpha (nCi/g)	REVISED Total Cs (nCi/g)	REVISED Alpha: Cs	REVISED TRU:Cs	REVISED TRU (nCi/g)
1-1a	50	6247	6,247,000	0.008%	373.51	0.0299	373.54	42,847	0.00872	0.00617	264.52
1-1b	50	2525	2,525,000	0.020%	92.99	0.0184	93.01	12,533	0.00742	0.00599	75.03
1-2a	50	6441	6,441,000	0.008%	314.35	0.0244	314.37	30,756	0.01022	0.00754	231.77
1-2b	50	2494	2,494,000	0.020%	121.45	0.0243	121.48	23,714	0.00512	0.00447	106.01
3-1a	50	1329	1,329,000	0.038%	66.52	0.0250	66.55	17,773	0.00374	0.00343	60.99
3-1b	50	831	831,000	0.060%	35.59	0.0214	35.61	15,901	0.00224	0.00215	34.24
3-2a	400	2269	2,269,000	0.176%	72.42	0.1277	72.54	16,497	0.00440	0.00383	63.11
3-2b	100	831	831,000	0.120%	50.38	0.0606	50.44	10,704	0.00471	0.00357	38.26
Average	100	2,871	2,870,875	0.056%	140.90	0.0415	140.94	21,341	0.00582	0.00464	109.24
SD	122	2,251	2,250,952	0.061%	128.94	0.0373	128.93	10,779	0.00270	0.00177	88.98

AVE = Average; SD = Standard Deviation; TRU = Transuranic; GEA = Gamma Energy Analysis; PAM = Portable Alpha Monitor.

Table A-4. Combined Water Wash, Mixed Acid Etch, and Siliceous Solids Results for 1B Rack Samples (nCi/g)

SAMPLE	Etched Surface Area (cm ²)	Weight of Etched Area (g)	Pu239/ Pu240	Pu238	Am241	Cm243/ Cm244	Calc'd Cm243	Calc'd Cm244	Calc'd TRU	Calc'd Alpha Total	RPT'D TOTAL ALPHA	Cs137	Sr90	Co60	En154	En155	Total Uranium (ppb)	TOTAL ACTIVITY (nCi/g)
1-1a	5.30	5.39	3.41	6.33	253.20	109.08	1.558	107.5	264.52	372.0	373.51	42,847	29,432	<48.4	<186.8	<222.4	<66.8	72,837
1-1b	8.69	8.83	1.05	1.90	71.72	23.12	0.330	22.8	75.03	97.8	92.99	12,533	10,960	<25.6	<83.1	<93.5	<53.2	23,674
1-2a	6.52	6.62	2.99	5.18	222.22	95.65	1.366	94.3	231.77	326.0	314.35	30,756	25,149	<42.4	<127.7	<174.8	<38.2	56,358
1-2b	6.54	6.64	1.45	2.98	101.20	26.18	0.374	25.8	106.01	131.8	121.45	23,714	14,798	<31.8	<114.8	<127.8	<72.4	38,759
3-1a	6.44	6.54	2.46	3.76	54.46	19.62	0.280	19.3	60.99	80.3	66.52	17,773	27,210	<35.6	<123.7	<135.6	<57.5	45,187
3-1b	7.45	7.57	1.43	2.28	30.37	9.69	0.138	9.6	34.24	43.8	35.59	15,901	8,000	<18.5	<62.0	<59.8	<54.4	24,007
3-2a	9.97	10.12	1.99	3.02	57.71	19.95	0.285	19.7	63.11	82.7	72.42	16,497	25,290	<17.5	<61.4	<81.0	<33.7	41,932
3-2b	5.25	5.33	1.83	2.83	33.37	11.85	0.169	11.7	38.26	49.9	50.38	10,704	15,290	<0.6	<19.3	<9.4	<65.7	26,064
AVE	7.02	7.13	2.08	3.53	103.03	39.39	0.563	38.8	109.21	148.0	140.90	21,255	19,516	<27.6	<97.4	<113.0	<55.2	41,102
SD	1.63	1.65	0.82	1.50	86.43	39.40	0.563	38.8	88.99	127.6	128.94	10,808	8,181	<15.4	<51.8	<67.1	<13.6	17,258

