HNF-7640
Revision 3

CSER 01-001: Remote Entry into Six Process Cells in 224-T Building for Characterization

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management
Project Hanford Management Contract for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

Fluor Hanford
P. O. Box 1000
Richland, Washington

Approved for public release further dissemination unlimited

S

HNF-7640
Revision 3

EDC-02-12409

CSER 01-001: Remote Entry into Six Process Cells in 224-T Building for Characterization

Document Type: CSER Division: RCP

EM Miller
Fluor Hanford

Date Published
September 2002

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management
Project Hanford Management Contract for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

Fluor Hanford
P. O. Box 1000
Richland, Washington

SEP 2 6 2002
DATE:
STA: 15
HANFORD RELEASE
ID: 22

Chris Willingham
Release Approval

9/26/02
Date

Release Stamp

Approved for public release further dissemination unlimited

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, Process, or service by trade name trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.

Printed in the United States of America

Total Pages: 63

CSER 01-001: Remote Entry into Six Process Cells in 224-T Building for Characterization

Key Words: 224-T, cleanup, C-Cell, criticality, water, silt

Abstract: The CSER for cleanup of the 224-T Building is revised to allow the water accumulation in C-Cell pit to be pumped out and silt on the pit floor to be removed.

RECORD OF REVISION

(1) Document Number: HNF-7640, Rev. 3

(2) Title
CSER 01-001, Rev. 3: Remote Entry into Six Process Cells in 224-T Building for Characterization

Change Control Record

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release (5) Cog. Engr.	Authorized for Release (6) Cog. Mgr. Date
0	(7) Initial Release, EDT-630120, dated 01/02/2001	JE Ham	GB Chronister
1	Added limits and process controls for characterization of sump pit in C Cell containing	JE Ham	GB Chronister
	eleven feet of water, ECN-670315, dated 01/22/2002		
2	Added limits and process controls for vacuuming dust from cell floors and other surfaces,	SJ Giamber ardini	GB Chronister
	ECN-670334		
3 RS	Add limits and process controls for removing water and silt from C-Cell. EDC-02-12423	SJ Giamber ardini	GB Chronister GBC 9/25/02
		for signature See page 2 of EDC for signature	EW 9-20-02

CSER 01-001: Remote Entry into Six Process Cells in 224-T Building for Characterization

September 2002

Prepared by
Fluor Hanford, Inc.

Prepared by: Edward M. Miller Date: 17 Sept 02
E. M. Miller, Criticality and Shielding

Reviewed by: K. N. Schwinkendorf Date: 9/17/02
K. N. Schwinkendorf, Criticality and Shielding

Approved by: Hans Toffer Date: 9/18/02
H. Toffer, Manager, Criticality and Shielding

This page intentionally left blank.

TABLE OF CONTENTS

1.0 INTRODUCTION AND SUMMARY 1
1.1 INTRODUCTION 1
1.2 SUMMARY 1
2.0 DESCRIPTION 3
2.1 FACILITY DESCRIPTION 3
2.2 PROCESS CELLS 3
2.3 REMOTE RADIATION MONITORING 7
2.4 SAMPLE RESULTS FOR WATER AND SILT IN C-CELL PIT 7
3.0 LIMITS AND CONTROLS 9
3.1 UNKNOWN QUANTITIES OF FISSIONABLE MATERIAL IN PROCESS CELLS 9
3.1.1 LIMITS 10
3.1.2 PROCESS CONTROLS 11
3.2 PROCESS CELL FISSIONABLE INVENTORY LESS THAN 450 G 11
3.2.1 LIMITS 12
3.2.2 PROCESS CONTROLS 12
4.0 METHODOLOGY 13
5.0 ANALYSIS 13
5.1 BASIS FOR LIMITS OF PROCESS CELLS CONTAINING AN UNKNOWN AMOUNT OF FISSIONABLE MATERIAL 13
5.2 BASIS FOR CHARACTERIZING PROCESS CELLS CONTAINING AN UNKNOWN AMOUNT OF FISSIONABLE MATERIAL WITHOUT A CAS 23
5.3 BASIS FOR LIMITS OF PROCESS CELLS WITH LESS THAN 450 G OF FISSIONABLE MATERIAL 24
5.4 BASIS FOR CHARACTERIZING PROCESS CELLS WITH LESS THAN 450 G OF FISSIONABLE MATERIAL WITHOUT A CAS 24
5.5 224-T BUILDING CRITICALITY SAFETY CLASSIFICATION 25
6.0 REFERENCES 25
APPENDIX A - INDEPENDENT REVIEW COMMENTS AND CHECKLIST A-1
APPENDIX B -C-Cell PIT WATER AND SILT SAMPLE DATA B-1
APPENDIX C - ISOLATION FROM T PLANT C-1
APPENDIX D - CORRECTION TO NDA FOR WATER IN TANKS D-1

LIST OF TABLES

Table 2-1. 224T Process Cells Pu Hold Up (preliminary values).....8

LIST OF FIGURES

Figure 2-1. Process Cells in 224-T Building 4
Figure 2-2. Location of Tanks in 224-T Process Cells 5
Figure 5-1. Two Fissile Bearing Cylinder Experiment.....17
Figure 5-2. Mass/Volume Critical Curves. 18
Figure 5-3. Critical Slab Thicknesses on Concrete Floors. 20

1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

The 200 Area Facility Disposition is working to decontaminate and deactivate the six process cells in the 224-T Building in the 200 Area. Site documents do not adequately specify the contents of tanks in the cells unused since 1956. The last entry into the cells was in 1986. In the 1940's, operators concentrated plutonium solutions in the tanks in the six cells in the 224-T Building. In the first step in the deactivation process, the project made a series of entries to characterize the state of the cells and the contents of the tanks and sumps. Operations has determined the mass and location of fissile material in most of the tanks in the six cells using remote nondestructive analysis. This CSER lists the types of characterization activities and closest approach that can safely be made to tanks that have an unknown mass and form of fissionable material. This CSER also lists the types of characterization activities allowable for cells with less than 450 g of fissionable material and for areas with characterized liquid and silt.

The project entry into Cell C discovered that the nineteen foot deep sump pit had eleven feet of water in it. The last entry into the cells was in 1986 so unexpected changes were possible. This CSER also develops controls for characterizing and removing water and silt from the C-Cell sump pit.

1.2 SUMMARY

This CSER lists the criticality safety controls on the activities operators may perform to characterize and to cleanup the process cells in 224-T Building. The activities are specified (1) for cells and tanks with unknown fissile content and forms, (2) for cells and tanks with fissile content known to be 450 g or less, and (3) for C-Cell water and silt in the pit with known masses and concentration of fissile material. The justifications for the controls are developed in Section 5. The basis is also developed for not requiring a criticality alarm system in the 224-T Facility for the above mentioned operations. These CSER bases meet the requirements of the DOE Order 5480.24 and 420.1.

The information on the cleanup of the cells in the 1950s said that the tanks had been rinsed to remove all but fixed residual fissile material. The preliminary NDA analysis of all but nine out of twenty eight tanks conducted in 2001 showed that tanks had less than 2 grams of fissile material, except one tank that had 4 g. Process knowledge and confirmatory measurements indicated that the entire facility did not have enough fissile material to form a critical configuration by a factor of fifty. Lack of a significant amount of fissile material is the first barrier to criticality. Operations would have to bring in kilogram quantities of fissile material to form a critical configuration. The operations are not allowed to bring in fissile material and do not use any fissile material in their operation except as sources and as fission monitors which have only small amounts of fissile material that is well contained. Since no fissile material is moved, stored, or processed as part of the characterization activities, it could not be brought in accidentally as it could in a glovebox operation processing plutonium. The first barrier to reaching a potential critical configuration is that fissile material must be added to

the facility. Failure to prevent fissile material being added to the facility would be a contingency.

The second contingency or barrier preventing a criticality is that fissile material must be assembled if available in the cells, moderated, and reflected by operator action. The criticality safety limits and process controls on operations' activities prohibit actions that would increase reactivity. By these controls, double contingency is established for characterizing the 224-T Cells when the fissile content has not been documented. Incredibility arguments for not requiring a criticality alarm system are summarized in the second to the last paragraph in this section. Note that no fissile material is to be added to the facility in any operation, except as a source or as a fission detector. So double batching and over batching are not a contingent event as they would be in a glovebox where fissile material is routinely brought into the glovebox.

The discovery that the sump pit in Cell C had eleven feet of water meant that fissile material in the pit would be fully reflected and if stirred up from a layer of particulate on the bottom of the pit into the water, would be moderated. The first contingency or barrier that the cells have insignificant fissile material is still based on process knowledge and NDA results from the tanks in the cells. Characterization of the water and silt in C-Cell has shown only gram quantities of fissile material are present in them. Although documentation for the fissile inventory of the cells was not available from the closeout of process activity in the cells, the available records and 2001 NDA characterization of the tanks are the basis for considering it incredible that significant fissile material is present in the sump pit. To make a second barrier, sampling is limited to containers that could not hold a critical configuration for the material being sampled and restricted sampling to prevent agitating enough particulate on the pit floor to create a critical configuration. This second barrier is maintained during water removal from the pit by using sample results of the plutonium in the water to determine that the water being removed does not have more than 450 g of fissile material. After sampling, the water in the sump pit has shown that the water and remainder of cell above the water has less than 450 g of fissile material, then the water can be removed by a process that does not agitate silt on the floor. When sampling material from the tanks and the floor demonstrates that the cell fissile inventory is less than 450 g, then remaining water and silt can be removed because the addition of fissile material is not credible. Sampling has determined that the C-Cell pit contained less than 200 g of fissionable material. This revision of CSER 01-001 allows removal of the water and silt form C-Cell because of the low mass and concentration of fissile material. Section 2.4 derives the plutonium mass sample results for the silt and water.

Once NDA has established that the ANS single parameter limit of 450 g is satisfied in a 224-T cell, the list of allowed operator activities can be expanded because it is now incredible that the cell has enough inventory for a critical configuration and fissile material is not part of the operations so over batching is not credible. Also, when the cell inventory is 450 g or less, ANS standard 8.3 does not require a criticality alarm system. This condition meets the DOE orders 5480.24 and 420.1 because they incorporate the ANS 450 g mass value explicitly.

Before NDA has confirmed that 224-T cells contain less than 450 g of fissile material, Section 5 gives a basis that a critical alarm system is not required. A criticality is considered impossible, because, based on process knowledge and NDA results, it is incredible that there is

enough fissile material for a critical configuration and because operations actions are restricted to those that would not increase the reactivity of the material in the cells. This basis meets the requirements of DOE orders 5480.24 and 420.1.

The CSER justifies the characterization activities allowed by the limits and process controls listed in Section 3. The characterization activities allowed, meet the requirements of the Hanford Criticality Safety Program, HNF-7098, and ANS criticality standards.

2.0 DESCRIPTION

2.1 FACILITY DESCRIPTION

The 224-T Building, located in the 200 West Area parallel to T-Plant, the 221-T Canyon building, is currently being maintained in a surveillance and maintenance mode by 200 ADP. The site has excessed the building and has no plans to use the building again.

The 224-T Building is a small canyon type structure with six process cells on the southeast side of the building. The outside wall of the building is one-foot of concrete. A one-foot thick concrete wall separates the cells from three levels of operating galleries in the northeast section of the building. Figure 2-1 shows the location of the process cells in the building. Figure 2-2 shows the location of tanks in the six cells.

The 224-T Building first and second floor outside dimensions are 60 m (197 ft) by 18 m (60 ft). The third floor is 44.2 m (145 ft) by 18 m (60 ft). A 30 cm (12 in.) -thick concrete wall divides the building into two main sections. Offices and operating galleries are on the northwest side of the dividing wall. The process cells are on the southeast side and have been sealed from the operating galleries for over 25 years. The 224-T building process cells are isolated from input from 221-T. Appendix C describes the barriers to fluid flow from 221-T Building to 224-T.

2.2 PROCESS CELLS

The process cell portion of the building consists of six cells (A through F). Cells A through E are three stories high, or 12 meters (40 feet), and are separated from each other by 4.5 m (15 ft) high, 20 cm (8 in)-thick concrete walls. The outside wall and the wall with the galleries are 30 cm (12 in.) -thick concrete. The concrete cell floors and cell decks thickness are not specified, but must be at least 10 cm (4 in.) thick concrete. Each cell is approximately 7.5 m (25 ft) by 8.5 m (28 ft). Cells A, B, D, and E are similar in configuration and contain similar equipment. There are two 2.7 m (9 ft) diameter by 2.7 m (9 ft) high tanks and one 1.4 m (4.5 ft) diameter by 2.1 m (7 ft) high tank on the first floor of each cell. B cell has an additional tank of the smaller dimensions. Some of the tanks are equipped with agitators and motors. A, B, D, and E cells also have a 3 m (10 ft) by 4.3 m (14 ft) operating deck at the second floor level. A 1 m (40 in) centrifuge is located on each of these operating decks.

