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7. Abstract

This document summarizes the information on the historical uses, present status, and the sampling and analysis results of waste stored in tank 241-C-111. This report supports the requirements of Tri-Party Agreement Milestone M-44-08.

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Tank Characterization Report for Single-Shell Tank 241-C-111

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Approved for Public Release

EXECUTIVE SUMMARY

This tank characterization report presents an overview of Single-Shell Tank 241-C-111 and its waste contents. It provides estimated concentrations and inventories for the waste components based on the latest sampling and analysis activities, in combination with background tank information. This report supports the requirements of the *Hanford Federal Facility Agreement and Consent Order* Milestone M-44-08 (Ecology, EPA, and DOE 1994) and the Ferrocyanide Tank Safety Program Milestone T2B-95-123.

A summary of the configuration of Tank 241-C-111 is provided in Table ES-1. This tank is a passively ventilated, out-of-service 2,010 kL (530 kgal) capacity single-shell tank built between 1943 and 1944. Tank 241-C-111 is part of the C Tank Farm located in the 200 East Area of the Hanford Site. The tank is reported to contain approximately 216 kL (57 kgal) of non-complexed sludge (Hanlon 1995). Interim stabilization of the tank was completed in 1984 with the removal of supernatant by pumping and completion of intrusion prevention measures. Prior to interim stabilization, the tank is thought to have leaked approximately 21 kL (5 kgal) of waste to the ground and is therefore identified as an assumed leaker (Hanlon 1995). Tank 241-C-111 is classified as a Ferrocyanide Watch List tank, because of its role in the ferrocyanide scavenging process in the 1950's.

Initially, tank 241-C-111 was used as an evaporator feed tank and received first cycle decontamination waste from the bismuth phosphate process (1C) which took place at B and T Plants.

The tank is believed to contain the following four major types of waste:

- Bismuth phosphate first cycle decontamination waste (1C)
- Ferrocyanide-scavenged waste (FeCN) from scavenging of uranium recovery waste initially stored in other tanks
- Purex cladding wastes (CWP).
- Hot Semiworks waste

Three sets of waste samples have been obtained from Tank 241-C-111. These sets consist of a supernate sample obtained in 1975, three push-mode core samples taken in April of 1994, and four auger samples taken in January and March of 1995. Only the 1994 and 1995 samples will be used for characterization of the tank waste since the supernatant from which the 1975 sample was taken has since been transferred out of Tank 241-C-111. The 1994 and 1995 samples were safety screening samples. These sampling events were performed in accordance with the *Tank 241-C-111 Tank Characterization Plan* (Bell 1994, Schreiber 1994, and Schreiber 1995). Sampling and analysis procedures are discussed in detail in the *Tank Characterization Reference Guide* (De Lorenzo et al. 1994). Estimates of the concentrations and projected inventories for major analytes and analytes of concern, based on the available sampling and analytical data, has been summarized in Table ES-2.

The available available data are consistent with expected characteristics of the three waste types (PUREX Cladding waste, ferrocyanide scavenged waste, and first cycle bismuth phosphate

waste) predicted to be in the tank based upon historical process knowledge. The data also suggest the presence of a fourth waste type, Hot Semiworks waste, that was known to have been placed in the tank but was no longer predicted to remain by the Tank Layering Model. The sampling and analysis data were compared to the historical tank content estimates (HTCE). Of the 16 analytes included in the comparison, only 4 analytes differed by less than a factor of 2.5 and nearly half the analytes (7) differed by greater than a factor of 4. Because of the disparities between the two estimation methods and the presence of a waste type (Hot Semiworks waste) not predicted by the Tank Layering Model nor included in the HTCE, it is recommended that the HTCE not be used for this tank. Instead, the sampling and analysis based estimates should be considered the best source of information on the waste.

The analytical data collected from this tank met all of the criteria identified in the tank safety screening Data Quality Objectives - DQO (Babad and Redus 1994) and the ferrocyanide DQO (Meacham et al. 1994). Samples were collected and analyzed from three widely spaced risers. The differential scanning calorimetry (DSC) measurements did not identify any exothermic reactions above the 481 J/g threshold criterion and the thermogravimetric analyses (TGA) indicate that the water content is above the 17% minimum threshold. The original ferrocyanide inventory has been shown to have degraded from an estimated 10,451 kg to only 28.1 kg. The calculated heat load and estimated plutonium content are both well below the respective criteria of 40,000 BTU/hr and 1 g/l, respectively. The tank headspace has also been characterized but the vapor sampling and analysis data and its interpretation are included in a separate report (Huckaby, 1995).