SAMPLE	RPT'D ALPHA/Cs	CALC'D ALPHA/Cs	TRU/Cs	Sr90/Cs137	Rpt'd Alpha/ Calc'd Alpha
1-1A	0.00872	0.00868	0.00617	0.687	1.004
1-1B	0.00742	0.00780	0.00599	0.874	0.951
1-2A	0.01022	0.01060	0.00754	0.818	0.964
1-2B	0.00512	0.00556	0.00447	0.624	0.921
3-1A	0.00374	0.00452	0.00343	1.531	0.828
3-1B	0.00224	0.00275	0.00215	0.503	0.813
3-2A	0.00440	0.00501	0.00383	1.533	0.876
3-2B	0.00471	0.00466	0.00357	1.428	1.010
AVE	0.00582	0.00620	0.00464	1.000	0.921
SD	0.00270	0.00259	0.00177	0.428	0.075

AVE = Average; SD = Standard Deviation; Calc'd = Calculated; RPT'D = Reported; TRU = Transuronic.

Table A-5. Water Wash Results for First Batch of 1A Rack Samples (nCi/g)

SAMPLE	Etched Surface Area (cm ²)	Weight of Etched Area (g)	Pu239/ Pu240	Pu238	Am241	Cm243/ Cm244	Calc'd Cm243	Calc'd Cm244	Calc'd TRU	Calc'd Alpha Total	RPT'D TOTAL ALPHA	Cs137	Si90	Co60	Eu154	Eu155	TOTAL ACTIVITY (nCi/g)
1A-1c	5.52	9.81	<3.89E-3	6.04E-03	9.28E-02	2.91E-02	4.16E-04	2.87E-02	0.103	0.132	0.138	497	319	<0.112	<0.316	<1.060	818
1A-1e	11.19	19.29	<2.53E-3	3.55E-03	1.67E-02	<1.25E-2	<1.79E-4	<1.23E-2	0.023	0.035	<0.0281	306	554	<0.288	<0.727	<1.780	863
1A-1f	9.72	18.65	1.99E-02	3.58E-02	1.65E-01	6.15E-02	8.79E-04	6.06E-02	0.222	0.282	0.272	827	675	<0.301	<0.923	<2.970	1,506
1A-1g	14.57	29.46	1.11E-02	1.20E-02	6.73E-02	2.14E-02	3.06E-04	2.11E-02	0.091	0.112	0.089	773	382	<0.162	<0.567	<2.260	1,158
1A-1h	4.70	8.90	<3.44E-3	3.72E-03	1.78E-02	<1.32E-2	<1.89E-4	<1.30E-2	0.025	0.038	<0.0339	267	304	<0.338	<0.867	<1.890	574
2B-1b	16.49	88.41	7.61E-04	1.45E-03	2.89E-03	<2.16E-3	<3.09E-5	<2.13E-3	0.005	0.007	<0.0048	140	72	<0.014	<0.041	<0.212	212
AVE	10.37	29.09	6.94E-03	1.04E-02	6.04E-02	2.33E-02	3.33E-04	2.30E-02	0.08	0.10	0.0943	468	384	<0.203	<0.574	<1.695	855.26
SD	4.73	30.01	7.27E-03	1.29E-02	6.18E-02	2.08E-02	2.97E-04	2.05E-02	0.08	0.10	0.0996	282	210	<0.127	<0.341	<0.958	449.36

SAMPLE	RPT'D ALPHAS	CALC'D ALPHAS	TRU/Cs	Si90/Cs137	Rpt'd Alpha/ Calc'd Alpha
1A-1c	0.00028	0.00027	0.0002075	0.642	1.05
1A-1e	0.00009	0.00012	0.0000750	1.810	0.80
1A-1f	0.00033	0.00034	0.0002679	0.816	0.96
1A-1g	0.00012	0.00014	0.0001173	0.494	0.80
1A-1h	0.00013	0.00014	0.0000942	1.139	0.89
2B-1b	0.00003	0.00005	0.0000367	0.515	0.66
AVE	0.00016	0.00018	0.0001331	0.903	0.86
SD	0.00011	0.00011	0.0000874	0.504	0.14

AVE = Average; SD = Standard Deviation; Calc'd = Calculated; RPT'D = Reported; TRU = Transuranic.