Figure 2-1. Process Cells in 224-T Building

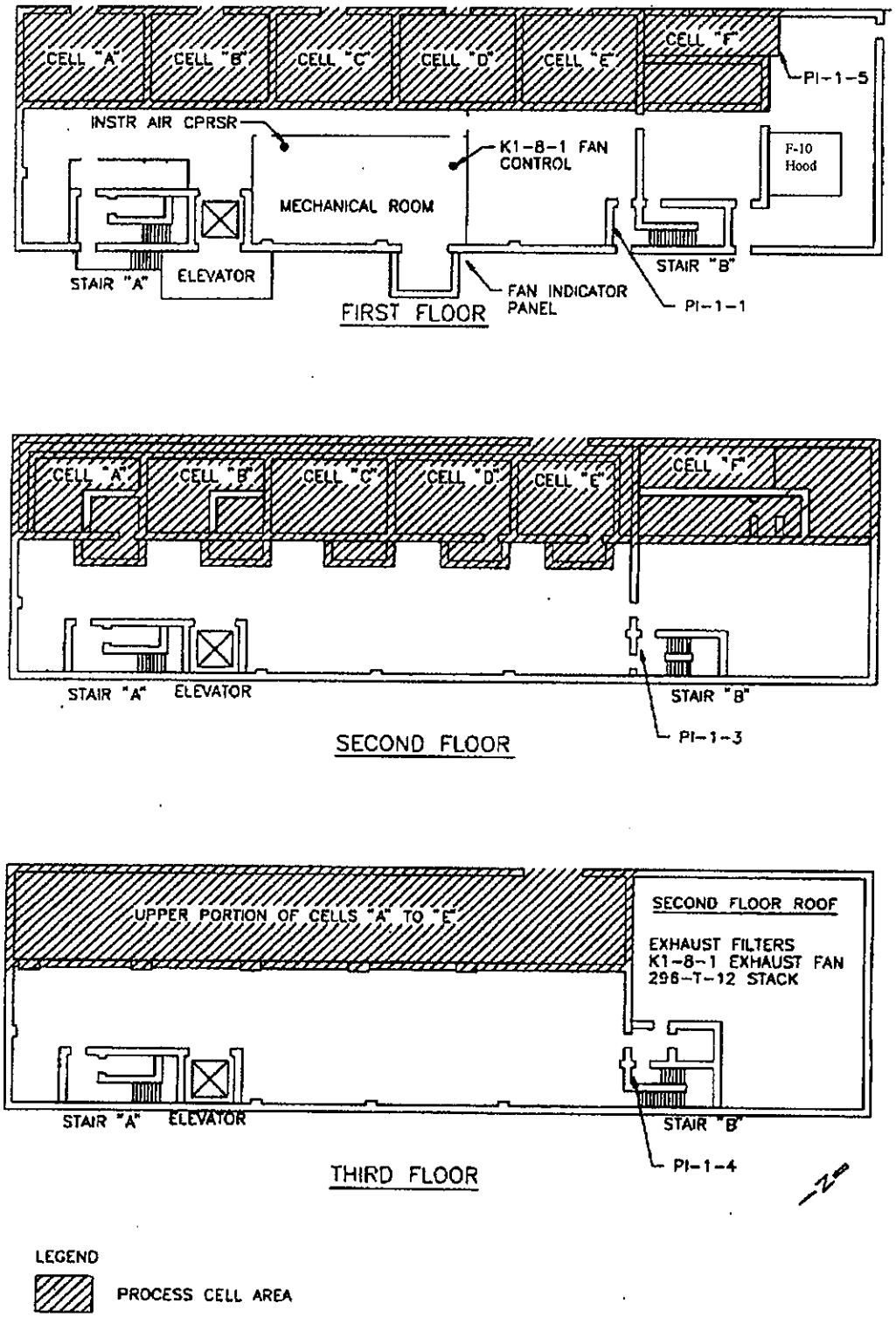
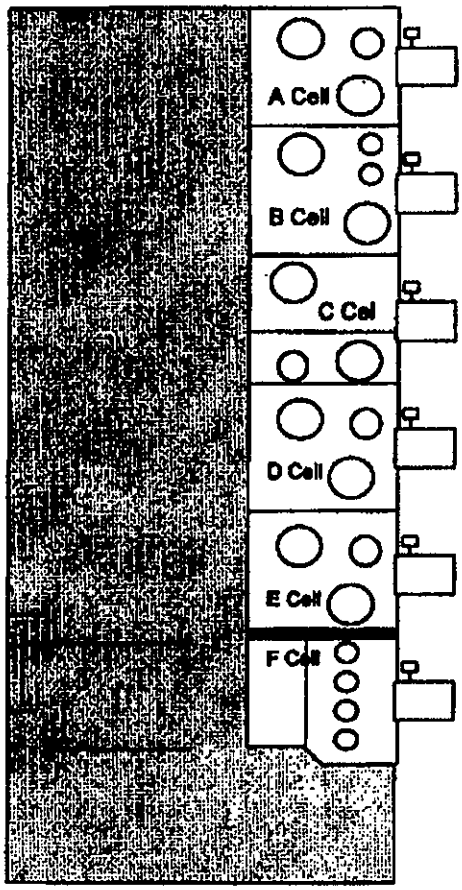


Figure 2-2. Location of Tanks in 224-T Process Cells



The process cells concentrated an input solution of 0.16 g Pu/L to a product of 12.9 g Pu/L by a batch process. Each batch contained a maximum of 323 g of plutonium. Based on historical information, A cell is considered the most contaminated of the six process cells. A 224-T characterization sheet from 8/71 says that the cells are in laid-away status.

C cell differs in structure and arrangement from the other cells referenced above. Approximately one-half of the cell is a deep pit, 7.62 m (25 ft) by 4.11 (13.5 ft), where the high point of the pit floor is 5.8 m (19 ft) below the first floor level. A two-foot deep, two by one and a half foot sump is located in the southeast corner of the sump pit. The pit section of the cell contains one 2.7 m (9 ft) diameter by 2.7 m (9 ft) high tank, C-7, and one 1.4 m (4.5 ft) diameter by 2.1 m (7 ft) high tank, C-4. Drawing H-2-2690 shows that a third tank, C-9, was added to C cell sump pit. The sump pit floor slopes to a trough on the northeast side of the pit. The sump is at the south end of this low side of the sump pit. The figure in Appendix B shows the pit configuration. A 1.7 m (5.5 ft) by 3.3 m (11 ft) high pipe tunnel extends 10.4 m (34 ft) from the deep cell beneath the first floor to a pipe encasement. The piping in this tunnel and the encasement were used for transferring fissile and other solutions between the 221-T building and the 224-T building, and connects with the 221-T main building exhaust tunnel. The first floor level of C cell contains one 2.7 m (9 ft) diameter by 2.7 m (9 ft) high tank.

There are ground level personnel access doors into cells A, B, C, D, E, and F on the southeast side of the building. In addition, there is a 3.7 m (12 ft) by 3.7 m (12 ft) high equipment access door located at the second floor level outside of E cell. Cell B has a piece of equipment four feet directly in front of the door. The other tanks and equipment are at least four feet from the wall with the door, but are 1.67 m (5-1/2 ft) or more from the door.

The 7.5 m (24.5 ft) by 7.6 m (25 ft) by 7.6 m (25 ft) high F cell is separated from the other cells by a concrete wall. Modifications completed in the 1970s reduced the size of F cell to approximately 50% of its original size with the installation of concrete or steel barrier walls. F cell also contains a 3.9 m (12.7 ft) by 7.6 m (25 ft) centrifuge deck (mezzanine) that is elevated 2.1 m (7 ft) above the cell floor. Access to the F cell mezzanine is gained via an external staircase and door in the Transuranic Waste Storage and Assay Facility (TRUSAF) receiving area. There are two additional points of access to F cell. One is an exterior door on the southwest side of the building and the other is through a door in the TRUSAF receiving area. The first floor level of F cell contains four vessels with dimensions of 1.2 m (4 ft) diameter by 1.5 m (5 ft) high. The F cell mezzanine contains two centrifuge vessels and associated piping.

The 224-T internal cell drainage system collects wastewater in a receiver tank in the deep portion of C cell, the sump pit. A gutter along the base of the northeast wall in cells A to F drains to a 15 cm (6 in.) clay pipe laid below the cell floors. The floors in the cells slope toward this gutter. The operating decks, where the centrifuges are located, in cells A, B, D, and E also drain to C cell. Water leaking into any of the cells will eventually drain to the 2.7 m (9 ft) high tank in the C cell sump pit. Because there are no active pumps to transfer liquids, accumulated liquids could overflow the 2.7 m (9 ft) high tank and collect in the pit. This tank and others in the facility have overflow lines from a tank to the cell floor. Drawing HW-72939 shows that tanks C-4 and C-7 in the sump pit and C-8 on the main floor level have overflow piping to the floors supporting the tank.

The T Plant main exhaust system provides ventilation to the 224-T tanks and centrifuges with the vacuum created by the 291-T fans. Stainless steel subheaders connect to tanks and centrifuges inside the cells and exit the southeast side of the building 1.8 m (6 ft) above grade. The stainless steel headers are directed down and transition to 15 cm (6 in.) clay pipe below ground level. The clay pipes connect to a 61 cm (24 in.) diameter clay main header below grade about 7 m (23 ft) from the 224-T Building. The 61 cm (24 in.) diameter clay main header connects to the T Plant main exhaust tunnel at the west end of 221-T.

2.3 REMOTE RADIATION MONITORING

An eighteen-inch wide track robot is to carry a radiation probe near each tank in turn to monitor the radiation field from that tank. The data is used to estimate the fissionable inventory of the tank. The robot is required to stay more than two feet away from a tank with unknown fissionable material inventory. If the tank is determined to contain less than 450 g of fissionable material, the robot does not have to maintain any spacing to the tank in moving to monitor tanks further into the process cell. People supporting the robot entry are required to keep all parts of their bodies from entering more than one foot from the doorway.

Table 2-1 lists the preliminary results of NDA measurement of the 224-T process cells and an adjacent hood, F-10. This hood is located in the TRUSAF space on the other side of the southwest wall of F cell. Of the 52 g of plutonium found in measuring twenty-four of twenty-eight tanks, two cardboard boxes, and a hood, 11 g was in the hood outside of the process cells. Only 41 g was found in the A thru F process cell tanks. Four tanks are still to be measured in the process cells. If the four additional tanks have the same range of holdup as the twenty-four tanks already measured, the total tank plutonium holdup would be 48 g. If all the unmeasured tanks have the maximum found in a tank, 12 g, the total tank holdup would be 89 g. These preliminary findings leave a wide margin to an isolated facility maximum of 177 g and to the ANS single parameter value of 450 g for plutonium.

The tanks in 224-T Building cells could contain water. This water could shield the plutonium radiation reducing the NDA determined plutonium inventory. The report in Appendix D says that for the NDA measurement geometry used to measure the tank plutonium inventory, the largest correction factor would be 25 to correct for water in a tank. The tanks in F-Cell have a combined inventory of 15 grams, the largest of any cell and larger than any individual tank in 224-T building. Even if all the tanks in F-Cell contained water, the total plutonium inventory in F-Cell would be 375 g, a value still less than the 450 g ANS single parameter limit.

2.4 SAMPLE RESULTS FOR WATER AND SILT IN C-CELL PIT

Samples from C-Cell water were taken and analyzed for total alpha particles. Appendix B reproduces the report from WSCF. Page 3 of the report gives the total alpha as 4.3 E+02 piCi/L. This value is considered a good number because it is significantly larger than the minimum detectable value of 1.4 piCi/L. Assuming all the alpha activity is ^{239}Pu, the total alpha count is converted to 7.0 E-9 g ^{239}Pu/L of water using a value of 0.062 Ci/g. This concentration

Table 2-1. 224T Process Cells Pu Hold Up (preliminary values)

TANK	Pu HOLD UP (grams)	COMMENTS
A CELL		
A-1	0.875	
A-2	--	NDA during manned entry
A-3	4.51	
A-4	0.086	
Total	5.47	
B CELL		
B-1	0.959	
B-2	8.9	NDA during manned entry
B-3	0.368	
B-4	0.686	
B-6	0.22	
Total	11.13	
C CELL		
C-4	--	In pit, under water
C-7	--	In pit, under water
C-8	1.7	
C-0	--	In pit, under water
Water & silt	2.41	In C-Cell pit
Total	4.11	
D CELL		
D-1	0.58	
D-2	0.5	NDA during manned entry
D-3	0.0018	
D-4	0.25	
Total	1.33	
E CELL		
E-1	0.0017	
E-2	2.40	NDA during manned entry
E-3	0.0017	
E-4	0.916	
Total	3.32	
F CELL		
F-1	0.799	
F-7	0.649	
F-8	0.514	
F-9	0.818	
F-2	0.7	NDA during manned entry
F-22	11.9	NDA during manned entry
Special Tank	0.0004	
Cardboard Boxes	0.817	
F-10 HOOD	10.3	
Total	26.5	

Total all cells: 51.86 g

is 1 E-9 less than a minimum critical concentration of plutonium in water. The flooded C-Cell pit contains about 35,000 gallons (140,000 L). This amounts to about 0.001 g of plutonium in the water in the C-Cell pit. A minimum critical mass of plutonium in water is 500,000 times larger than this mass.

Samples from C-Cell silt solids were taken in four places along the deep side of the pit with one from the sump as shown in the figure in Appendix B labeled 224-T Building C-Cell Pit. The four samples were mixed together, centrifuged, and the dried solids measured for alpha activity. The final report for 224T C-PIT1 Sample gives an alpha particle count rate of 0.105 μCi/g of solids. From the reported standard % of 100, the blank of <6.01 E-05, the detection limit of 9.70 E-05, and a count error % of 1.9, the result would be a reliable value. Assuming a one inch layer on the entire 25 ft by 13.5 ft of the pit floor and two inches on the 2 ft by 1.5 ft at a density of clay, 1.8 g/cm^3, the total alpha activity in the pit solids would be 0.152 Ci. Using 0.062 Ci/g of ^{239}Pu to convert all alpha activity into fissile plutonium, the total mass of plutonium in the silt in the pit would be 2.4 g. This value is two hundred times smaller than the minimum critical mass for plutonium in water.

3.0 LIMITS AND CONTROLS

3.1 UNKNOWN QUANTITIES OF FISSIONABLE MATERIAL IN PROCESS CELLS

The following operations may be performed in accordance with approved work plans and/or procedures that incorporate the limits and process controls listed in this section for areas with unknown quantities of fissionable material.

1. Radiation and other monitoring
2. Installation of radiation or other survey equipment
3. Photography
4. Neutron activation studies
5. Sample Swipes
6. Installation of monitoring equipment
7. Installation of TV, optical or other surveillance equipment
8. Setting up entrance, exit, and other structures for contamination control
9. Hand spraying disinfectant
10. Sweeping and dusting
11. Sampling liquid in pits, sumps, vessels, and piping
12. Sampling silt in pits, sumps, vessels, and piping
13. Removing and recirculating liquid from C-Cell
14. Removing silt from C-Cell
15. Vacuuming and vacuumed dust disposal of characterized material

3.1.1 LIMITS

1. Sensors smaller than ½ L (a soda can), are to be spaced nominally 25.4 cm (10 in.) or more from any vessel larger than 3 L in volume with unknown fissionable mass inventory.

2. Equipment larger than ½ L (a soda can), including robots, are to be spaced nominally 61 cm (24 in.) or more from any vessel larger than 3 L in volume with unknown fissionable mass inventory.

3. People or a 2 L or less size bottle of disinfectant/fixative are to be spaced nominally 91.4 cm (3 ft) or more from any vessel larger than 3 L in volume with unknown fissionable mass inventory.

4. Tanks and equipment known to have less than 450 g of fissionable material, do not have spacing requirements for non-fissile bearing equipment and people.

5. No material that can possibly be fissionable or reflective (e.g., bricks, furniture, trash cans, bottles) may be moved, rearranged, or otherwise disturbed in a process cell within a nominal 91.4 cm (3 ft) or less of a vessel larger than 3 L, EXCEPT vacuuming covered by limit 12 and other explicitly authorized activities.

6. No water or oils may be introduced into a process cell, EXCEPT that as lubricant for equipment, the robot, or pumps or those allowed by item 3 above.

7. No fissionable material is to be introduced in a process cell, EXCEPT as part of monitoring equipment.

8. Sweeping or dusting, not vacuuming, may accumulate a pile of material 5 cm (2 in.) or smaller or a volume of 3 L or smaller until the material is characterized as having less than 250 g of fissionable material. Disposal of uncharacterized sweepings shall be in one-half liter or smaller containers spaced 25.4 cm (10 in.) or more from each other and any other fissionable material in transit and 91 cm (3 ft) or more for storage, except one empty container may brought next to material to fill the container.

9. Liquid sample container volume shall be less than 4.7 L or the container is to be less than five inches in diameter.

10. Silt sample container volume shall be nominally less than a half-liter.

11. In flooded spaces, visual, radiation and other monitoring equipment may be used without a requirement for spacing. But monitoring equipment is not to collect uncharacterized silt or silt with more than 200 g of fissile material in a pile and is not to stir up silt so that it mixes with the surrounding liquid.