Because of the small total volume of waste, this tank will not be a significant driver for the retrieval, pretreatment, or disposal programs. Further sampling efforts to provide a more complete understanding of this tank are not recommended.

Table ES-1. TANK 241-C-111

TANK DESCRIPTION	
Type:	Single-Shell
Constructed:	1943-1944
In-Service:	August 1946
Diameter:	22.9 m (75 ft)
Usable Depth:	5.2 m (17 ft)
Operating Capacity:	2,010 kL (530 kgal)
Bottom Shape:	Dish (12.5 kgal)
Ventilation:	Passive
Interim Stabilization:	Complete
Intrusion Prevention:	Complete
TANK STATUS	
Total Waste Volume:	216 kL (57 kgal)
Sludge Volume:	216 kL (57 kgal)
Supernatant Volume:	0 kL
Surface Level:	41.10 cm (16.18 inches)
Waste Material:	Non-Complexed Sludge
Temperature:	11 °C (51 °F) to 41 °C (106 °F) 3/8/94 9/11/90
Integrity Classification:	Assumed Leaker
Watch List Status:	Ferrocyanide
SAMPLING DATES	
Supernatant Sample:	1975
Core Samples	April 1994
Auger Samples	January and March 1995
SERVICE STATUS	Inactive

Table ES-2. Single-Shell Tank 241-C-111 Concentrations and Inventories for Major Analytes and Analytes of Concern

Physical Properties	Results	Projected Inventory kg
Percent Water	21.1%	5.91E+04
Heat Load	7.83E+03 Watts (2.67E+04 BTU/hr)	NA
Chemical Constituent	**Concentration µg/g**	**Projected Inventory kg**
Metals		
Al (aluminum)	1.28E+05	3.58E+04
Ca (calcium)	1.17E+04	3.28E+03
Cr (chromium)	2.22E+02	6.22E+02
Fe (iron)	5.47E+04	1.53E+04
Mg (magnesium)	1.54E+03	4.31E+02
Mn (manganese)	3.07E+02	8.60E+01
Ni (nickel)	2.07E+04	5.80E+03
P (phosphorus)	1.11E+04	3.11E+03
Si (silicon)	8.92E+03	2.50E+03
Na (sodium)	2.70E+04	7.56E+03
U (uranium)	1.51E+04	4.23E+03
Organics		
Total Organic Carbon	1.25E+03	3.50E+02
Total Cyanide		
Total Cyanide	3.76E+01	4.28E+01
Radionuclides	**µCi/g**	**Ci**
^{137}Cs	4.32E+01	1.21E+04
^{90}Sr	4.16E+03	1.16E+06
Total Alpha	8.84E-01	2.48E+02

Notes:
NR = Not reported
NA= Not applicable

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1.0 INTRODUCTION

This tank characterization report presents an overview of Single-Shell Tank 241-C-111 (Tank 241-C-111) and its waste contents. It provides estimated concentrations and inventories for the waste components based on the latest sampling and analysis activities, in combination with background tank information. This tank characterization report utilizes the results of four tank safety screening sampling efforts to address concerns regarding tank safety. This report supports the requirements of the *Hanford Federal Facility Agreement and Consent Order* Milestone M-44-08 (Ecology, EPA, and DOE 1994) and Ferrocyanide Tank Safety Program Milestone T2B-95-123..

1.1 PURPOSE

The primary purpose of this report is to summarize the information about the use and contents of Tank 241-C-111. Where possible, this information will be used to assess issues associated with safety, operations, environmental, and process development activities. This report also serves as a data interpretation report for the Ferrocyanide Tank Safety Program (part of Milestone T2B-95-123) and as a reference point for obtaining more detailed information about Tank 241-C-111.

1.2 SCOPE

This report presents a broad background of preliminary information that was available prior to core sampling, and which initially guided the development of the sampling and analysis program. The results of tank 241-C-111 core and auger sample analyses are summarized and presented, along with a statistical interpretation of the data.