Table A-6. Mixed Acid Etch Results for First Batch of 1A Rack Samples (nCi/g)

SAMPLE	Etched Surface Area (cm ²)	Weight of Etched Area (g)	Pu239/ Pu240	Pu238	Am241	Cm243/ Cm244	Calc'd Cm243	Calc'd Cm244	Calc'd TRU	Calc'd Alpha Total	RPT'D TOTAL ALPHA	Cs137	Sr90	Co60	Ba154	Ba155	TOTAL ACTIVITY (nCi/g)
1A-1c	5.52	9.81	0.157	0.321	10.90	3.41	4.87E-02	3.36E+00	11.43	14.79	14.80	1,430	1,270	<0.0419	7.14	2.86	2,725
1A-1e	11.19	19.29	0.167	0.366	3.49	1.01	1.44E-02	9.96E-01	4.04	5.03	5.41	1,460	3,940	<0.0252	2.25	<0.682	5,408
1A-1f	9.72	18.65	0.583	0.719	3.73	1.07	1.53E-02	1.05E+00	5.05	6.10	6.67	4,140	6,940	<0.0548	2.44	<2.360	11,091
1A-1g	14.57	29.46	2.070	2.150	11.20	3.01	4.30E-02	2.97E+00	15.46	18.43	19.30	14,100	14,700	<0.1210	6.81	<6.640	28,832
1A-1h	4.70	8.90	<0.0887	0.136	0.976	0.333	4.76E-03	3.28E-01	1.21	1.53	1.83	1,580	1,060	<0.0418	0.543	<0.887	2,643
2B-1b	16.49	88.41	0.491	0.662	1.00	0.16	2.21E-03	1.53E-01	2.15	2.31	2.34	250	66.7	0.0102	0.21	<0.110	319
AVE	10.37	29.09	0.593	0.726	5.22	1.50	0.02	1.48	6.56	8.03	8.392	3,827	4,663	0.0492	3.23	2.26	8,503
SD	4.73	30.01	0.751	0.731	4.67	1.38	0.02	1.36	5.65	6.95	7.094	5,193	5,515	0.0384	3.03	2.39	10,623

SAMPLE	RPT'D ALPHA/Cs	CALC'D ALPHA/Cs	TRU/Cs	Sr90/Cs137	Rpt'd Alpha/ Calc'd Alpha
1A-1c	0.01035	0.01034	0.00799	0.888	1.00
1A-1e	0.00371	0.00345	0.00277	2.699	1.07
1A-1f	0.00161	0.00147	0.00122	1.676	1.09
1A-1g	0.00137	0.00131	0.00110	1.043	1.05
1A-1h	0.00116	0.00097	0.00076	0.671	1.19
2B-1b	0.00936	0.00922	0.00861	0.267	1.01
AVE	0.00459	0.00446	0.0037	1.207	1.07
SD	0.00419	0.00423	0.0036	0.865	0.07

AVE = Average; SD = Standard Deviation; Calc'd = Calculated; RPT'D = Reported; TRU = Transuranic.

Table A-7. Combined Water Wash and Mixed Acid Etch Results for First Batch of 1A Rack Samples (nCi/g)