12. The maximum mass of plutonium or equivalent fissile material allowed in a vacuum of any size, an array of vacuum cleaners, an array of vacuum collector units, or a collection of vacuums, vacuum collectors, and other fissile is 200 grams and is to be spaced 91 cm (3 ft) from items with more than 15 grams of fissile material.

3.1.2 PROCESS CONTROLS

1. The Criticality Safety Representative may authorize in Criticality Prevention Specifications other operations that are within the limits specified in Section 3.1 above.

2. The Criticality Safety Representative is to approve work plans and procedures.

3. Sampling of liquid or silt shall not stir up uncharacterized silt into a contiguous volume of more than 5 liters. Objects that are put in or could fall into the sump pit or a tank and agitate the uncharacterized silt in the pit or a tank are to be prevented or restrained in two, independent ways (e.g., two separate tethers). A pipe, tubing, or a cable that is secured from falling into the sump pit or a tank is allowed into the pit or a tank. Liquid and silt containing less than 200 g of fissile material are not subject to any restrictions on sampling, disturbance, or removal.

4. Sampling of uncharacterized silt shall not collect silt into a pile of more than a half-liter volume; silt with less than 200 g of fissile material is not subject to any restrictions on sampling, disturbance, or removal.

5. Survey information is to be reviewed by the CSR/CSE.

6. If an aggregation of fissionable material in excess of 450 g is found, suspend work allowed by this CSER in that process cell.

7. The process cells are to be Fire Fighting Category C.

8. Personnel may sample vessels or deposits that have or are being water reflected without spacing requirements.

9. The mass of plutonium and equivalent fissile material in dust to be vacuumed up must be known before vacuuming.

3.2 PROCESS CELL FISSIONABLE INVENTORY LESS THAN 450 G

The following operations may be performed in accordance with approved work plans and/or procedures for areas with quantities of fissionable material measured to be less than 450 g per cell.

1. All activities previously approved in Section 3.1

2. Opening containers and vessels

3. Valve opening and closing, EXCEPT if an uncontrolled path to C cell is established that could increase fissile inventory above 450 g in an area, then two barriers are required in the flow path (e.g., a valve and catch pan).

4. Sampling of vessels, containers, and piping

5. Movement and removal of material and items

6. Installation of neutron poisons and personnel shielding of less than 2.5 in thickness

7. Use of water and oils in hydraulic equipment (Hydraulic oil limited to 5 L)

8. Plastic fixatives may be applied but not removed.

9. Removing liquid in pits, sumps, vessels, and piping.

3.2.1 LIMITS

1. No fissionable material is to be introduced in a process cell, EXCEPT as part of the monitoring equipment.

2. Plastic and plastic type materials are not to be mixed with fissionable material.

3. Oils are not to be introduced to containers, vessels, and piping.

3.2.2 PROCESS CONTROLS

1. The Criticality Safety Representative may authorize in Criticality Prevention Specifications other operations that are within the limits specified in the limits of Section 3.2 of this CSER.

2. The Criticality Safety Representative is to approve work plans and procedures.

3. The Criticality Safety Representative is to assure that all fissionable material inventory masses are determined in accordance with Chapter 4 of Section 3.5.4.d in HNF-9078, Rev. 0.

4. No operation is allowed that can transport fissionable material to C cell, the pipe tunnel, the pipe encasement, or another cell or area and result in that space increasing in fissionable inventory above 450 g.

5. The process cells are Fire Fighting Category A. (This fire fighting category does not impose any restrictions on fire fighting.)

4.0 METHODOLOGY

This CSER shows that criticality is not possible when activities are conducted as allowed in the limits and process controls of this CSER. For the case where the form and quantity of fissionable material is not known, the methodology is to demonstrate that any aggregation of fissionable material in the process cell would not be made more reactive by activities allowed to be performed within the limits and process controls of this CSER. For a total process cell inventory of less than 450 g of fissile material, criticality can be shown to be impossible for the conditions allowed in this CSER. This CSER does not cover known aggregations of fissionable material in excess of 450 g. Specific analysis of the configuration will be necessary in a separate CSER.

Determining the mass of fissionable material in the cells will use nondestructive assay methods that are not accurate to 5 % with a 95 % confidence level. HNF-9078, Rev. 0, requires that the masses compared to criticality prevention specification limits developed in a CSER be determined by adding the measured mass and the mass corresponding to the uncertainty in the measurement. This high value in reported nondestructive assay (NDA) results is the value that needs to be used and it is often twice the measured value. This high value needs to be compared to the 450 g limit specified in this CSER to determine the actions that may be taken.

5.0 ANALYSIS

5.1 BASIS FOR LIMITS OF PROCESS CELLS CONTAINING AN UNKNOWN AMOUNT OF FISSIONABLE MATERIAL

Figure 2-2 shows that each process cell has several tanks, centrifuges, and other equipment that concentrated plutonium solutions in the 1940's and 50's. The input solution specified to be at a concentration of 0.16 g Pu/L would have to be 43 times more concentrated to reach a minimum critical concentration of plutonium in water of 7 g Pu/L. Limits allowed only up to 323 g of plutonium in a batch. This mass is less than the minimum critical mass of 531 g of plutonium in water fully water reflected. A batch could not go critical even when concentrated to the output target of 12.9 g Pu/L. Even over-batches, total plutonium mass of more than 531 g, would be safe in the facility tanks. The tanks are so large that sufficiently concentrated plutonium would have a small volume and spread out to less than the several inch depth needed to go critical or the plutonium concentration would be too low to go critical because of the volume of fluid needed for a critical depth in a tank.

A 9-foot tall tank would have 255 L in a one square foot column. Since the minimum critical areal density for plutonium in water from Figure III.A.8(100)-3 in ARH-600 (Carter 1968) is 240 g Pu/ft^2, a solution left in a tank and concentrating over the years would have to have started at greater than 0.94 g Pu/L to have the potential to reach a critical configuration.

Since a batch was about 2000 L (500 gallons) and a full 9 ft diameter 9 foot tall tank holds 16,000 L (4000 gallons), it is improbable that a full tank volume was left in a tank with a plutonium concentration above a rinse solution of 0.001 g Pu/L. Operations trying to scavenge plutonium would not have left a concentrated solution in a tank. That a close to critical system is in the tanks from process material left there is remote.

The process reported a process loss of 0.42 % of the plutonium processed. This amount was the plutonium entrained in the discarded waste solutions. Some could have deposited on tank, equipment, and piping inner surfaces. If the process equipment were rinsed, some of the plutonium would have been removed. Any residual is spread in a thin layer adherent to the equipment inner surfaces. This contamination does not pose a criticality concern because none of the actions allowed by this CSER could bring this distributed material into an aggregate to make a critical configuration.

If a tank is rusting, the fissile contamination on the inside tank surface could collect in the bottom of a tank. However, the accumulation of debris would have a low density, small amount of fissile material, and large amounts of iron in the rust, a neutron absorber. Diffusion in these cool, static tanks is not expected to separate rust from fissile material. These factors make a critical configuration remote.

The amount and form of any residual fissile material is uncertain. Although records and personnel recollections are that the process vessels were rinsed and miscellaneous items in old files indicate that equipment is only contaminated, no documented, specific values are available for the mass of fissionable material in the process cells. Operators used the cell tanks and centrifuges to concentrate plutonium solutions. Without a concrete basis for an inventory value for plutonium in the cell, the analysis must proceed on the basis that one or more tanks or pieces of equipment have a just subcritical mass of plutonium.

Although all activities in or around the process cells have some effect on reactivity, classes of actions can be shown to result in a small enough effect to be considered insignificant. This section shows that the actions allowed by the limits and process controls in Section 3.1 have an insignificant effect on reactivity in a process cell.

Characterization of a process cell begins with building a structure over the entrance doorway to prevent contamination dispersion. These activities are behind the door and the 12-inch thick outside concrete wall that surrounds the doorway. The activities are at least four feet from the closest tank to the door. The distance and concrete reduce any increase in reflection from this activity to insignificance.

Next, the door is opened and an operator may move to one foot inside the door. The tanks are 4.5 and 9 feet in diameter with up to a 9-foot height in a three-story 25 by 28 foot rectangular silo of concrete walls 8 or 12 inches thick. Floor and roof are also of concrete. The effect of the introduction of a robot, and other equipment at a minimum of two feet or a person at a minimum of 3 feet from a tank is insignificant as a reflector. The massive amount of thick concrete surrounding the tanks on six sides is overwhelming. Personnel, who are largely water, are a more efficient reflector than a robot or other monitoring equipment. Personnel are to be

spaced one foot further from tanks and other vessels with unknown fissionable inventory. A ½ L detector is allowed to a nominal 25.4 cm (10 in.) of the tanks with unknown inventories of fissionable material because the detectors' small size would have insignificant reflection.

The above paragraph implicitly assumes that any fissionable material is spread out in the tank as a residue or a solution. This paragraph looks at a case of a 30 cm (12 in.) diameter cylinder about 40 cm (16 in.) tall approached by an identical cylinder. Figure 5-1 (Paxton 1987) shows the change in critical height of plutonium or uranium solution in the tanks as they close the distance from infinite spacing (single solution cylinder) to contact (zero surface separation). The fissile levels in the cylinders remain almost flat up to a separation of 90 cm (36 in.), then decreases more rapidly. This analysis used the plutonium curve rather than the uranium curve as the most likely fissile residue, but both curves are similar and would give the same result. This analysis is done using a single plutonium solution cylinder with a critical height of 40.8 cm, a critical height of 30.5 cm for two cylinders touching, and heights of 40.25 cm and 39.75 cm for 90 cm and 60 cm separation from the figure. The height of fissile solution decreases by 5.3 % in the two cylinders when moved to within 90 cm (36 in.) and by 10 % when moved to within 60 cm (24 in.) from infinite separation to maintain a constant reactivity. This experiment uses two cylinders of fissile solution to determine interaction. In the case of a person or a robot, the second cylinder would be a reflector of water or combination of metal, plastic, and lubricating oil. The effect would be only a fraction of that of fissile material. Assuming the reflector effect is 1/5 that of fissile material, the increase in reactivity would then be only 1 or 2 %, too small to be considered a credible concern to the criticality safety of the process cells.

If a space is flooded, adding monitoring equipment does not increase reflection. Submersible TV camera and radiation measuring equipment would not be as reflective as close fitting water. These items can be used for characterizing the space since they would not change the reactivity by changing the amount of reflection of the water. The procedure to use submersible equipment must include steps to keep from mixing silt on surfaces with the water. Mixing could increase reactivity by increasing the moderation and concentration of fissile material. The amount of disturbance allowed is specified later in this section. The procedures need to have two independent ways the device is kept from disturbing silt that is under water. Having two independently anchored tethers on a submersible TV camera would have two independent lines to keep the camera from falling to the bottom of a pit and disturbing the silt. A pipe, tubing, or a cable that is anchored from falling into a pit or tank is allowed in the water in a pit or tank because it is self tethered and would agitate silt in a line, not a compact area, if it fell in.

Once the liquid in C-Cell above the silt layer is found to have too little fissile mater to represent a criticality hazard, it can be removed provided the silt layer is not perturbed in a manner that could adversely impact subcriticality. If the water had a total of up to two hundred grams of plutonium in it, the water could be removed. The minimum critical mass of plutonium in water is 531 g as shown in Figure 5-2 in this CSER. Two hundred grams of plutonium in the liquid or silt when removed separately or in the liquid and silt when removed together would be less than 0.45 of the minimum critical mass. The 0.45 margin is specified in HNF-7098. Section 2.4 shows that the total mass of plutonium in the water and silt in C-Cell is less than 3 grams. Both the total mass and concentration are factors of ten away from limits. These materials may

be removed from the C-Cell pit without controls on volumes. As a conservatism and good practice, the water should be removed without stirring the silt into the water.

During the water removal process the entire cell inventory could still be above 450 g fissile material. The amounts of fissile material in the sump tanks and the silt are still undetermined. However, the cell as a system should become less reactive as water reflector is removed around the sump tanks. The removal of the surrounding water should facilitate sampling and NDA measurements. Both instrumentation and personnel could approach the sump tanks without a 3-foot spacing requirement. The reflection by instruments and people would represent a small fraction of reflection provided by the water before removal. Limits established for other aspects of sampling and measurements defined in this CSER need to be adhered to. Again during sampling and measurement care has to be exercised to preclude perturbing the silt layer.

The limits allow unlimited access to containers of volume up to 3 L. Figure 5-2 from Figure III.A.9(100)-4 in ARH-600 (Carter 1978) shows that for a 3 L volume, the plutonium mass must be at least 10 kg and the plutonium density must be greater than 3 g/cm^3 to be critical. Such a mass of concentrated plutonium would not have been left in an abandoned facility in the 1950's. This density is the upper bound for plutonium powders produced at PFP before the present facility cleanup operations. Since PFP took design efforts to reach 3 g Pu/cm^3, accidental processes after closure of 224-T are unlikely to have made so dense a powder. Even if evaporation concentrated a residual material to this density, the amount would be only a residue, not a container full as it could have been before concentration. The 224-T process cells would not have plutonium at greater than 3 g/cm^3 from intended processes left in the cell or from concentration over the years. This analysis judges that a criticality is incredible in containers smaller than 3 L so no restrictions have been placed on approaching these containers.

The limit of 5 L of oil is based on the judgement that plutonium is not available at high densities. A residue density of 1 g Pu/cm^3 is considered impossibly high. Figure 5-2 shows that more than an eight-liter volume is needed for a criticality of 1 g Pu/cm^3 optimally water moderated and with one inch of water reflection. There is no water or other reflector material allowed during characterization in the process cells. One inch of nominal water reflection from the process cell is the only reflection available. Oil can be a slightly better moderator than water, but an accidental oil spill mixing with plutonium is unlikely to be fully reflected, so a limit of 5 L on oil is adequate to preclude a criticality from this limited amount of moderator.

Figure 5-1. Two Fissile Bearing Cylinder Experiment.