All of the sample sets were taken to support evaluation of both the tank safety screening data quality objectives (Babad and Redus 1994) and the ferrocyanide data quality objectives (Meacham et al. 1994) for the tank waste. The four sampling events encompassed three core samples and four auger samples. Analyses addressed eight primary parameters: energetics, percent water, cyanide content, inductively coupled plasma metals content, total alpha activity content, total organic carbon content, gamma energy level, and total beta activity by proportional counting. These analyses were selected to quickly and effectively screen tanks for unsafe conditions and to help resolve the ferrocyanide tank safety issue. The tank headspace has also been characterized but the vapor sampling and analysis data and its interpretation are included in a separate report (Huckaby, 1995).

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2.0 HISTORICAL TANK INFORMATION

Tank 241-C-111 is no longer active and will not have additional transfers that would result in alteration of waste volume and composition, prior to waste retrieval. The current status of the tank is provided in routinely updated reports. This description of the tank's history includes information on tank design, information on historical waste transfers, an estimation of tank contents based on historical information, and waste level and temperature data from surveillance activities.

2.1 TANK STATUS

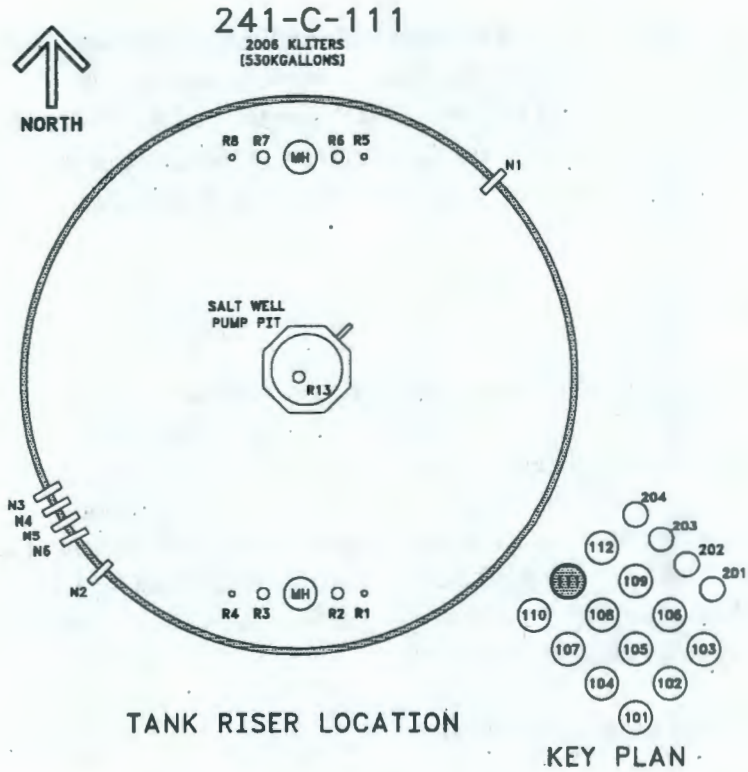
Tank 241-C-111 is a passively ventilated, inactive single-shell tank. It is reported to contain approximately 216,000 L (57,000 gal) of non-complexed sludge (Hanlon 1995). Interim stabilization of the tank was completed in 1984, and intrusion prevention measures have been put into place. Prior to interim stabilization, the tank is thought to have leaked approximately 21,000 L (5500 gal) of waste to the ground and is therefore identified as an assumed leaker (Hanlon 1995). Tank 241-C-111 is classified as a Ferrocyanide Watch List tank, as a result of its role in the ferrocyanide scavenging process in the 1950's. The tank is currently in compliance with all surveillance requirements (Hanlon 1995).

2.2 TANK DESIGN AND BACKGROUND

Tank 241-C-111 is part of the C Tank Farm, a first generation single-shell tank (SST) farm built between 1943 and 1944 (see Figure 2-1). The tank farm consists of twelve 2 million liter (530,000 gal) tanks and four 208,000 L (55,000 gal) tanks. Each 2 million liter (530,000 gal) tank, like 241-C-111, has a diameter of 22.9 m (75 ft) and an operating depth of 5.2 m (17 ft). These tanks were designed for non-boiling waste with a maximum fluid temperature of 104°C (220°F). As with all first generation tank farms, minimal waste monitoring equipment was originally provided on the tank (DeLorenzo et.al., 1994).