SAMPLE	Etched Surface Area (cm ²)	Weight of Etched Area (g)	Pu238/Pu240	Pu238	Am241	Cm243/Cm244	Calc'd Cm243	Calc'd Cm244	Calc'd TRU	Calc'd Alpha Total	RPT'D TOTAL ALPHA	Cs137	Sr90	Co60	En154	En155	TOTAL ACTIVITY (nCi/g)
1A-1c	5.52	9.81	0.161	0.327	10.99	3.44	0.0491	3.390	11.53	14.92	14.94	1,927	1,589	<0.154	7.46	3.92	3,538
1A-1e	11.19	19.29	0.170	0.370	3.51	1.02	0.0146	1.008	4.06	5.07	5.44	1,766	4,494	<0.313	2.98	<2.46	6,268
1A-1f	9.72	18.65	0.603	0.755	3.90	1.13	0.0162	1.115	5.27	6.38	6.94	4,967	7,615	<0.356	3.36	<5.33	12,592
1A-1g	14.57	29.46	2.081	2.162	11.27	3.03	0.0433	2.988	15.55	18.54	19.39	14,873	15,082	<0.283	7.38	<8.90	29,981
1A-1h	4.70	8.90	0.092	0.140	0.99	0.35	0.0049	0.341	1.23	1.57	1.86	1,847	1,364	<0.380	1.41	<2.78	3,214
2B-1b	16.49	88.41	0.492	0.663	1.00	0.16	0.0022	0.155	2.16	2.31	2.34	390	139	<0.024	0.25	<0.32	531
AVE	10.37	29.09	0.600	0.736	5.28	1.52	0.0217	1.500	6.63	8.13	8.49	4,295	5,047	<0.252	3.81	3.95	9,354
SD	4.73	30.01	0.754	0.734	4.70	1.39	0.0198	1.366	5.68	6.98	7.12	5,396	5,607	<0.137	3.01	2.94	10,907

SAMPLE	RPT'D ALPHA/Cs	CALC'D ALPHA/Cs	TRU/Cs	Sr90/Cs137	Rpt'd Alpha/Calc'd Alpha
1A-1c	0.00775	0.00774	0.00598	0.825	1.00
1A-1e	0.00308	0.00287	0.00230	2.545	1.07
1A-1f	0.00140	0.00129	0.00106	1.533	1.09
1A-1g	0.00130	0.00125	0.00105	1.014	1.05
1A-1h	0.00101	0.00085	0.00067	0.738	1.19
2B-1b	0.00601	0.00593	0.00553	0.356	1.01
AVE	0.00343	0.00332	0.00276	1.168	1.07
SD	0.00283	0.00287	0.00239	0.776	0.07

AVE = Average; SD = Standard Deviation; Calc'd = Calculated; RPT'D = Reported; TRU = Transuranic.

Table A-8. Mixed Acid Etch Results for Second Batch of 1A Rack Samples (nCi/g)

SAMPLE	Etched Surface Area (cm ²)	Weight of Etched Area (g)	Pu239/Pu240	Pu238	Am241	Cm243/Cm244	Calc'd Cm243	Calc'd Cm244	Calc'd TRU	Calc'd Alpha Total	RPTD TOTAL ALPHA	Cs137	Sr90	Co60	Em154	Em155	Sb125	TOTAL ACTIVITY (nCi/g)
1A-1a	27.90	57.651	0.218	0.465	5.720	1.810	0.0259	1.784	6.43	8.21	6.56	3,050	5,450	<0.524	4.44	<5.240	—	8,518
1A-1b	12.00	22.995	0.266	0.478	10.30	3.340	0.0477	3.292	11.09	14.38	11.50	3,310	9,480	<0.661	9.35	<6.440	—	12,821
1A-1d	12.00	22.205	0.743	0.694	15.80	5.400	0.0771	5.323	17.31	22.64	20.60	6,440	10,500	<0.144	9.86	<3.740	—	16,976
1A-2	21.80	25.259	0.221	0.461	1.820	0.687	0.0098	0.677	2.51	3.19	3.81	2,030	1,620	<0.974	<3.120	<2.680	—	3,660
1A-3	42.90	54.833	0.042	0.095	0.368	0.131	0.0019	0.129	0.51	0.64	0.54	843	233	<0.050	<0.188	<0.799	—	1,078
1A-5	44.50	53.855	0.204	0.417	2.130	0.757	0.0108	0.746	2.76	3.51	3.27	478	729	<0.067	1.36	<0.752	—	1,213
1A-7	31.80	39.409	0.695	1.730	19.10	6.900	0.0986	6.801	21.62	28.43	28.30	2,950	1,480	<0.142	8.83	<1.150	—	4,469
1A-8	24.80	19.087	0.116	0.313	1.490	0.488	0.0070	0.481	1.93	2.41	2.73	1,620	1,770	<0.279	2.76	<1.320	—	3,397
1A-9	33.20	81.109	0.296	0.624	2.960	1.020	0.0146	1.005	3.89	4.90	3.55	1,500	1,640	<0.402	1.30	<3.010	—	3,150
1A-10	22.50	39.781	0.189	0.420	1.710	0.581	0.0083	0.573	2.33	2.90	2.92	1,470	518	<0.322	1.36	<2.890	—	1,995
1A-11	26.00	50.209	0.040	0.084	0.594	0.226	0.0032	0.223	0.72	0.94	0.86	613	339	<0.538	1.66	<2.650	—	958
1A-12	18.20	43.398	0.689	0.710	5.180	1.590	0.0227	1.567	6.60	8.17	7.95	3,800	4,220	<0.119	3.27	<2.830	—	8,034
1A-14	58.90	106.695	0.529	0.930	4.650	2.100	0.0300	2.070	6.14	8.21	6.94	808	1,660	<2.270	7.31	<4.520	—	2,490
2B-1a	12.00	60.862	1.130	1.510	1.770	0.206	0.0029	0.203	4.41	4.62	4.34	414	184	<0.348	1.16	<0.848	—	605
AVE	27.75	48.382	0.384	0.638	5.257	1.803	0.0258	1.777	6.30	8.08	7.42	2,095	2,845	<0.489	4.00	<2.776	—	4,955
SD	13.69	24.322	0.322	0.475	5.819	2.065	0.0295	2.035	6.29	8.31	7.92	1,681	3,383	<0.574	3.39	<1.755	—	4,922