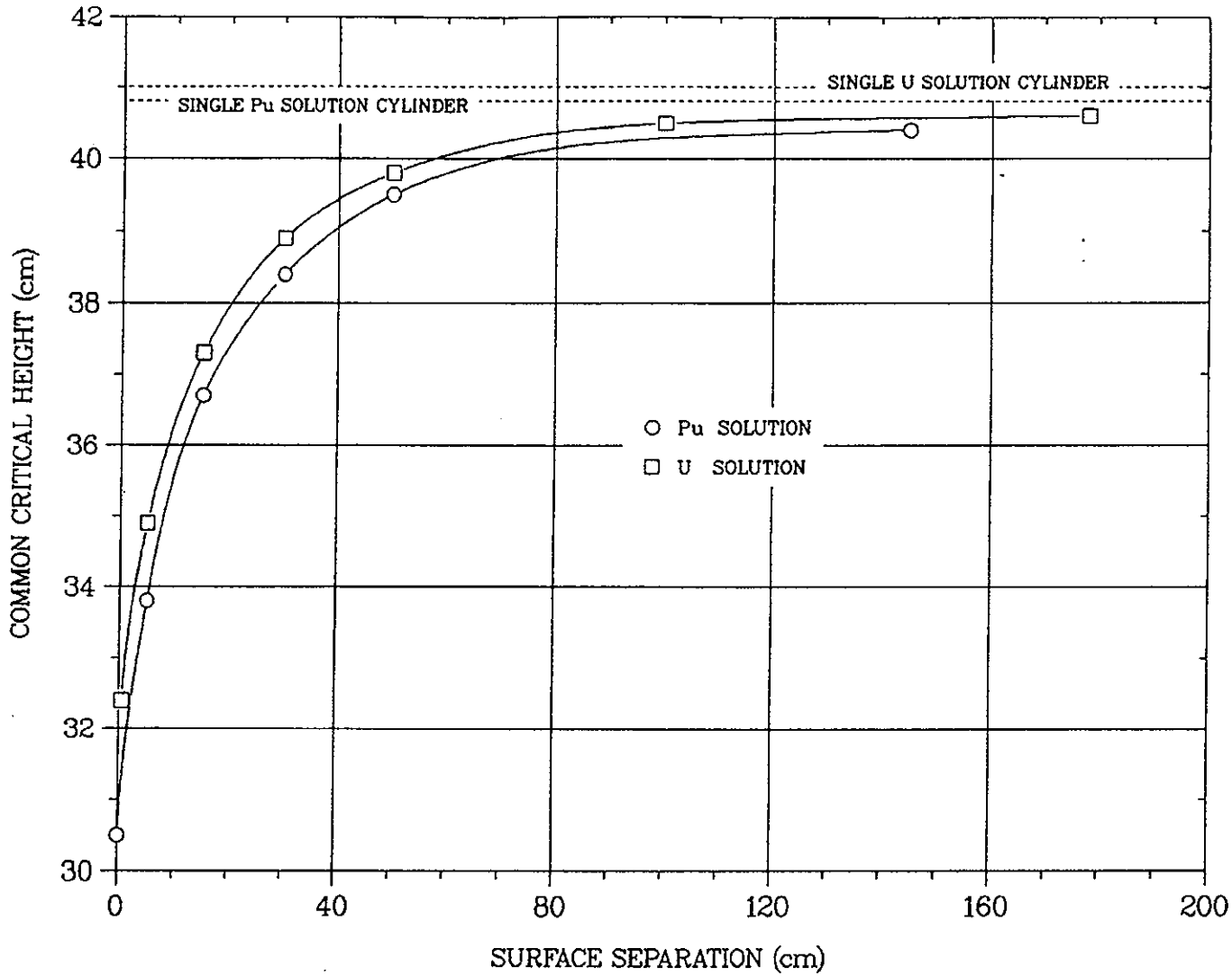
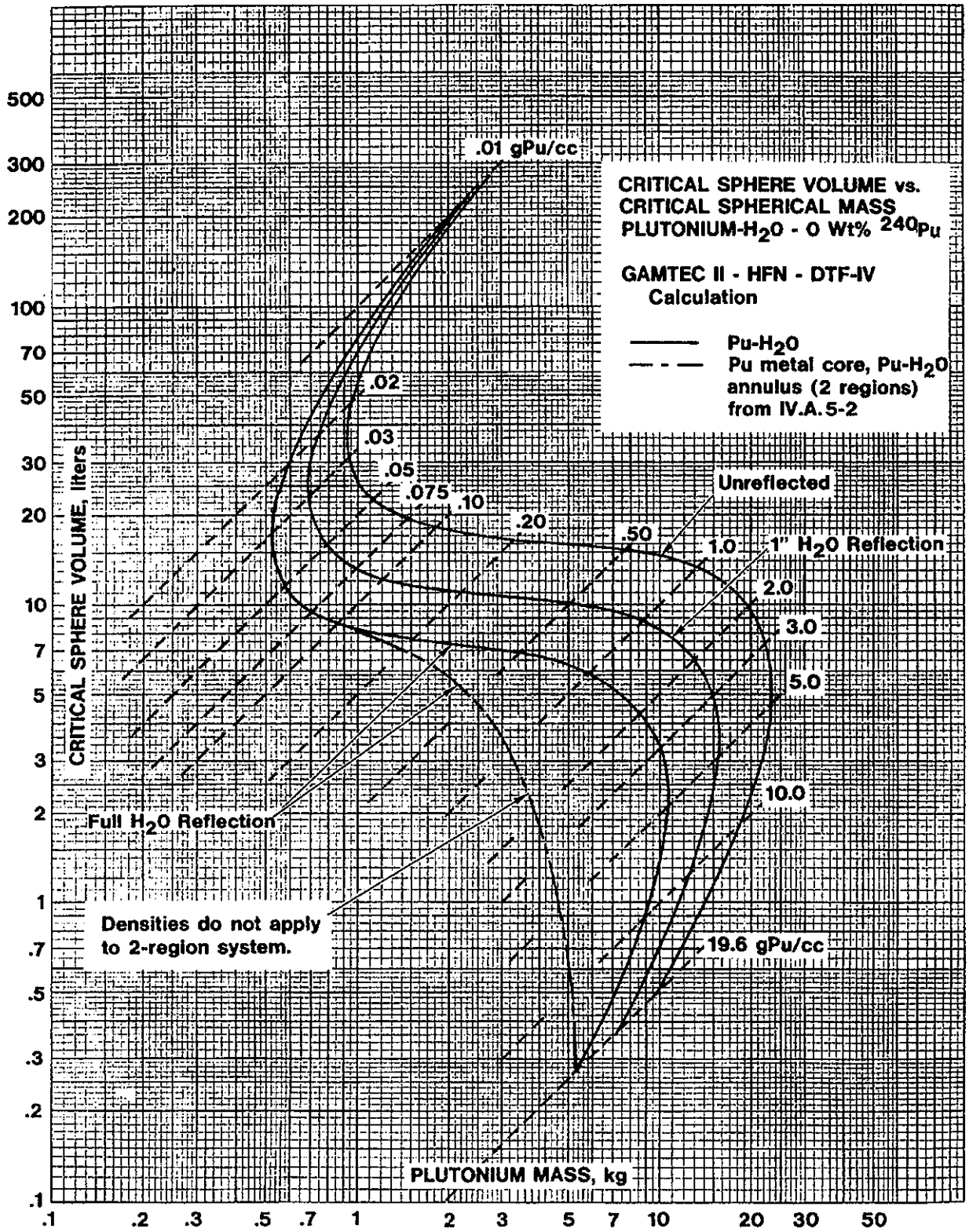


Fig. 72. Common critical height of two unreflected $Pu(NO_3)_4$ solution cylinders at 0.110 g/cm^3 of ^{239}Pu + ^{241}Pu or two $U(90)O_2(NO_3)_2$ solution cylinders at the equivalent concentration of 0.081 g ^{235}U/cm^3. Stainless steel containers 30-cm-o.d. with 0.3-cm-thick walls.

Figure 5-2. Mass/Volume Critical Curves.



The process cells may have hazardous biological material that needs to be disinfected using a sprayed mist of bleach and water. The bottle is to remain three feet from tanks, but the mist is desired to go everywhere in the cell. A hand spray bottle of up to 2 L capacity is a far smaller amount of water than a person is, so the argument for a personnel entry to within 3 feet of tanks bounds a spray bottle entry. The amount and density of spray released by a hand held spray bottle is so small that weather and wildlife could be a larger reflector to the tanks. Any of these reflectors are considered to be negligible in comparison to the other tanks, equipment, and concrete walls, floor, and ceiling. These same arguments apply to use of fixatives to control the spread of contamination. These fixatives can be a plastic. A thin layer of plastic on plutonium is not very reactive, but stripped from a surface and wadded into a container it is. This plastic carrying plutonium can reach a critical configuration with only 370 g of plutonium. Stripping the fixative is prohibited by this CSER. If flaked off pieces are removed, containers no larger than a nominal ½ L are to be used as required in the process controls. If fixatives are to be removed, the process needs to be analyzed to establish criticality limits and process controls for that activity.

The basis for allowing operators to sweep and dust loose waste to a pile height of 5 cm (2 in.) is ARH-600 (Carter 1968) Figure III.A.5 (100) - 5. This data is included as Figure 5-3. When dry, a 5 cm thickness of waste material cannot go critical, unless there are pieces of plutonium metal or the plutonium powder is mixed with small pieces of plastic. These two conditions are not credible in this facility for the operations that are or were allowed. Removal of a plastic strippable paint that could mix residual plutonium with plastic moderator is not an allowed operation. The figure shows that criticality is not possible for an infinite 2-inch thick slab on a concrete floor with one inch of water on top for a plutonium density of less than 1000 g/L (1 g/cm^3). This figure assumes the plutonium is optimally mixed with water. Floor sweepings are assumed to always be far less than 1 g/cm^3 and to have other materials in the dust than plutonium so the mixture can not reach optimal water moderation. This figure shows that if water enters the cell and wets the sweepings on the floor, the pile cannot go critical. The figure assumes 0 wt % ^{240}Pu. Since plutonium is normally 5 or more wt % ^{240}Pu, this finding is another conservatism in the analysis.

The following data shows that the sizes of containers to be used for sampling liquid and silt are too small for a critical configuration to be possible. A 4.7 L container is allowed for a liquid sample. Figure 5-2 in this CSER shows that 8 kg of plutonium, fully water moderated and reflected is required for a critical configuration. The plutonium concentration has to be almost 2 g Pu/cm^3. Figure III.B.9(100)-2 from ARH-600 shows that ^{235}U would require more fissile mass and greater concentration than does plutonium. That liquid in C cell sump pit would have kilograms of fissile material when the NDA measurements have found less than four grams of plutonium per tank and similarly small amounts on the cell floors is considered incredible. This size sample could be critical only if filled with plutonium or uranium slurry. The 4.7-liter sample container is allowed for liquids only.

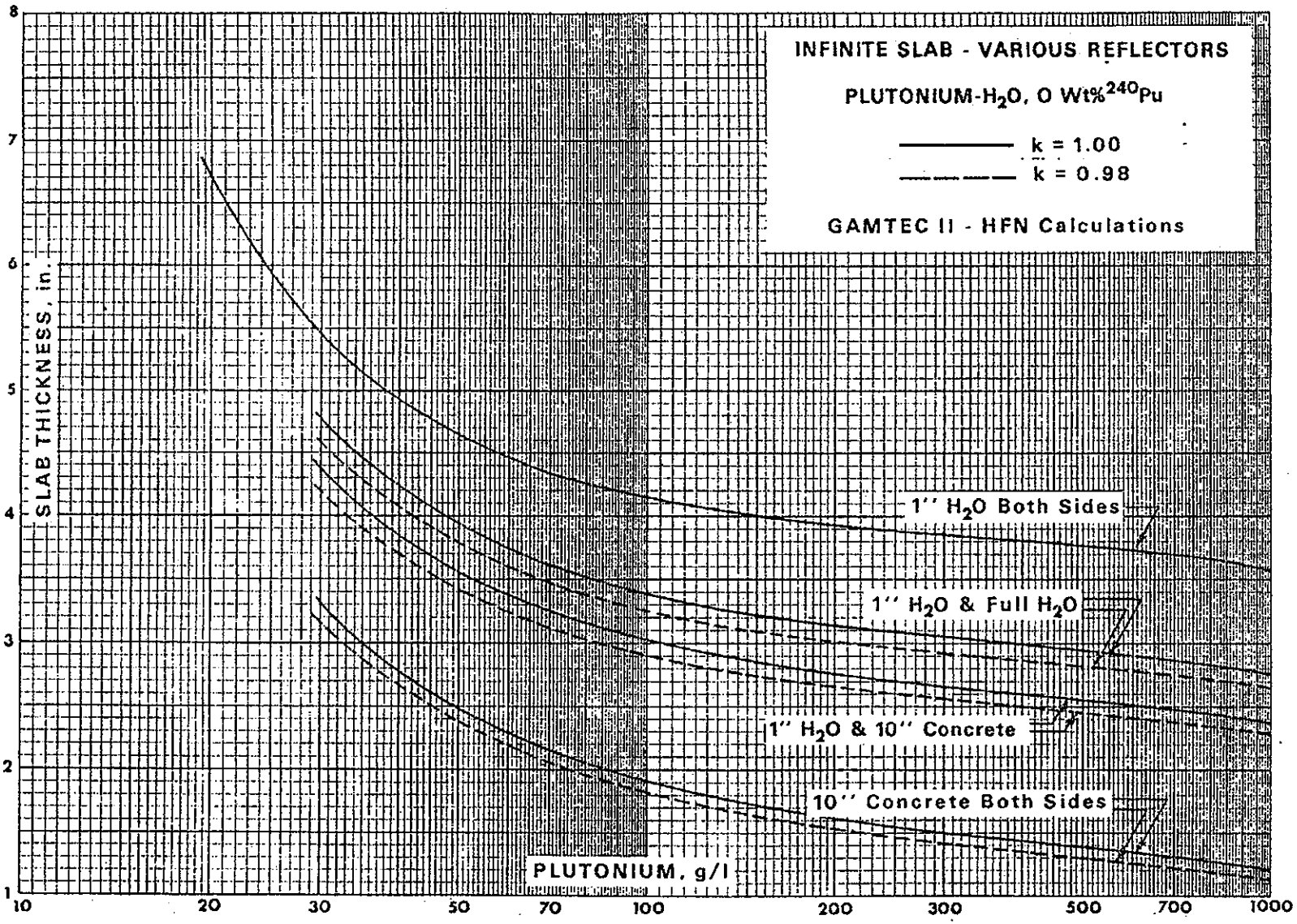


Figure 5-3. Critical Slab Thicknesses on Concrete Floors.

For sampling silt or slurries, the following container can be used. The volume of the container is limited to a half liter when the sample could be a slurry or silt. The same figures referenced in the paragraph above show that a critical configuration is not possible for uranium, even as metal, and that seven kilograms of plutonium is required for a critical configuration in a half-liter container. Using this size container makes a criticality for a sample of silt incredible.

Alternately, liquid samples could be taken in five-inch diameter, straight cylinders of any length. Figure III.A.4-1 of ARH-600 shows that for this shape a critical configuration requires a plutonium concentration of 1.8 g Pu/cm^3. This dense a plutonium water mixture is not a liquid, but a wet powder. Figure 8 from LA-12808 shows that ^{235}U has to have a concentration of 2.6 g U/cm^3 for a critical configuration in a five inch diameter container. It is incredible that using five inch diameter containers could hold a critical configuration because of the small amount of fissile material found in the facility and because liquid samples could not hold enough fissile material. Damp powders or denser fissile material is required for a critical configuration in a five-inch diameter container.

This CSER requires sampling of silt, if there is any in the sump pit, on a horizontal surface not to disturb more than a volume of five contiguous liters. This volume is a cube 6.7 inches on a side. This CSER has shown that eight kilograms of plutonium or 14 kilograms of uranium is required for a critical configuration in a five-liter volume. This presumes the fissile material is in a sphere mixed with water and fully water reflected. This is an incredible amount of fissile material given that less than 41 grams has been found in the tanks in all six cells by NDA. Also, the material has to be at a concentration of 2 g/cm^3. This concentration is not stirred up silt in water; it is a pile of silt. That five liters of silt could be piled up from sampling that is designed to avoid moving silt is also incredible.