Tank 241-C-111 entered service in August 1946 as the second tank in a three-tank cascade series. A cascade series is a set of tanks constructed such that as the first tank becomes full, it overflows to the next tank in the series. This often results in settling of particulate matter primarily in the first tanks. The last tank in the cascade typically empties into a soil column or crib. The tank is constructed of 300 mm (1 ft) thick reinforced concrete with a 6.4 mm (0.25 in) mild carbon steel liner (ASTM A283 Grade C) on the bottom and sides, and a 380 mm (1.25 ft) thick domed concrete top. The bottom of the tank is a dish approximately 300 mm (1 ft) deep, with a 1.2 m (4 ft) radius knuckle. The bottom center elevation of Tank 241-C-110 is 185.6 m (609 ft) above sea level, with a cascade to Tank 241-C-111 at 185 m (608 ft). Tank 241-C-111 cascades to Tank 241-C-112 at 185 m (607 ft) bottom center elevation. The cascade overflow height is approximately 4.78 m (15 ft, 8 in) from the tank bottom and 0.6 m (2 ft) below the top of the

Figure 2-1. Tank 241-C-111 Plan View



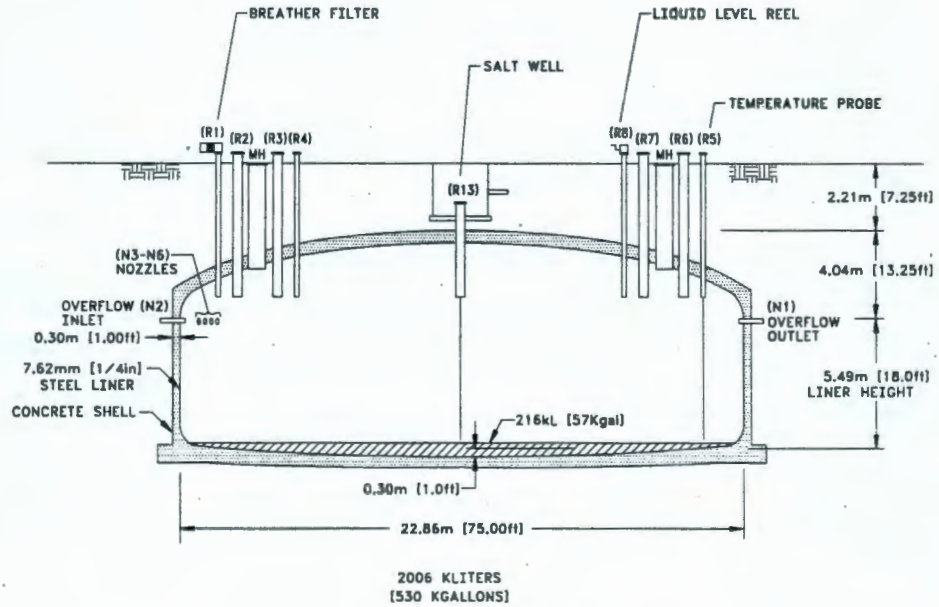
steel liner. The tanks are set on a reinforced concrete foundation. Each tank dome is covered with approximately 2.2 m (7.25 ft) of overburden. (See Figure 2-2.)

The waste surface level is monitored through riser 8 with a manual tape. Liquid waste volume is determined using a manual tape surface level gauge, while solid waste volume is determined using a sludge level measurement device. Figure 2-1 shows a plan view that depicts riser configuration, while Table 2-1 lists Tank 241-C-111 risers with size and current uses. As shown in Figure 2-1, the risers are located in two rows on opposite sides of the tank, close to each corresponding wall. This configuration results in very limited access to most of the tank waste volume, especially the center of the tank and creates significant challenges in collecting representative samples. The tank has two thermocouple trees. This constitutes all installed equipment for Tank 241-C-111. Figure 2-2 provides a tank cross-section showing an approximation of the reported waste level, along with a schematic of the tank equipment. Tank 241-C-111 has two construction manholes and nine grade level risers. Riser 4, which is 100 mm (4 in) in diameter, and risers 2 and 6, both 300 mm (12 in) in diameter, are available for use. If used as sampling ports, the risers would give access to opposite sides of the tank. Risers 2 and 4 are approximately 45 degrees counterclockwise from the inlet and riser 6 is approximately 70 degrees clockwise from the inlet. The position of sampling points relative to inlet locations has a significant impact on the observations obtained from a sample due to the effects of local filling patterns on the distribution of the waste.