AVE = Average; SD = Standard Deviation; Calc'd = Calculated; RPTD = Reported; TRU = Transuranic.

Table A-8. Mixed Acid Etch Results for Second Batch of 1A Rack Samples (nCi/g) (continued)

SAMPLE	RPT'D ALPHA/Cs	CALC'D ALPHA/Cs	TRU/Cs	Sr90/Cs137	Rpt'd Alpha/ Calc'd Alpha
1A-1a	0.00215	0.00269	0.00211	1.787	0.799
1A-1b	0.00347	0.00435	0.00335	2.864	0.799
1A-1d	0.00320	0.00352	0.00269	1.630	0.910
1A-2	0.00188	0.00157	0.00124	0.798	1.195
1A-3	0.00064	0.00075	0.000601	0.276	0.843
1A-5	0.00684	0.00734	0.00578	1.525	0.932
1A-7	0.00959	0.00964	0.00733	0.502	0.996
1A-8	0.00169	0.00149	0.00119	1.093	1.134
1A-9	0.00237	0.00327	0.00260	1.093	0.724
1A-10	0.00199	0.00197	0.00158	0.352	1.007
1A-11	0.00140	0.00154	0.00118	0.553	0.911
1A-12	0.00209	0.00215	0.00174	1.111	0.973
1A-14	0.00859	0.01016	0.00760	2.054	0.845
2B-1a	0.01048	0.01115	0.01066	0.444	0.940
AVE	0.00403	0.00440	0.00355	1.149	0.929
SD	0.00334	0.00360	0.00307	0.751	0.129

AVE = Average; SD = Standard Deviation; Calc'd = Calculated; RPT'D = Reported; TRU = Transuranic.

Table A-9. Combined Mixed Acid Etch and Hydrochloric Acid Etch Results for Four Titanium Samples (nCi/g)