The information on the cleanup of the cells in the 1950s said that the tanks had been rinsed to remove all but fixed residual fissile material. NDA analysis of all but nine out of twenty eight tanks conducted in 2001 showed that each tank had less than 12 grams of fissile material. Process knowledge and confirmatory measurements indicated that the entire facility does not have enough fissile material to form a critical configuration by a factor of about thirteen. Lack of a significant amount of fissile material is the first barrier to criticality. Operations would have to bring in kilogram quantities of fissile material to form a critical configuration. The operations are not allowed to bring in fissile material and do not use any fissile material in their operation except sources and fission monitors which have only small amounts fissile material that is well contained. Since no fissile material is moved, stored, or processed as part of the characterization activities, it could not be brought in accidentally as it could in a glovebox operation processing plutonium. The first contingency to reaching a potential critical configuration is that fissile material must be added to the facility. Discovering enough fissile material in the facility for a criticality is considered incredible.

The second contingency or barrier preventing a criticality is that fissile material must be assembled, if available, in the cells, moderated, and, to reduce the mass needed, reflected by operator action. The criticality safety limits and process controls on operations' activities prohibit actions that would increase reactivity. All containers and sampling operations are specified to make a possible critical configuration incredible for the material being handled. By

these controls, double contingency is established for characterizing the 224-T Cells when the fissile content has not been documented. Incredibility arguments for not requiring a criticality alarm system are summarized in Section 5.2 below. Note that no fissile material is to be added to the facility in any operation, except as a source or as a fission detector. So double batching and over batching are not a contingent event as they would be in a glovebox where fissile material is routinely brought into the glovebox.

The discovery that the sump pit in C cell has eleven feet of water means that fissile material in the pit is fully reflected and, if stirred up from a layer of particulate on the bottom of the pit into the water, could be optimally moderated. The first condition to meeting the double contingency criteria is that the cells have insignificant fissile material. The estimate that the cells do not contain significant amounts of fissile material is based on process knowledge and NDA results from the tanks in the cells. Although documentation for the fissile inventory of the cells was not available from the closeout of process activity in the cells, the available records and 2001 NDA characterization of the tanks are the basis for considering it incredible that significant fissile material is present in the sump pit. The second condition to establish double contingency is that sampling is limited to containers that could not hold a critical configuration for the material being sampled and is restricted to prevent agitating enough particulate on the pit floor to create a critical configuration.

Double contingency is to be maintained during water removal from the pit by using sample results to determine that the material being removed does not have more than 200 g of fissile material. After sampling the water in the sump pit has shown that the water and remainder of cell above the water has less than 450 g of fissile material, then the water can be removed by a process that does not agitate silt on the floor. The fissile mass in the uncharacterized tanks in the pit is not considered to affect water removal because removing water reduces reflection on the tanks.

When sampling silt from the floor demonstrates that the silt inventory is less than 200 g, then the remaining water and silt can be removed because the addition of fissile material is not credible. If sampling determined that the sump pit contains more than 450 grams of fissile material, specific analysis would be required for water and silt removal from the sump pit floor and the tanks in the sump pit.

The 224-T cells have dispersible dust that clouds the cell when making entries to survey equipment. For work to proceed, the dust needs to be vacuumed up. This dust is expected to be blown in dirt, but will be considered as any non-fissile material.

Figure 5-2 shows that for 100% ^{239}Pu, homogeneously mixed with water, and fully water reflected, the minimum critical mass is 530 g of plutonium. HNF-7098, *Criticality Safety Program*, allows a single item or an array of items if the item's or array's total fissile mass is 45% or less of the minimum critical mass. Multiplying the fraction 0.45 times the minimum critical mass of 530 g gives 238 g. A conservative mass limit of 200 grams based on a minimum critical mass allows a vacuum cleaner or vacuum collection unit of any volume. This minimum critical mass is for plutonium and water. The dust could have plastic, carbon, or most likely sand, silicon dioxide. A 200 g plutonium limit is safely subcritical for these and any other

materials that were used in the chemical process or that would blow into the cells in the last fifty years.

The above approach of setting the mass limit low does not require restrictions on the size of the vacuum or the dust to be vacuumed. The results of a preliminary survey of C Cell shows that the total amount of plutonium in the dust in C Cell is less than 10^{-4} grams of ^{239}Pu.

The criticality firefighting category is specified as C during characterization to prevent use of solid streams of water that could add large amounts of reflection and wash material into the drain tank in C cell. Fire Fighting Category C allows only low density foam and fog water nozzles. These foams and fogs are much less than a tenth of a percent water. They form a minimal reflector material. When a cell is characterized as having less than 450 g of fissionable material, the Fire Fighting Category can be A, which has no restrictions on fire fighting. This category is appropriate because water mixed with 450 g of plutonium cannot go critical.

5.2 BASIS FOR CHARACTERIZING PROCESS CELLS CONTAINING AN UNKNOWN AMOUNT OF FISSIONABLE MATERIAL WITHOUT A CAS

The DOE Orders 5480.24 and 420.1, one of which is applicable at Hanford, requires a Criticality Alarm System (CAS) unless the amount of fissionable material is less than 450 g or a criticality is not possible or the probability of a criticality less then 10^{-6}, beyond extremely unlikely. For the period of characterization when the fissionable inventory is being determined, this section shows that activities allowed by this CSER have an insignificant effect on the reactivity of any fissile material, so that a criticality is so improbable as to be considered impossible or beyond extremely unlikely. A criticality requires at least 521 g of plutonium in 18 L of water. But this mixture put in a tank at 224-T would spread out into a thin subcritical layer. Tens of kilograms of plutonium would be needed to make up a 3 or 4-inch thick layer of plutonium and water to be close to criticality. Hanford did not abandon that amount of plutonium in tanks in the 1950's. The probability that that much plutonium is in a tank is vanishingly small. The restricted approach distances for people and robots limits the increase of reflection for a tank in a concrete cell to insignificant levels. The probability that that change in reflection will be sufficient to bring about a criticality is considered vanishingly small. The combination of these two small probabilities justifies considering a criticality impossible or beyond extremely unlikely for the activities allowed by this CSER in the 224-T Process Cells.

Activities in the flooded sump pit in C cell are restricted to prevent an increase in reactivity by mixing silt and water or pilling up silt. Characterization activities are to be conducted to meet double contingency requirements to restrain accidental dropping of maintenance equipment into the silt or pilling up silt. This requirement and having to operate to procedures makes the probability that operations will increase the reactivity in the sump pit a small value. These restrictions and the improbability of significant amounts of fissile material, combine to make the probability of a criticality in the sump pit vanishingly small or beyond extremely unlikely.

5.3 BASIS FOR LIMITS OF PROCESS CELLS WITH LESS THAN 450 G OF FISSIONABLE MATERIAL

Section 5, *Single-Parameter Limits for Fissionable Nuclides*, of ANS Standard 8.1 (ANS 1998) specifies a single-parameter limit of 450 g for fissionable material with moderator and reflector no more reactive than water. The limits and process controls of this CSER limit the oils and other moderator and reflector materials allowed in the process cells to meet the conditions that make this single-parameter limit valid. The ANS standard limit is based on full water reflection. Personnel radiation shielding of plastic, lead, steel, and concrete can be more reflective than water. If the material is only tangent or not in contact with a tank and has a width less than half the diameter of a tank, its reflection would be much less than that of tight fitting water surrounding an object. ARH-600 (Carter 1978) shows in II.E-2 that the increase in reflector savings for water reaches an asymptote at a 6-inch thickness. The other listed materials may be more efficient, but never by a factor of two. Shielding thickness of 2-½ inches or less of these materials would be less reflective than the full water reflection allowed by the ANS standard.

HNF-7098 allows use of ANS standards for limiting Hanford operations.

HNF-7098 specifies the rules for determining how well the value of 450 g of fissile material is known or the amount of uncertainty to be added for a usable value. The basis for saying a process cell had less than 450 g fissionable material is to be peer reviewed and signed off by a qualified specialist.

5.4 BASIS FOR CHARACTERIZING PROCESS CELLS WITH LESS THAN 450 G OF FISSIONABLE MATERIAL WITHOUT A CAS

Section 3.2, *Coverage*, of ANS Standard 8.3 (ANS 1997) does not require a criticality alarm system for fissionable material/water systems with less than 450 g of fissionable material. This exemption is based on the fissionable material being ^{239}Pu or ^{235}U. The operating history only lists plutonium as processed in the cells so significant amounts of other more reactive isotopes would not be present. The limits of this CSER preclude significant quantities of more reactive moderators and reflectors that may be introduced into the cells to keep the system to a configuration that can be considered a fissionable material/water system. The concrete walls, floor, and ceiling of the cell are more reflective than water of the same thickness and configuration, but are not close enough to be as effective as close fitting, full water assumed in setting the single parameter limit. For plutonium, the exemption from a criticality alarm system applies if (1) uncontrolled transfer between areas can not occur, (2) there is at least a 10 cm spacing between material in separate cells, and (3) aerial density of fissionable material averaged over a cell is less than 50 g/m^2. The process cells are separated by an eight-inch thick concrete wall. The tanks are more than four feet, edge-to-edge, from the closest cell wall. The concrete wall prevents uncontrolled transfer between cells and control of admitted water controls transfer to C cell catch tanks. The wall and separation cover the 10 cm spacing requirement. The process cells floor area is larger than 58 m^2 (7.62 m (25 ft) on a side). A cell inventory of less than 450 g would have an aerial density of less than 7.8 g/m^2. The 224-T Building Process cells

meet the requirements of ANS Standard 8.3 (ANS 1997) to be exempted from having a criticality alarm system to monitor the activities with fissionable material.

5.5 224-T BUILDING CRITICALITY SAFETY CLASSIFICATION

The 224-T Building may be classified as an Isolated Facility if the total fissionable mass in all the process cells and other cells and galleries is less than 177 g of plutonium. The facility may be exempt from HNF-7098 requirement for a criticality safety program if the total inventory of fissionable material is less than 15 grams. However, this approach is not recommended during characterization phases for deactivated facilities. If fissionable material is found in quantities greater than 15 g during operations, the reporting of working with fissionable material without a criticality safety program would probably be more disruptive than the minimal effort to have a criticality program for an isolated facility. If the facility has more than 177 g of fissionable material, it may be classified as a Limited Control Facility. HNF-7098 spells out the requirements for a criticality safety program for each of these two conditions. An alternative is to make each area with fissionable material that would not transfer material to another area in an accident, classified according to how much fissionable material is present in that area.

6.0 REFERENCES

ANSI/ANS-8.1, 1998, *Nuclear Criticality Safety in Operations with Fissionable Material Outside Reactors*, American Nuclear Society, La Grange Park, Illinois.

ANSI/ANS-8.3, 1997, *Criticality Accident Alarm System*, American Nuclear Society, La Grange Park, Illinois.

Carter, R. D., 1998, *Criticality Handbook*, ARH-600, Atlantic Richfield Company, Richland, Washington.

Drawing HW-72939, *Arrangement & Piping, Cell "C" Sheet No. 1, BLDG No. 224-T-U-B.*

HNF-7098, 2001, *Criticality Safety Program*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

Paxton, H. C. and N. L. Provost, 1987 *Criticality Dimensions of Systems Containing* ^{235}U ^{239}Pu, *and* ^{233}U, *1986 Revision*, LA-10860-MS (UC-46), Los Alamos National Laboratory, Los Alamos, New Mexico.

Paxton, H. C. and N. L. Provost, 1996, *Nuclear Criticality Safety Guide*, LA-12808 (UC-714), Los Alamos National Laboratory, Los Alamos, New Mexico.

This page intentionally left blank.

APPENDIX A

INDEPENDENT REVIEW COMMENTS AND CHECKLIST

This page intentionally left blank.

Desk Instruction 2.0, Rev. 1

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed - HNF-7640, Rev. 3

Title: CSER 01-001: Remote Entry into Six Process Cells in 224-T Building for Characterization

Author: E. M. Miller

Date: August 2002

Yes	No*	NA		
[✓]	[ ]	[ ]		Referenced analyses appropriate.
[✓]	[ ]	[ ]		Problem completely defined and all potential configurations considered.
[✓]	[ ]	[ ]		Accident scenarios developed in a clear and logical manner.
[✓]	[ ]	[ ]		Necessary assumptions explicitly stated and supported.
[ ]	[ ]	[✓]		Computer codes and data files documented.
[ ]	[ ]	[✓]		Data used in calculations explicitly stated in document.
[ ]	[ ]	[✓]		Data checked for consistency with original source information as applicable.
[✓]	[ ]	[ ]		Mathematical derivations checked including dimensional consistency of results
[✓]	[ ]	[ ]		Models appropriate and used within range of validity, or use outside range of established validity justified.
[✓]	[ ]	[ ]		Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[ ]	[ ]	[✓]		Software input correct and consistent with document reviewed.
[ ]	[ ]	[✓]		Software output consistent with input and with results reported in document reviewed.
[✓]	[ ]	[ ]		Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[✓]	[ ]	[ ]		Safety margins consistent with good engineering practices.
[✓]	[ ]	[ ]		Conclusions consistent with analytical results and applicable limits.
[✓]	[ ]	[ ]		Results and conclusions address all points required in the problem statement.
[✓]	[ ]	[ ]		Format consistent with applicable guides or other standards.
[✓]	[ ]	[ ]	**	Review calculations, comments, and/or notes are attached.
[✓]	[ ]	[ ]		Document approved (for example, the reviewer affirms the technical accuracy of the document). The original review comments made on 1/25/01 remain valid, as this is a minor revision including site measurements.

K. N. Schwinkendorf K. N. Schwinkendorf 9/5/02

Technical Peer Reviewer (printed name and signature) Date

* All "no" responses must be explained below or on an additional sheet.

** Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. The material should be labeled and recorded in such a manner as to be understandable to a technically qualified third party.

Review Comments from K. N. Schwinkendorf - 1/25/2001

This CSER was independently peer reviewed by K. N. Schwinkendorf, a qualified Criticality Safety Specialist in the Criticality and Shielding group of Fluor Federal Services. This technical review covered all aspects of this CSER. As shown in the Independent Review Checklist, this CSER was reviewed with no gaps.

Several comparisons were made in this CSER to handbook graphs of cylinder interaction. These figures were used as a basis to support the assertion that the presence of a person (a reflecting cylinder) would have an insignificant effect on the system k_{eff} of large tanks containing dilute quantities of fissile material. Intuitively, this argument makes sense. The concrete walls, even though they are several feet away from fissile-bearing tanks, would be expected to mimic close reflection. They nearly surround the tanks (the solid angle is large), and they have a low absorption cross section (lower than water). Hence, neutrons that leak out of a tank have a relatively high probability of eventually scattering back into the fissile-bearing tank. Several comparison calculations were performed using MCNP4B to quantify this hypothesis. In these models, a 4-ft diameter by 4-ft high tank filled with 7 gPu/L solution was placed into a cubicle 30 ft square by 15 ft high. Concrete walls 8 inches thick and a concrete floor 4 inches thick were included. A water cylinder (i.e., "phantom"), representing a person, was placed at various distances from the fissile tank. A second series of calculations replaced the water phantom with another tank of 7 gPu/L solution (see Table 1). Neither partial solid angle reflection by water nor fissile interaction had a significant effect on the k_{eff} of the system. The presence of a person anywhere in the room is thus expected to have a negligible neutronic effect, and it is judged to be incredible for this person to directly cause a criticality. For comparison, several water phantom cases were rerun without the concrete wall reflection. These results are contained in Table 2. The k_∞ of the fissile solution is 0.98866 ± 0.00024.