Table 2-1. Tank 241-C-111 Risers and Inlets

NO.	DIA.	DESCRIPTION AND	Elevation
R1	4"	BREATHER FILTER	647.21
R2	12"	FLANGE, BM	647.20
R3	12"	FLANGE EXHAUSTER	647.20
R4	4"	FLANGE	647.19
R5	4"	TEMPERATURE PROBE	647.74
R6	12"	TEMPERATURE PROBE	647.74
R7	12"	EXHAUSTER INLET	647.27
R8	4"	LIQUID LEVEL REEL	647.79
R13	12"	SALTWELL RISER WC	
N1	3"	OUTLET NOZZLE OVERFLOW	
N2	3"	INLET NOZZLE OVERFLOW	
N3	3"	SPARE	
N4	3"	SPARE	
N5	3"	SPARE	
N6	3"	SPARE	

241-C-111



TANK RISER SECTION

Figure 2-2. Cross-Section View of Tank 241-C-111

2.3 PROCESS KNOWLEDGE

Initially, tank 241-C-111 was used as an evaporator feed tank and received first cycle decontamination waste (1C) from the bismuth phosphate process conducted at B and T Plants. The tank received three major types of waste likely to deposit solids during its operating history (Agnew et al. 1995). The waste types, in chronological order, were as follows:

- Bismuth phosphate first cycle decontamination waste (1C);
- Ferrocyanide-scavenged waste (FeCN) from scavenging of uranium recovery waste initially stored in other tanks;
- PUREX cladding wastes (CWP).

2.3.1 Waste Transfer History

Tank 241-C-111 received no waste from early 1944 to mid-1946. First cycle waste from the bismuth phosphate process began cascading from tank 241-C-110 into tank 241-C-111 during the third quarter of 1946. In November 1946, the tank was declared full.

During the early 1950's, supernatant was transferred out of tank 214-C-111, and the tank began to receive uranium recovery (UR) waste from U-222. In the mid-1950's, tank 241-C-111 served primarily as the settling tank for ferrocyanide waste resulting from in-farm scavenging of ^{137}Cs (Borsheim and Simpson 1991). During the first quarter of 1956, that ferrocyanide waste was transferred and the tank received PUREX organic wash waste and cladding waste from unknown sources. Also during this time period (from the first quarter of 1956 to the fourth quarter of 1957), supernatant that had been scavenged of ^{137}Cs was intermittently transferred from the tank to disposal cribs. Tank 241-C-111 received intermittent transfers of supernatant from 241-C-105 and other sources from late in 1959 until early in 1961.

Waste from the Hot (or Strontium) Semi-Works (HS or SSW) plant was intermittently transferred to Tank 241-C-111 for approximately two years in the early 1960's. Final transfers of supernatant out of Tank 241-C-111 occurred during the late 1960's and early 1970's. The final waste transfer was completed in approximately 1976. Tank 241-C-111 was removed from service in 1975 and was declared inactive in 1978 (Agnew 1994).

Tables 2-2 describes the major waste transfers which occurred while tank 241-C-111 remained in service, and Table 2-3 provides a synopsis of transfers by waste type.

Table 2-2. Tank 241-C-111 Major Transfers (Two Sheets)

Year: Qtr	Waste Received by Tank 241-C-111				Waste Transferred out of Tank 241-C-111		
	Transaction Source	No. of Transfers	Waste Type	Waste Amount kL (kgal)	No. of Transfers	Transfer to Tank Farm (Waste Type)	Waste Amount kL (kgal)
1946:3-1947:2	C-110	9	1C	4,001 (1,057)	-	-	-
1946:4-1953:2	-	-	-	-	10	C-112 (SU)	3,903 (1,031)
1952:3-1953:3	-	-	-	-	2	B-106 (SU)	1,870 (494)
1952:4-1953:2	U-222	4	UR	3,748 (990)	-	-	-
1956:1-1956:1	-	-	-	-	1	C-112 (T03)	1,836 (485)
1956:1-1956:1	-	-	-	-	1	C-109 (T04)	121 (32)
1956:1-1956:1	C-105	1	T05	125 (33)	-	-	-
1956:1-1956:1	C-108	1	T05	1,378 (364)	-	-	-
1956:3-1956:3	-	-	-	-	1	Crib B-020 (SU)	1,802 (476)
1956:3-1956:4	Unknown	3	OWW	64 (17)	-	-	-
1957:1-1957:2	Unknown	4	CWP	1,283 (339)	-	-	-
1957:2-1957:2	-	-	-	-	1	BY-111 (SU)	1,374 (363)
1957:2-1957:2	C-103	1	T11	1,840 (486)	-	-	-
1957:2-1957:2	-	-	-	-	1	Crib B-030 (SU)	1,745 (461)
1957:2-1957:2	BY-102	1	T14	1,651 (436)	-	-	-