SAMPLE	Etched Surface Area (cm ²)	Weight of Etched Area (g)	Pu239/Pu240	Pu238	Am241	Cm243/Cm244	Calc'd Cm243	Calc'd Cm244	Calc'd TRU	Calc'd Alpha Total	RPT'D TOTAL ALPHA	Cs137	Sr90	Co60	Em154	Em155	Sb-125	TOTAL ACTIVITY (nCi/g)
1A-2	21.8	25.3	0.238	0.501	1.979	0.746	0.0107	0.735	2.73	3.46	4.04	2,353	1,959	<1.035	<3.289	<3.325	81.16	4,404
1A-5	44.5	53.9	0.220	0.445	2.266	0.807	0.0115	0.796	2.94	3.74	3.48	494	749	<0.132	<1.553	<0.950	<0.288	1,249
1A-7	31.8	39.4	0.973	2.253	22.741	8.207	0.1172	8.090	26.09	34.17	33.39	3,078	1,616	<0.492	<9.629	<2.501	<34.83	4,775
1A-8	24.8	19.1	0.147	0.386	2.747	0.758	0.0108	0.748	3.29	4.04	4.33	1,899	2,226	<0.578	<4.065	<2.687	2.01	4,138
AVE	33.5	38.3	0.360	0.806	6.400	2.265	0.032	2.233	7.60	9.83	9.74	1,664	1,460	<0.474	<4.018	<2.083	23.71	3,163
SD	10.7	16.0	0.345	0.810	9.139	3.322	0.047	3.274	10.34	13.61	13.23	1,147	684	<0.374	<3.323	<1.078	35.33	1,761

SAMPLE	RPT'D ALPHA/Cs	CALC'D ALPHA/Cs	TRU/Cs	Sr90/Cs137	Rpt'd/Calc'd Alpha
1A-2	0.00172	0.00147	0.00116	0.832	1.168
1A-5	0.00704	0.00757	0.00596	1.516	0.930
1A-7	0.01085	0.01110	0.00848	0.525	0.977
1A-8	0.00228	0.00213	0.00173	1.172	1.073
AVE	0.00578	0.00597	0.00466	1.112	1.016
SD	0.00379	0.00408	0.00311	0.434	0.103

AVE = Average; SD = Standard Deviation; Calc'd = Calculated; RPT'D = Reported; TRU = Transuranic.

Table A-10. Siliceous Solids Results and Revised ^{137}Cs and TRU Concentrations for 1A Rack Samples (nCi/g)

GEA & PAM Results ($\mu\text{Ci}/\text{Sample}$)											
Sample	Dry Wt (g)	Cs137	Co60	Eu154	Alpha <1% *	Cs In acid	Solids (% Acid)	Etched Metal Wt (g)	Cs In Solids (nCi/g metal sample)	Cs In Acid (nCi/g)	REVISED Total Cs (nCi/g)
1A-1c	--	--	--	--	--	--	--	--	--	--	--
1A-1e	--	--	--	--	--	--	--	--	--	--	--
1A-1f	--	--	--	--	--	--	--	--	--	--	--
1A-1g	0.003	--	--	--	--	--	--	--	--	--	--
1A-1h	--	--	--	--	--	--	--	--	--	--	--
2B-1b	--	--	--	--	--	--	--	--	--	--	--
1A-1a	0.106	3.82	4.61E-04	8.44E-04	Y	176	2.17%	57.651	66.3	3,050	3,116
1A-1b	<0.0100	3.5	1.82E-04	<1.69E-4	Y	76	4.59%	22.995	152.2	3,310	3,462
1A-1d	0.055	5.09	3.15E-04	<4.69E-4	Y	143	3.56%	22.205	229.2	6,440	6,669
1A-2	0.011	0.598	7.25E-05	2.50E-04	Y	51	1.17%	25.259	23.7	2,353	2,376
1A-3	0.028	4.12	3.50E-04	<1.88E-4	N	46	8.92%	54.833	75.1	843	918
1A-5	<0.0100	0.33	6.27E-05	3.15E-04	Y	26	1.28%	53.855	6.13	494	500
1A-7	<0.0100	0.454	<2.51E-5	3.35E-04	Y	155	0.29%	39.409	11.5	3,078	3,089
1A-8	<0.0100	0.73	<2.56E-5	<5.32E-4	N	155	0.47%	19.087	38.2	1,899	1,937
1A-9	0.107	7.73	3.03E-03	2.38E-03	N	122	6.34%	81.109	95.3	1,500	1,595
1A-10	0.014	1.58	3.07E-04	<1.28E-2	Y	58	2.71%	39.781	39.7	1,470	1,509
1A-11	0.131	1.66	2.89E-04	6.04E-04	N	31	5.39%	50.209	33.1	613	646
1A-12	0.022	10.9	7.87E-04	<9.14E-4	Y	165	6.61%	43.398	251.2	3,800	4,051
1A-14	0.079	10.2	8.19E-04	1.00E-02	Y	86	11.83%	106.695	95.6	808	903
2B-1a	<0.0100	0.622	7.17E-05	4.91E-04	Y	25	2.47%	60.862	10.2	414	424

From Table 7 of WMH-9955401

AVE = Average; SD = Standard Deviation; TRU = Transuranic; GEA = Gamma Energy Analysis; PAM = Portable Alpha Monitor.