Finally, editorial comments received in the round table discussion and elsewhere were incorporated, and this CSER is approved.

Table 1. MCNP4B Test Cases with Concrete Wall Reflection.

Case description	Water phantom	Second Fissile Tank
no second body, just tank	k_{eff} = 0.93933 ± 0.00042	-----
10 ft edge-to-edge separation	k_{eff} = 0.93763 ± 0.00046	k_{eff} = 0.93753 ± 0.00048
3 ft edge-to-edge separation	k_{eff} = 0.93983 ± 0.00045	k_{eff} = 0.93849 ± 0.00049
2 ft edge-to-edge separation	k_{eff} = 0.93974 ± 0.00044	k_{eff} = 0.93916 ± 0.00047
1 ft edge-to-edge separation	k_{eff} = 0.93954 ± 0.00046	k_{eff} = 0.93765 ± 0.00045

Table 2. MCNP4B Test Cases without Concrete Wall Reflection.

Case description	Water phantom
no second body, just tank	k_{eff} = 0.93615 ± 0.00049
10 ft edge-to-edge separation	k_{eff} = 0.93832 ± 0.00047
3 ft edge-to-edge separation	k_{eff} = 0.93732 ± 0.00043
2 ft edge-to-edge separation	k_{eff} = 0.93875 ± 0.00046
1 ft edge-to-edge separation	k_{eff} = 0.93928 ± 0.00044
touching	k_{eff} = 0.93805 ± 0.00044

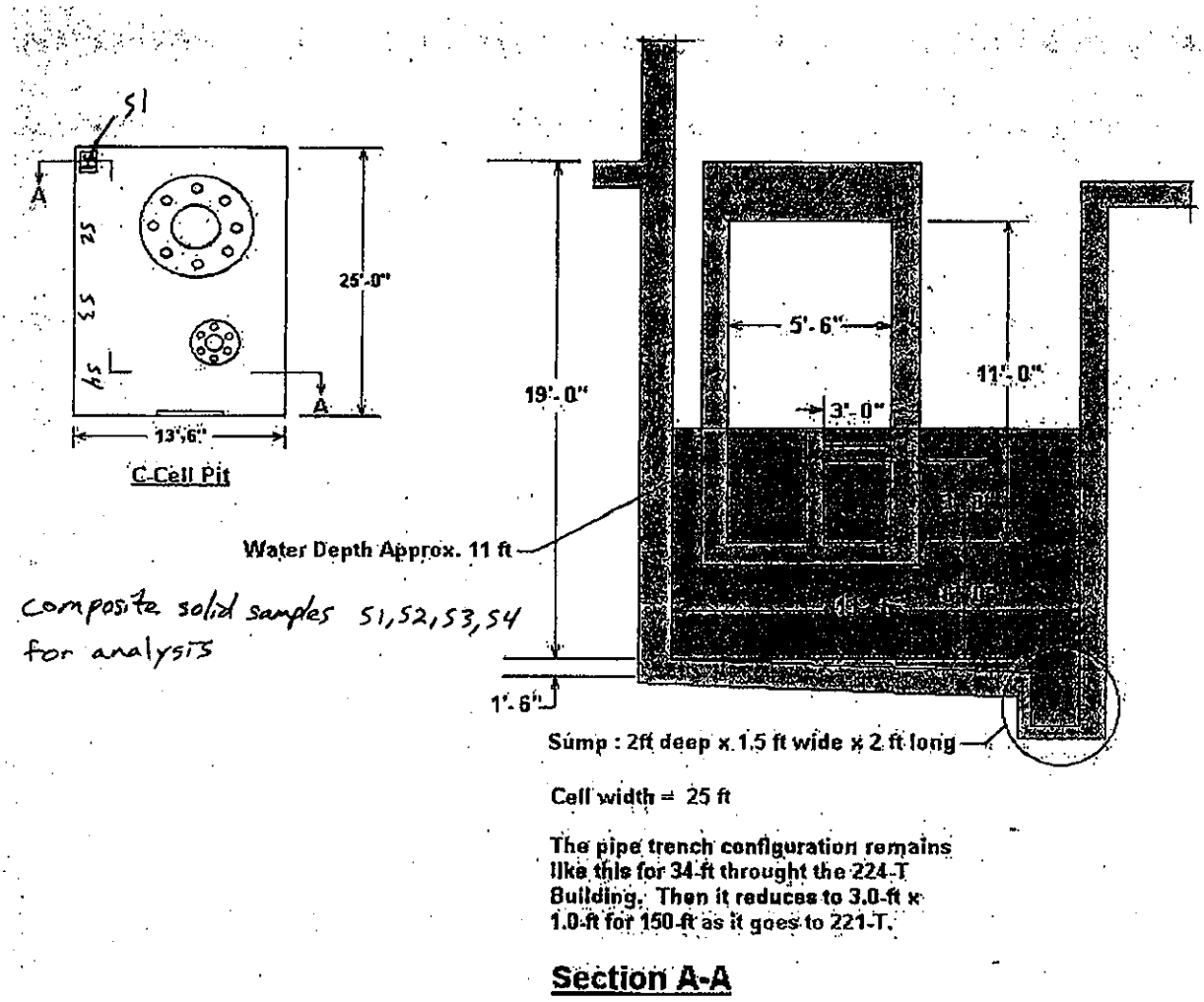
This page intentionally left blank.

APPENDIX B

C-CELL PIT WATER AND SILT SAMPLE DATA

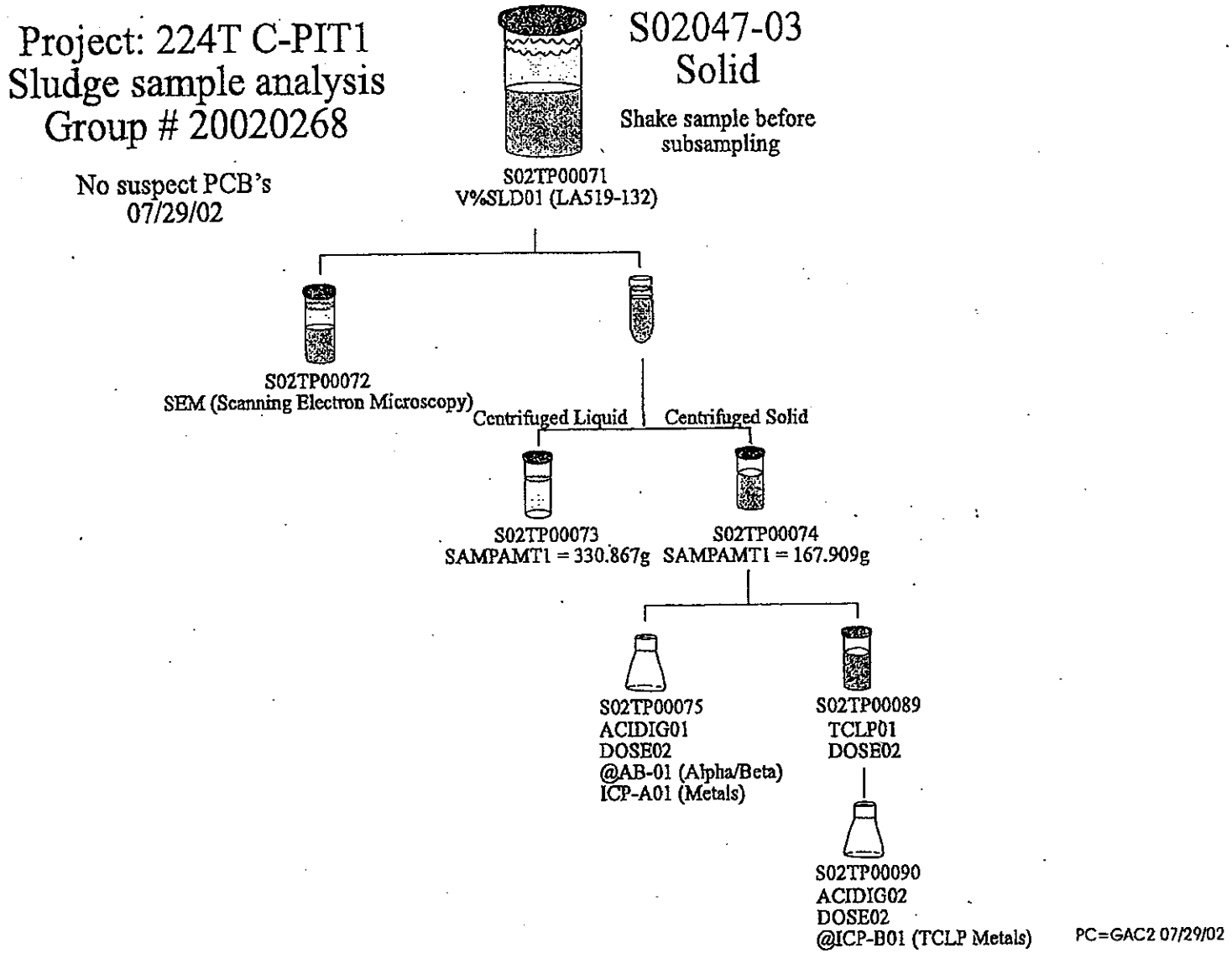
This page intentionally left blank

B-1 Four Silt Sample Locations



224-T Building C-Cell Pit

B-2 Silt Sample Analysis Process



B-3 Silt Sample Analysis

FINAL REPORT FOR 224T C-PIT1 SAMPLE

Customer ID#	Sample Portion	Lab ID#	A#	Analyte	Unit	Standard %	Blank	Result	Duplicate	Average	RPD %	Spk Rec %	Det Limit	Count Err
S02047-03	Parent	S02TP00071		Volume % Centrifuged Solids	%	n/a	n/a	50	n/a	n/a	n/a	n/a	n/a	n/a
S02047-03	SEM	S02TP00072		Scanning Electron Microscope		n/a	n/a	complete	n/a	n/a	n/a	n/a	0.1	n/a
S02047-03	Centrifuged Liquid	S02TP00073		Amount of Sam/Present/holcell	g	n/a	n/a	331	n/a	n/a	n/a	n/a	n/a	n/a
S02047-03	Centrifuged Solid	S02TP00074		Amount of Sam/Present/holcell	g	n/a	n/a	166	n/a	n/a	n/a	n/a	n/a	n/a

Customer ID#	Sample Portion	Lab ID#	A#	Analyte	Unit	Standard %	Blank	Result	Duplicate	Average	RPD %	Spk Rec %	Det Limit	Count Err %
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Acid Digest for ICP/AA/Radchem	g/L	100	1	5.18	n/a	n/a	n/a	n/a	0.01	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075		Dose Rate(samp prep)in mrem/hr	mrem/hr	n/a	n/a	<.5	n/a	n/a	n/a	n/a	0.1	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Silver -ICP-Acid Digest	ug/g	94.5	<0.0100	<1.94	<1.94	n/a	n/a	82.1	1.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Aluminium -ICP-Acid Digest	ug/g	100	<0.0500	3.92E+03	3.97E+03	3.95E+03	1.23	201	9.7	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Arsenic -ICP-Acid Digest	ug/g	110	<0.100	<19.4	<19.4	n/a	n/a	101	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Boron -ICP-Acid Digest	ug/g	91.3	<0.0500	<9.70	<9.70	n/a	n/a	84.5	9.7	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Barium -ICP-Acid Digest	ug/g	96.6	<0.0500	96.1	97.3	96.7	1.17	86.4	9.7	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Beryllium -ICP-Acid Digest	ug/g	97.1	<5.00e-03	<0.970	<0.970	n/a	n/a	87.2	0.97	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Bismuth -ICP-Acid Digest	ug/g	92.5	<0.100	46.7	46	47.4	2.58	82.1	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Calcium -ICP-Acid Digest	ug/g	104	<0.100	9.51E+03	9.62E+03	9.56E+03	1.15	283	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Cadmium -ICP-Acid Digest	ug/g	91.6	<5.00e-03	<0.970	1	n/a	n/a	81.4	0.97	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Cerium -ICP-Acid Digest	ug/g	96.6	<0.100	<19.4	<19.4	n/a	n/a	87.6	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Cobalt -ICP-Acid Digest	ug/g	94	<0.0200	8.2	7.08	7.64	14.6	83.4	3.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Chromium -ICP-Acid Digest	ug/g	95.8	<0.0100	9.03E+03	9.09E+03	9.06E+03	0.657	81.7	1.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Copper -ICP-Acid Digest	ug/g	96.4	<0.0100	72.6	73.5	73	1.21	86.5	1.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Europium ICP-Acid Digest	ug/g	103	<0.100	<19.4	<19.4	n/a	n/a	95.9	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Iron -ICP-Acid Digest	ug/g	95.1	<0.0500	3.29E+04	3.33E+04	3.31E+04	0.955	53	9.7	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Potassium -ICP-Acid Digest	ug/g	93.1	<0.500	1.13E+03	1.11E+03	1.12E+03	1.51	96.5	97	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Lanthanum -ICP-Acid Digest	ug/g	96	<0.0500	<9.70	<9.70	n/a	n/a	87.7	9.7	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Lithium -ICP-Acid Digest	ug/g	98.6	<0.0100	<1.94	<1.94	n/a	n/a	87.7	1.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Magnesium -ICP-Acid Digest	ug/g	92.2	<0.100	518	522	520	0.747	103	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Manganese -ICP-Acid Digest	ug/g	92.4	<0.0100	235	238	237	1.19	83.8	1.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Molybdenum -ICP-Acid Digest	ug/g	96.1	<0.0500	<9.70	<9.70	n/a	n/a	88.8	9.7	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Sodium -ICP-Acid Digest	ug/g	102	0.341	5.11E+03	5.22E+03	5.16E+03	2.01	119	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Neodymium -ICP-Acid Digest	ug/g	98.3	<0.100	<19.4	<19.4	n/a	n/a	91.2	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Nickel -ICP-Acid Digest	ug/g	94.3	<0.0200	150	151	151	0.605	89.4	3.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Phosphorus -ICP-Acid Digest	ug/g	93.2	<0.200	8.28E+03	8.36E+03	8.32E+03	0.788	101	39	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Lead -ICP-Acid Digest	ug/g	90.7	<0.100	99.3	100	99.8	1.02	81.3	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Sulfur -ICP-Acid Digest	ug/g	94.1	<0.100	9.18E+03	9.28E+03	9.23E+03	0.994	213	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Antimony -ICP-Acid Digest	ug/g	91.5	<0.0600	<11.6	<11.6	n/a	n/a	85.9	12	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Selenium -ICP-Acid Digest	ug/g	94.9	<0.100	<19.4	<19.4	n/a	n/a	81.1	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Silicon -ICP-Acid Digest	ug/g	45	<0.0500	1.26E+03	1.27E+03	1.26E+03	0.793	298	9.7	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Samarium -ICP-Acid Digest	ug/g	99.8	<0.100	<19.4	<19.4	n/a	n/a	92.3	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Strontium -ICP-Acid Digest	ug/g	96.9	<0.0100	41.4	41.9	41.6	1.2	86.5	1.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Thorium -ICP-Acid Digest	ug/g	97.1	<0.100	<19.4	<19.4	n/a	n/a	88.9	19	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Titanium-ICP-Acid Digest	ug/g	95	<0.0100	173	174	174	0.968	94	1.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Thallium -ICP-Acid Digest	ug/g	n/a	<0.200	<38.8	<38.8	n/a	n/a	n/a	39	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Uranium -ICP-Acid Digest	ug/g	91.4	<0.250	<48.5	<48.5	n/a	n/a	87.7	48	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Vanadium -ICP-Acid Digest	ug/g	97.1	<0.0500	<9.70	<9.70	n/a	n/a	85.1	9.7	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Yttrium -ICP-Acid Digest	ug/g	104	<0.0100	<1.94	<1.94	n/a	n/a	96.4	1.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Zinc -ICP-Acid Digest	ug/g	88.7	<0.0100	247	249	248	0.929	80.5	1.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Zirconium -ICP-Acid Digest	ug/g	97.1	<0.0100	<1.94	<1.94	n/a	n/a	88.6	1.9	n/a
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Alpha of Digested Solid	uCi/g	100	<8.01e-05	0.105	n/a	n/a	n/a	109	9.70E-05	1.9
S02047-03	Acid Digest/Total Metals	S02TP00075	A	Beta of Solid Sample	uCi/g	106	<2.78e-04	0.0226	n/a	n/a	n/a	107	5.00E-04	3.6