Table 2-2. Tank 241-C-111 Major Transfers (Two Sheets)

Year: Qtr	Waste Received by Tank 241-C-111				Waste Transferred out of Tank 241-C-111		
	Transaction Source	No. of Transfers	Waste Type	Waste Amount kL (kgal)	No. of Transfers	Transfer to Tank Farm (Waste Type)	Waste Amount kL (kgal)
1957:3-1957:3	-	-	-	-	1	Crib B-031 (SU)	1,760 (465)
1957:3-1957:3	BY-103	2	T17 & T18	2,722 (719)	-	-	-
1957:3-1957:3	-	-	-	-	1	C-108 (SU)	1,707 (451)
1957:3-1957:3	B-108	1	T22	151 (40)	-	-	-
1957:3-1957:3	-	-	-	-	1	Crib B-033 (SU)	1,121 (296)
1957:3-1957:3	B-109	1	T22	1,760 (465)	-	-	-
1957:4-1957:4	-	-	-	-	1	Crib B-034 (SU)	1,499 (396)
1957:4-1957:4	B-112	1	T26	333 (88)	-	-	-
1957:4-1957:4	BX-110	1	T26	1,211 (320)	-	-	-
1957:4-1957:4	-	-	-	-	1	Crib B-035 (SU)	1,412 (373)
1959:4-1960:1	C-105	2	SU	856 (226)	-	-	-
1962:4-1964:2	Unknown	4	HS	863 (228)	-	-	-
1969:4-1974:2	-	-	-	-	2	C-104 (SU)	-1,567 (-414)
1976:1-1976:2	-	-	-	-	2	C-103 (SU)	-246 (-65)

1C - 1st cycle decontamination waste from the $BiPO_4$ process (contains 10% of the fission products, 1% plutonium and often includes cladding waste).

CWP - PUREX cladding waste

OWW	-	Organic Wash Waste from PUREX. Evidently, this was combined with P waste in 1960-61, but was usually kept separate.
P	-	PUREX high level waste
UR	-	Uranium recovery operation waste from U-222 (U Plant)
HS	-	Hot Semi-Works (a pilot facility that had a variety of operations, one of which was the recovery of strontium).
SU	-	Supernatant. Liquid considered free of contamination to the extent it could be pumped to a crib.
T03	-	Waste sent to tank 241-C-112 for settling of or in-farm ferrocyanide scavenged waste.
T04	-	Waste sent to tank 241-C-109 for settling of or in-farm ferrocyanide scavenged waste.
T05	-	Waste sent to tank 241-C-111 for settling of or in-farm ferrocyanide scavenged waste.
T11	-	Waste sent to tank 241-C-111 for settling of or in-farm ferrocyanide scavenged waste.
T17	-	Waste sent to tank 241-C-111 for settling of or in-farm ferrocyanide scavenged waste.
T18	-	Waste sent to tank 241-C-111 for settling of or in-farm ferrocyanide scavenged waste.
T22	-	Waste sent to tank 241-C-111 for settling of or in-farm ferrocyanide scavenged waste.
T26	-	Waste sent to tank 241-C-111 for settling of or in-farm ferrocyanide scavenged waste.