* (as % of Acid Etch Total Alpha)

Table A-10. Siliceous Solids Results and Revised ^{137}Cs and TRU Concentrations for 1A Rack Samples (nCi/g) (continued)

Sample	PAM (cpm)	1% Alpha in Mixed Acid (cpm)	100% Alpha Mixed Acid (cpm)	Calc'd % Alpha	Total Alpha Mixed Acid (nCi/g)	Solids Alpha (nCi/g)	REVISED Total Alpha (nCi/g)	REVISED Total Cs (nCi/g)	REVISED Alpha: Cs	REVISED TRU:Cs	REVISED TRU (nCi/g)
1A-1a	500	1175	1,175,000	0.43%	6.56	0.0279	6.59	3116.3	0.00211	0.00207	6.456
1A-1b	300	824	824,000	0.36%	11.50	0.0419	11.54	3462.2	0.00333	0.00322	11.13
1A-1d	400	1423	1,423,000	0.28%	20.60	0.0579	20.66	6669.2	0.00310	0.00260	17.36
1A-2	100	299	299,000	0.33%	4.04	0.0135	4.06	2376.7	0.00171	0.00115	2.737
1A-3	500	91	91,000	5.49%	0.54	0.0295	0.57	918.1	0.00062	0.00058	0.534
1A-5	400	548	548,000	0.73%	3.48	0.0254	3.50	500.3	0.00700	0.00593	2.964
1A-7	200	3469	3,469,000	0.06%	33.39	0.0193	33.41	3089.0	0.01082	0.00845	26.10
1A-8	180	162	162,000	1.11%	4.33	0.0481	4.38	1937.0	0.00226	0.00172	3.328
1A-9	1500	895	895,000	1.68%	3.55	0.0595	3.61	1595.3	0.00226	0.00248	3.960
1A-10	300	361	361,000	0.83%	2.92	0.0243	2.94	1509.7	0.00195	0.00155	2.347
1A-11	400	134	134,000	2.99%	0.86	0.0257	0.89	646.1	0.00137	0.00115	0.743
1A-12	500	1072	1,072,000	0.47%	7.95	0.0371	7.99	4051.2	0.00197	0.00164	6.633
1A-14	2000	2300	2,300,000	0.87%	6.94	0.0603	7.00	903.6	0.00775	0.00685	6.192
2B-1a	200	821	821,000	0.24%	4.34	0.0106	4.35	424.2	0.01026	0.01043	4.424

AVE = Average; SD = Standard Deviation; TRU = Transuranic; GEA = Gamma Energy Analysis; PAM = Portable Alpha Monitor.

Table A-11. Combined Mixed Acid Etch, Siliceous Solids, and Titanium Etch Results for 1B Rack Samples (nCi/g)