FINAL REPORT FOR 224T C-PIT1 SAMPLE

Customer ID#	Sample Portion	Lab ID#	A#	Analyte	Unit	Standard %	Blank	Result	Duplicate	Average	RPD %	Spk Rec %	Det Limit	Count Err
S02047-03	TCLP DIGEST	S02TP00089		Dose Rate(samp prep)in mrem/hr	mrem/hr	n/a	n/a	<.5	n/a	n/a	n/a	n/a	0.1	n/a
S02047-03	TCLP DIGEST	S02TP00089	T	TOXICICTY LEACHING PROCED	DF	n/a	n/a	complete	n/a	n/a	n/a	n/a	0.01	n/a

Customer ID#	Sample Portion	Lab ID#	A#	Analyte	Unit	Standard %	Blank	Result	Duplicate	Average	RPD %	Spk Rec %	Det Limit	Count Err
S02047-03	TCLP/METALS	S02TP00090	B	Acid Digest for ICP/AA/Radchem	DF	n/a	1	5	5	5	0	1	0.01	n/a
S02047-03	TCLP/METALS	S02TP00090		Dose Rate(samp prep)in mrem/hr	mrem/hr	n/a	n/a	<.5	n/a	n/a	n/a	n/a	0.1	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Silver -ICP-Acid Digest-Liquid	ug/mL	99.2	<0.0100	<0.0500	<0.0500	n/a	n/a	96.2	0.05	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Aluminium -ICP-Acid Digest-Liq	ug/mL	103	<0.0500	1.98	1.99	1.99	0.514	101	0.25	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Arsenic -ICP-Acid Digest-Liq	ug/mL	116	<0.100	<0.500	<0.500	n/a	n/a	114	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Boron -ICP-Acid Digest-Liquid	ug/mL	95	<0.0500	<0.250	<0.250	n/a	n/a	94.6	0.25	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Barium -ICP-Acid Digest-Liquid	ug/mL	97.4	<0.0500	<0.250	<0.250	n/a	n/a	95	0.25	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Beryllium -ICP-Acid Digest/Liq	ug/mL	98.5	<5.00e-03	<0.0250	<0.0250	n/a	n/a	95.8	0.025	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Bismuth -ICP-Acid Digest/Liq	ug/mL	97.6	<0.100	<0.500	<0.500	n/a	n/a	96.6	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Calcium -ICP-Acid Digest-Liq	ug/mL	108	<0.100	394	411	403	4.07	107	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Cadmium -ICP-Acid Digest-Liq	ug/mL	98.9	<5.00e-03	<0.0250	<0.0250	n/a	n/a	93.7	0.025	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Cerium -ICP-Acid Digest-Liq	ug/mL	96.7	<0.100	<0.500	<0.500	n/a	n/a	n/a	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Cobalt -ICP-Acid Digest-Liq	ug/mL	98.1	<0.0200	<0.100	<0.100	n/a	n/a	94.8	0.1	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Chromium -ICP-Acid Digest-Liq	ug/mL	98.3	<0.0100	0.144	0.148	0.146	2.51	94.9	0.05	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Copper -ICP-Acid Digest-Liquid	ug/mL	98.9	<0.0100	<0.0500	<0.0500	n/a	n/a	96.1	0.05	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Europium ICP-Acid Digest-Liq	ug/mL	89.4	<0.100	<0.500	<0.500	n/a	n/a	n/a	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Iron -ICP-Acid Digest-Liquid	ug/mL	96.4	<0.0500	4.77	4.96	4.87	4.32	93	0.25	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Potassium -ICP-Acid Digest-Liq	ug/mL	97.6	<0.500	24.5	23.7	24.1	3.34	89.5	2.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Lanthanum -ICP-Acid Digest-Liq	ug/mL	97.9	<0.0500	<0.250	<0.250	n/a	n/a	94.4	0.25	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Lithium -ICP-Acid Digest-Liq	ug/mL	97.9	<0.0100	<0.0500	<0.0500	n/a	n/a	95.1	0.05	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Magnesium -ICP-Acid Digest-Liq	ug/mL	97	<0.100	9.17	9.63	9.4	4.93	94.8	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Manganese -ICP-Acid Digest-Liq	ug/mL	95	<0.0100	6.58	6.87	6.73	4.37	93	0.05	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Molybdenum-ICP-Acid Digest-Liq	ug/mL	98.5	<0.0500	<0.250	<0.250	n/a	n/a	96.6	0.25	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Sodium -ICP-Acid Digest-Liquid	ug/mL	99.6	<0.100	828	870	849	4.85	143	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Neodymium -ICP-Acid Digest-Liq	ug/mL	97.8	<0.100	<0.500	<0.500	n/a	n/a	n/a	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Nickel -ICP-Acid Digest-Liquid	ug/mL	97.8	<0.0200	1.9	1.97	1.94	3.6	94.5	0.1	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Phosphorus-ICP-Acid Adjust-Liq	ug/mL	96.4	<0.200	<1.00	<1.00	n/a	n/a	99.4	1	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Lead -ICP-Acid Digest-Liquid	ug/mL	97.4	<0.100	<0.500	<0.500	n/a	n/a	95.1	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Sulfur -ICP-Acid Digest-Liquid	ug/mL	98.2	<0.100	416	438	427	4.96	115	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Antimony -ICP-Acid Digest-Liq	ug/mL	97.1	<0.0600	<0.300	<0.300	n/a	n/a	96.6	0.3	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Selenium -ICP-Acid Digest-Liq	ug/mL	98	<0.100	0.714	0.612	0.663	15.4	98	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Silicon -ICP-Acid Digest-Liq	ug/mL	34	<0.0500	13.4	14	13.7	4.71	62.6	0.25	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Samarium -ICP-Acid Digest-Liq	ug/mL	99.5	<0.100	<0.500	<0.500	n/a	n/a	n/a	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Strontium -ICP-Acid Digest-Liq	ug/mL	96.8	<0.0100	0.67	0.702	0.686	4.71	93.4	0.05	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Thorium -ICP-Acid Digestion	ug/mL	99.6	<0.100	<0.500	<0.500	n/a	n/a	n/a	0.5	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Titanium-ICP-Acid Digest-Liq	ug/mL	95.7	<0.0100	<0.0500	<0.0500	n/a	n/a	93.3	0.05	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Thallium -ICP-Acid Digest-Liq	ug/mL	n/a	<0.200	<1.00	<1.00	n/a	n/a	n/a	1	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Uranium -ICP-Acid Digest-Liq	ug/mL	89.4	<0.250	<1.25	<1.25	n/a	n/a	n/a	1.2	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Vanadium -ICP-Acid Digest-Liq	ug/mL	98.8	<0.0500	<0.250	<0.250	n/a	n/a	96.1	0.25	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Yttrium -ICP-Acid Digestion	ug/mL	94.3	<0.0100	<0.0500	<0.0500	n/a	n/a	n/a	0.05	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Zinc -ICP-Acid Digest-Liquid	ug/mL	95	<0.0100	2.41	2.51	2.46	4.08	93	0.05	n/a
S02047-03	TCLP/METALS	S02TP00090	B	Zirconium -ICP-Acid Digest-Liq	ug/mL	97.6	<0.0100	<0.0500	<0.0500	n/a	n/a	95.1	0.05	n/a

RT Steele
373-2951

WSCF
ANALYTICAL RESULTS REPORT

for

River Corridor

Hanford WA 99352

Attention: ED HAM S4-49

Report#: 20020306
Report Date: 18-mar-2002
Report W004/ver. 4.5
River Corridor

WSCF
ANALYTICAL RESULTS REPORT

Attention: ED HAM S4-49
Project: MISC: MISC

Group #: 20020306

Sample #	Client ID		Test Performed	Matrix	WSCF Method	RQ	Result	Units	MDL	Analyzed	Sampled	Received
W020000136	4T-W-001	HAM	Conductivity	WATER	LA-519-401		695.	uS/cm	0.49	03/07/02	03/06/02	03/05/02
W020000136	4T-W-001	HAM	pH Direct Measurement	WATER	LA-212-402		7.834	pH	0.01	03/07/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Ce-144 Rel.% Count Error (GEA)	WATER	LA-508-481		82.7	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Ce-144 by GEA	WATER	LA-508-481	U	3.58e+01	pCi/L	50.70	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	CePr-144 Rel.% Count Error	WATER	LA-508-481		82.7	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	CePr-144 by GEA	WATER	LA-508-481	U	7.16e+01	pCi/L	1.01e+002	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Co-60 Rel.% Count Error (GEA)	WATER	LA-508-481		193.	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Co-60 by GEA	WATER	LA-508-481	U	-1.99e+00	pCi/L	6.65	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Cs-134 Rel.% Count Error (GEA)	WATER	LA-508-481		173.	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Cs-134 by GEA	WATER	LA-508-481	U	-2.51e+00	pCi/L	7.31	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Cs-137 Rel.% Count Error (GEA)	WATER	LA-508-481		293.	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Cs-137 by GEA	WATER	LA-508-481	U	-1.46e+00	pCi/L	7.43	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Eu-152 Rel.% Count Error (GEA)	WATER	LA-508-481		168.	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Eu-152 by GEA	WATER	LA-508-481	U	8.22e+00	pCi/L	23.40	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Eu-154 Rel.% Count Error (GEA)	WATER	LA-508-481		822.	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Eu-154 by GEA	WATER	LA-508-481	U	1.63e+00	pCi/L	20.30	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Eu-155 Rel.% Count Error (GEA)	WATER	LA-508-481		114.	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Eu-155 by GEA	WATER	LA-508-481	U	-1.27e+01	pCi/L	22.90	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Nb-94 Rel.% Count Error (GEA)	WATER	LA-508-481		398.	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Nb-94 by GEA	WATER	LA-508-481	U	-1.03e+00	pCi/L	7.09	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Ru-103 Rel.% Count Error (GEA)	WATER	LA-508-481		160.	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Ru-103 by GEA	WATER	LA-508-481	U	2.66e+00	pCi/L	7.44	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Ru-106 Rel.% Count Error (GEA)	WATER	LA-508-481		385.	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Ru-106 by GEA	WATER	LA-508-481	U	9.90e+00	pCi/L	68.30	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Sb-125 Rel.% Count Error (GEA)	WATER	LA-508-481		626.	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Sb-125 by GEA	WATER	LA-508-481	U	1.97e+00	pCi/L	21.20	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Sn-113 Rel.% Count Error (GEA)	WATER	LA-508-481		230.	%	0.00	03/06/02	03/05/02	03/05/02

MDL=Minimum Detection Limit
RQ=Result Qualifier

B - The analyte was detected in the associated method blank.
E - Compound concentration exceeded calibration range.
N - Identification is based on a mass spectral library search.
D - Compound concentration resulted from a dilution.
J - Estimated value. Z - See Comments.
U - The analyte was analyzed for but not detected.

* - indicates results that have NOT been validated; + - indicates more than six qualifier symbols

Report W004/ver. 4.5
River Corridor

WSCF
ANALYTICAL RESULTS REPORT

Attention: ED HAM S4-49
Project: MISC: MISC

Group #: 20020306

Sample #	Client ID		Test Performed	Matrix	WSCF Method	RQ	Result	Units	MDL	Analyzed	Sampled	Received
W020000136	4T-W-001	HAM	Sn-113 by GEA	WATER	LA-508-481	U	-2.50e+00	pCi/L	9.56	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Zn-65 Rel.% Count Error (GEA)	WATER	LA-508-481		204.	%	0.00	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Zn-65 by GEA	WATER	LA-508-481	U	4.88e+00	pCi/L	15.60	03/06/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Gross Beta	WATER	LA-508-415		5.8e+01	pCi/L	1.20	03/08/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Gross Beta % Method Error	WATER	LA-508-415		11	%	0.00	03/08/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Total Alpha	WATER	LA-508-415		4.3e+02	pCi/L	1.40	03/08/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Total Alpha % Method Error	WATER	LA-508-415		10	%	0.00	03/08/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Arsenic by ICP-MS	WATER	LA-505-412	U	< 0.375	ug/L	0.38	03/14/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Barium by ICP-MS	WATER	LA-505-412		4.59	ug/L	0.25	03/14/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Cadmium by ICP-MS	WATER	LA-505-412		0.176	ug/L	0.12	03/14/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Chromium by ICP-MS	WATER	LA-505-412		0.747	ug/L	0.38	03/14/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Lead by ICP-MS	WATER	LA-505-412	U	< 1.50	ug/L	1.50	03/14/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Mercury by ICP-MS	WATER	LA-505-412	U	< 0.125	ug/L	0.12	03/14/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Selenium by ICP-MS	WATER	LA-505-412		0.681	ug/L	0.38	03/14/02	03/05/02	03/05/02
W020000136	4T-W-001	HAM	Silver by ICP-MS	WATER	LA-505-412	U	< 0.250	ug/L	0.25	03/14/02	03/05/02	03/05/02

MDL=Minimum Detection Limit
RQ=Result Qualifier

B - The analyte was detected in the associated method blank.
E - Compound concentration exceeded calibration range.
N - Identification is based on a mass spectral library search.
D - Compound concentration resulted from a dilution.
J - Estimated value.
Z - See Comments.
U - The analyte was analyzed for but not detected.