SAMPLE	Etched Surface Area (cm ²)	Weight of Etched Area (g)	Pu239/Pu240	Pu238	Am241	Cm243/Cm244	Calc'd Cm243	Calc'd Cm244	Calc'd TRU	Calc'd Alpha Total	RPT'D TOTAL ALPHA	Cs137	Sr90	Co60	Eu154	Eu155	Sb125	TOTAL ACTIVITY (nCi/g)
1A-1a	27.90	57.651	0.218	0.465	5.720	1.810	0.0259	1.784	6.46	8.21	6.56	3,116	5,450	<0.524	4.44	<5.240	—	8,585
1A-1b	12.00	22.995	0.266	0.478	10.30	3.340	0.0477	3.292	11.13	14.38	11.50	3,462	9,480	<0.661	9.35	<6.440	—	12,973
1A-1d	12.00	22.205	0.743	0.694	15.80	5.400	0.0771	5.323	17.36	22.64	20.60	6,669	10,500	<0.144	9.86	<3.740	—	17,206
1A-2	21.80	25.259	0.238	0.501	1.979	0.746	0.0107	0.735	2.74	3.46	4.04	2,377	1,959	<1.035	3.29	<3.325	81.16	4,428
1A-3	42.90	54.833	0.042	0.095	0.368	0.131	0.0019	0.129	0.53	0.64	0.54	918	233	<0.050	0.19	<0.799	—	1,153
1A-5	44.50	53.855	0.220	0.445	2.266	0.807	0.0115	0.796	2.96	3.74	3.48	500	749	<0.132	1.55	<0.950	<0.3	1,256
1A-7	31.80	39.409	0.973	2.253	22.741	8.207	0.1172	8.090	26.10	34.17	33.39	3,089	1,616	<0.492	9.63	<2.501	<34.8	4,786
1A-8	24.80	19.087	0.147	0.386	2.747	0.758	0.0108	0.748	3.33	4.04	4.33	1,937	2,226	<0.578	4.06	<2.687	2.01	4,176
1A-9	33.20	81.109	0.296	0.624	2.960	1.020	0.0146	1.005	3.96	4.90	3.55	1,595	1,640	<0.402	1.30	<3.010	—	3,245
1A-10	22.50	39.781	0.189	0.420	1.710	0.581	0.0083	0.573	2.35	2.90	2.92	1,510	518	<0.322	1.36	<2.890	—	2,035
1A-11	26.00	50.209	0.040	0.084	0.594	0.226	0.0032	0.223	0.74	0.94	0.86	646	339	<0.538	1.66	<2.650	—	991
1A-12	18.20	43.398	0.689	0.710	5.180	1.590	0.0227	1.567	6.63	8.17	7.95	4,051	4,220	<0.119	3.27	<2.830	—	8,286
1A-14	58.90	106.695	0.529	0.930	4.650	2.100	0.0300	2.070	6.19	8.21	6.94	904	1,660	<2.270	7.31	<4.520	—	2,586
AVE	28.96	47.422	0.353	0.622	5.924	2.055	0.0294	2.026	6.96	8.95	8.20	2,367	3,122	<0.559	4.41	<3.199	29.57	5,516
SD	13.45	25.037	0.289	0.542	6.624	2.349	0.0336	2.315	7.36	9.67	9.22	1,728	3,400	<0.582	3.48	<1.551	37.89	4,970

AVE = Average; SD = Standard Deviation; Calc'd = Calculated; RPT'D = Reported; TRU = Transuranic.

Table A-11. Combined Mixed Acid Etch, Siliceous Solids, and Titanium Etch Results for 1B Rack Samples (nCi/g) (continued)

SAMPLE	RPT'D ALPHA	CALC'D ALPHA	TRU/C	SI-90/Cs137	Rpt'd Alpha/ Calc'd Alpha
1A-1a	0.00211	0.00264	0.00207	1.749	0.799
1A-1b	0.00332	0.00415	0.00322	2.738	0.799
1A-1d	0.00309	0.00339	0.00260	1.574	0.910
1A-2	0.00170	0.00146	0.00115	0.824	1.168
1A-3	0.00058	0.00069	0.000582	0.254	0.843
1A-5	0.00695	0.00747	0.00593	1.497	0.930
1A-7	0.01081	0.01106	0.00845	0.523	0.977
1A-8	0.00224	0.00209	0.00172	1.149	1.073
1A-9	0.00223	0.00307	0.00248	1.028	0.724
1A-10	0.00193	0.00192	0.00155	0.343	1.007
1A-11	0.00133	0.00146	0.00115	0.525	0.911
1A-12	0.00196	0.00202	0.00164	1.042	0.973
1A-14	0.00768	0.00908	0.00685	1.837	0.845
AVE	0.00353	0.00389	0.00303	1.160	0.920
SD	0.00302	0.00325	0.00246	0.708	0.122

AVE = Average; SD = Standard Deviation; Calc'd = Calculated; RPT'D = Reported; TRU = Transuranic.