* - Indicates results that have NOT been validated; + - Indicates more than six qualifier symbols

Report W004/ver. 4.5
River Corridor

This page intentionally left blank.

APPENDIX C

ISOLATION FROM T PLANT

This page intentionally left blank.

-----Original Message-----

From: Brim, Fredrick S (Scott)
Sent: Tuesday, December 18, 2001 4:55 PM
To: Giamberardini, Steven J
Cc: Levinskas, David; Ayers, William S (Bill); Chronister, Glen B; Barmettlor, R B (Bob); Barnes, Brett M; Conners, Daniel A IV; Elliott, Scott D; McGuffey, Joyce C
Subject: Water in 224T Cell "C": Results of T Plant Investigation

Steve:

This note concerns the discovery of approximately 11 feet of standing water in Cell "C" in 224T, and describes the activity of T Plant personnel in investigating of the possibility that T Plant might be the source of this water, via a pipe trench that runs between T Plant cells in Sections 17/19 and 224T Cell "C".

Per the request made by FH River Corridor this morning to Joyce McGuffy, T Plant Operations, T Plant Engineering has examined existing documentation for the process cells in 221T Canyon Sections 17 an 19. We have examined both the engineering documentation, and also cell inventory notes and pictures that were made in 1986 and in April, 2001.

We believe it is highly unlikely that T Plant is the source of this water, for the following reasons:

-- Decontamination operations involving the use of substantial amounts of water have not been employed in the 221T Canyon since 1992, and all wet decontamination in the 221T Canyon was terminated in 1995. The water that was used in these operations was captured by the T Plant waste water collection systems, and there is little possibility, and no evidence, that substantial and uncontained quantities of fluid have previously been present in the cells located in Sections 17 and 19.

-- The T-Plant to 224T pipe trench openings in T Plant Sections 17 and 19 are located approximately 12 feet above the cell floor. Fluid would have to fill these cells up to a level of at least 12 feet for any substantial spillover to enter the pipe trench. There is no physical indication that such levels have been present in these cells at any time in the past fifteen years.

-- Neither of the cell inventories performed in 1986 or in April 2001 indicates the presence of water (or indeed any other kind of fluid) on the floors of cells located in Sections 17 and 19. In addition, the process pipe jumpers are capped off or are otherwise disconnected from any source of water or fluid.

Our T Plant ECO, Brett Barnes, suggests the possibility that the source of the water now contained in Cell "C" might be rain and snowmelt leakage from the 224T roof. A search of documents in RMIS that reference 224T cells reveals the following letter of correspondence numbered 9552285 (RMIS Accession # 295134434) titled 224-T PROCESS CELLS, dated May 3rd 1995. This letter contains an attachment in which the history of 224T is discussed. Among various other topics, the last page of the attachment contains these two bulleted items:

"A former Hanford employee remembers reading a liquid level on a tank or in a large pit in C cell. This former employee stated that this reading was the result of a roof leak, but is not sure how accurate his memory is."

"A former Hanford employee stated that an entry was made in 1986. It was noted that a liquid level reading of 2 feet was observed in the C Cell pit. It appeared to be rainwater or snowmelt. All other cells drain to C Cell pit."

Once again, T Plant Engineering believes that it is very unlikely that the water now contained in 224T Cell "C" comes from any T Plant source.

If we can be of any further assistance to you in this matter, please let us know.

Scott Brim
T Plant Engineering
271T / Rm202 / 200W
373-7327

This page intentionally left blank.

APPENDIX D

CORRECTION TO NDA FOR WATER IN TANKS

This page intentionally left blank.

POLESTAR
APPLIED TECHNOLOGY, INC

April 4, 2002

Mr. Glen Chronister
Manager 200 Area Surplus Facilities
Fluor Hanford, Inc.
PO Box 1000, MS S4-49
Richland, Washington 99352

Dear Mr. Chronister:

Attached please find a Polestar memo detailing the calculation method for estimating the correction factors to be applied to measurements of plutonium deposits in tanks, if an overlying layer of water is present. These correction factors were obtained with MicroShield MS-5, a commercially available shielding code.

Please note that because of the source-detector geometry used in the measurements, only water depths up to about four inches contribute significantly to the correction factors.

The results obtained indicate that even for the lowest energy gamma ray used in the measurements (0.129 Mev), the largest correction factor (if there were at least 4 in. water present) is approximately 25, i.e., the true amount of plutonium in the tank is no greater than 25 times the amount inferred from the measurement at that energy.

We assume that the inferred Pu values at each gamma ray energy have been somehow averaged to get a final measured value. If so, the overall corrected value would be gotten by correcting the individual measured values at each energy by the factors in Table 1 of the memo, and then averaging.

If you have any further questions about this study, please do not hesitate to contact Rudy Sher at the number below or by email: rsher@polestar.com.

Yours truly,

Martin W. Ellis
Manager, Richland Operations

attachment

601 WILLIAMS BOULEVARD - SUITE 2A - RICHLAND - WASHINGTON - 99352 - USA - (509) 946-8279 - FAX 946-8889

Polestar Applied Technology, Inc.
R. Sher

04/04/02

Effect of overlying water on plutonium determination in a tank.

Plutonium deposits on the bottom of a tank are measured by detecting gamma rays from Pu-239 with a high resolution Ge-Li detector, located externally to the tank. Typical amounts of measured Pu are in the range of several grams or less. In some tanks there is a possibility that an unknown amount of water is present, overlying the Pu deposit, and the problem is: what is the effect of this water on the measurement of the Pu?

The geometry of the tank and detector is shown in Figure 1. From the figure it is apparent that the line-of-sight from an area element furthest from the side of the tank that the detector faces to the detector passes through that side at a height of about 0.35 ft (~ 4 in). Water above that height will not affect the measurement (except for minor scattering effects), so that only water heights below that value have to be considered. In other words, whatever the correction factor is at a water height of 0.35 ft, it will not change significantly as the water height increases beyond that.

To estimate the correction factors, the shielding code MicroShield Version 5 (MS5) [1] was used. MS5 has been validated against other shielding codes, e.g. QADMOD [2]. One of the geometries that MS5 utilizes is a planar disc source with a shield as shown in Figure 2. However, the "dose point" (i.e., detector location) is restricted to the radius of the shield. Since we are only interested in the effect of the shield (water) thickness, this poses no limitation. It should also be noted that the shielding due to to the tank wall can be ignored, since it is present whether or not there is water in the tank.

In the measurements, three gamma ray energies were used, 0.129 Mev, 0.375 Mev, and 0.4137 Mev. The calculations were done for each of these source energies separately. The dose rate which is the output of an MS5 calculation is proportional to the detector response at each energy. The desired correction factor is the ratio of the MS5 dose rate with a (water) shield of thickness H to the dose rate with no shield.

The correction factors would then have to be applied to the raw data at each energy when the detector data are converted to Pu mass.

Table 1 shows the MS5 results.

As a check, MS5 calculations of correction factors to account for gamma ray attenuation by the tank wall at each of the energies (plus 0.0595 Mev) were compared with values stated by the facility. The MS5 calculations were done in plane geometry, with a shield consisting of a layer of 0.25 inch stainless steel (approximated as iron, density 8.02 g/cm^3). The results are shown in Table 2. (It should be noted that these correction factors are not used in obtaining the results in Table 1, since absolute Pu masses are not calculated – this comparison is only intended to check that there are no gross errors in MS5.) The MS5 factors are in good agreement with the facility values, except at 0.0595 and 0.1293 Mev, where they differ by about 27%.

Polestar Applied Technology, Inc.
R. Sher

04/04/02

Table 1. Correction factors. (Dose rate units are arbitrary.)

water height, H (ft)	MS5 dose rate, 0.129 Mev	corr. factor (ratio at height H to zero height)	MS5 dose rate, 0.375 Mev	corr. factor (ratio at height H to zero height)	MS5 dose rate, 0.414 Mev	corr. factor (ratio at height H to zero height)
0	3.1590	1.00	1.1260	1.00	1.2500	1.00
0.1	0.9007	3.51	0.4390	2.87	0.5021	2.49
0.2	0.3776	8.37	0.2222	5.07	0.2587	4.83
0.25	0.2578	12.25	0.1651	6.82	0.1938	6.45
0.3	0.1797	15.58	0.1250	9.01	0.1477	8.46
0.35	0.1272	24.83	0.0958	11.75	0.1141	10.96

Table 2. Comparison of attenuation factors.

Energy, Mev	dose rate, no shield (arb. units)	dose rate with 0.25" Fe shield	attenuation factor (ratio)	att. factor supplied by facility
0.4137	5.630	3.497	1.61	1.62
0.3750	5.011	3.079	1.63	1.66
0.1293	1.406	0.4496	3.13	3.99
0.05954	8.144	2.179E-2	373.8	479.68

It is not clear to the author whether the Am-241 content was inferred from the measured Pu-239 mass or by counting the 0.332 Mev gamma ray. If the former, the Pu mass corrected using the factors of Table 1 should be used to get the Am-241 mass. If the Am-241 mass was determined by counting the 0.332 Mev gamma ray, then the corrections to be applied would be slightly larger than the Table 1 values for 0.375 Mev energy, e. g., for 0.1 foot of water the factor would be ~ 3.0.

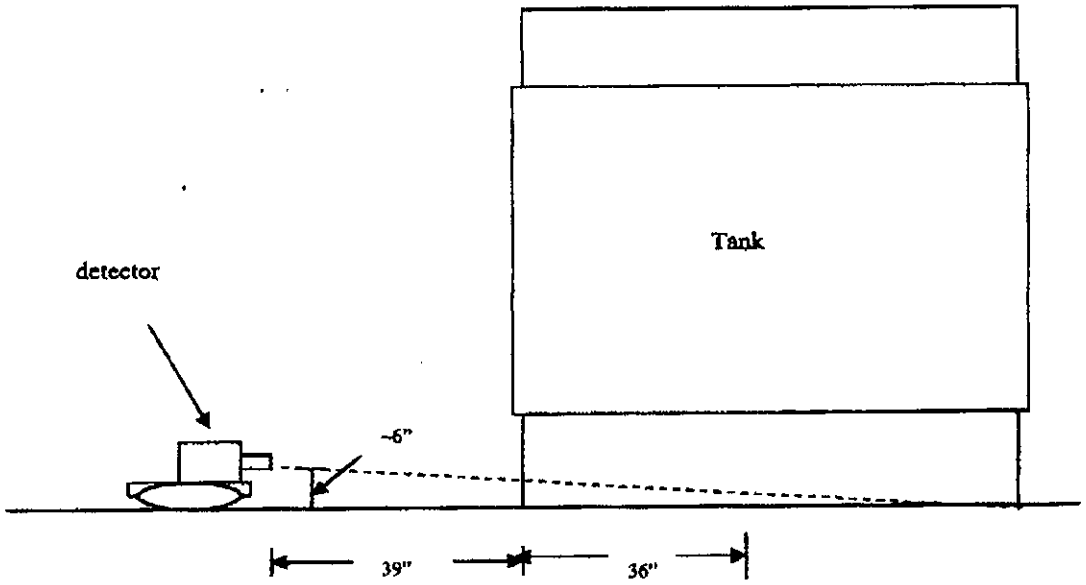
References:

1. MicroShield Version 5, Grove Engineering, Rockville, MD, 1996.

2. QADMOD-GP RSIC COMPUTER CODE COLLECTION CCC_565, "Point Kernel Gamma-Ray Shielding Code with Geometric Progression Buildup Factors", TU Electric, Nov. 1990.

Polestar Applied Technology, Inc.
R. Sher

04/04/02



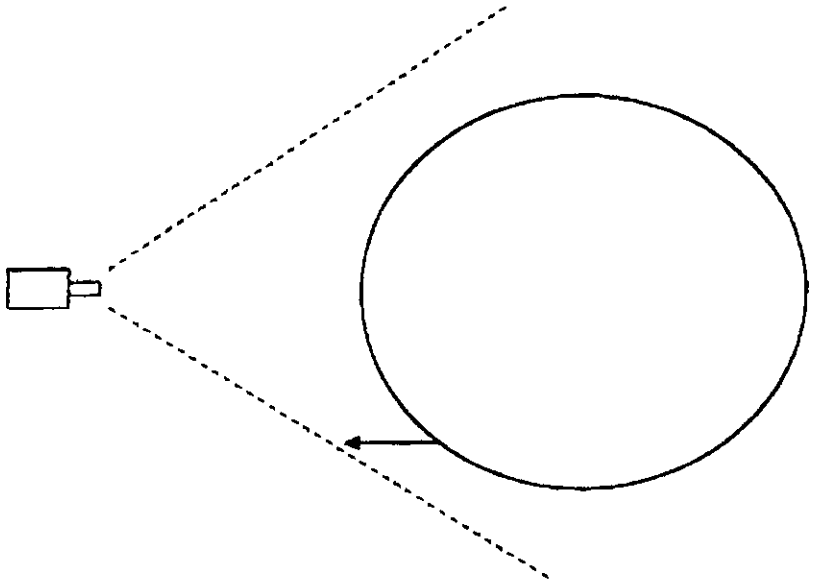


Figure 1. Counting geometry

Polestar Applied Technology, Inc.
R. Sher

04/04/02

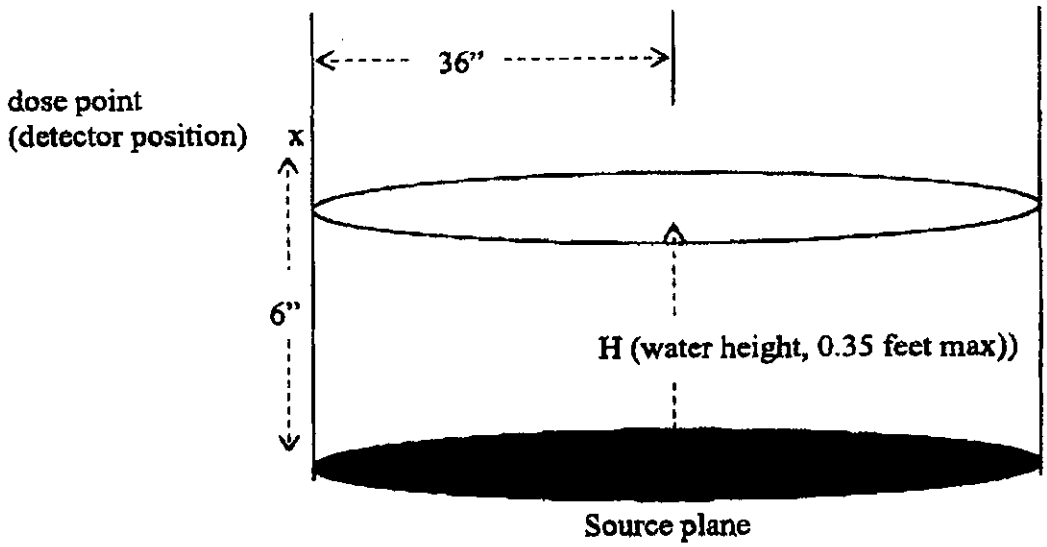


Figure 2. MS5 geometry (not to scale).

This page intentionally left blank.