Table 2-3. Synopsis of Major Waste Transferred

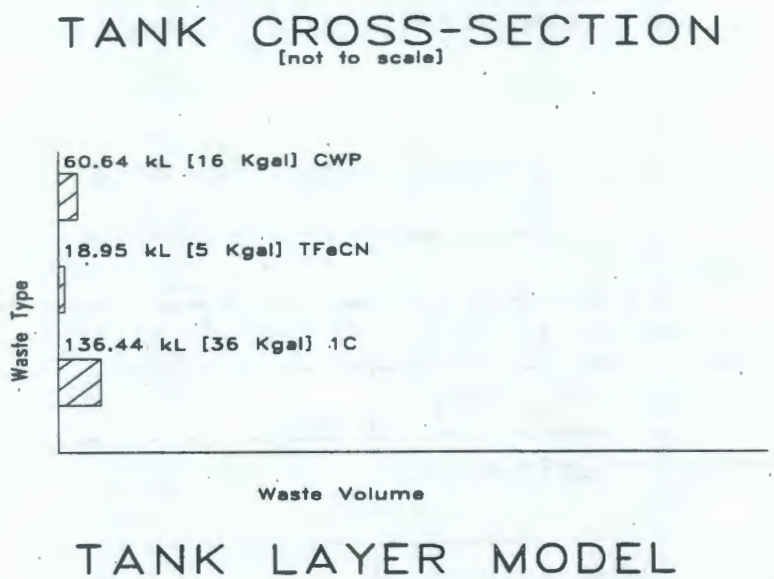
Transfer Type	Volume kL (kgal)
Addition - First Cycle Waste (1C)	4,001 (1,057)
Addition - Uranium Recovery Waste (UR)	3,748 (990)
Addition - In-Farm Ferrocyanide Scavenging Waste (FeCN)	11,171 (2,951)
Addition - Organic Wash Waste (OWW)	64 (17)
Addition - PUREX Cladding Waste (PCW)	1,283 (339)
Addition - Supernatant (SU)	856 (226)
Addition - Hot Semi-Works Waste (HS)	863 (228)
Transfer out - In-Farm Ferrocyanide Scavenging Waste (FeCN)	1,957 (517)
Transfer out - Supernatant (SU)	20,006 (5,285)

2.3.2 Historical Estimation of Tank Contents

Tank inventory estimates are based on the Historical Tank Content Estimate - HTCE (Brevick et al. 1995) and the Tank Layer Model (Agnew et al. 1995a). The Tank Layer Model was developed by

the Los Alamos National Laboratory (LANL) to evaluate the transaction records for each Hanford high-level waste tank and estimate the composition and volume of waste layers remaining in the tank. An estimated composition of each waste type has been developed and is known as the Hanford Defined Waste document (Agnew, 1995b). The estimated waste composition and the predicted layers are combined on a weighted average basis to provide the HTCE values. These results indicate that Tank 241-C-111 contains approximately 136 kL (36 kgal) of first cycle bismuth phosphate waste, 61 kL (16 kgal) of PUREX cladding waste and 19 kL (5 kgal) of in-farm ferrocyanide scavenging waste. Figure 2-3 presents a graphical illustration of the estimated waste type and volumes for the tank layers.

Figure 2-3 Tank Level Contents



2.3.2.1 First Cycle Decontamination Waste (1C). The bismuth phosphate first cycle (1C) waste type is predicted to be the bottom most layer of waste in tank 241-C-111. Based on the Tank Layer Model Agnew et al. 1995a), this waste is expected to completely fill the dished bottom, as well as extend approximately 8 inches above the dished bottom. First cycle waste is the aqueous solution remaining after the first product decontamination cycle of the $BiPO_4$ process. Nearly all of the uranium as well as 90% of the fission products were previously removed from the stream as metal waste (MW). First cycle wastes contained approximately 10% of the fission products and 1% of the plutonium content and should, therefore, have only a moderate level of radioactivity (Anderson 1990).

Bismuth phosphate waste is expected to contain appreciable amounts of Bi, Cr, Fe, and PO_4^{3-} resulting from additions to the product stream in earlier $BiPO_4$ stages. These four analytes are characteristic of all $BiPO_4$ wastes. Compounds containing bismuth served as both oxidizing and precipitation agents, while chromium was added in the form of sodium dichromate as a stabilizing oxidizer for the stronger bismuth compound (sodium bismuthate). Iron was added in the form of ferrous ammonium sulfamate as a Pu

reducing agent, and coating waste (CW) generated from the removal of aluminum cladding from the fuel slugs was added to the first cycle waste, comprising approximately 24% of the 1C waste stream. The aluminum cladding was dissolved in a solution of sodium nitrate/sodium hydroxide. Therefore, the waste is also expected to contain higher concentrations of Al, Na, and NO_3 relative to other $BiPO_4$ wastes.

2.3.2.2 Ferrocyanide Scavenged Waste. The in-farm ferrocyanide scavenging waste forms the middle layer of waste in the tank (just above the first cycle waste). The tank layering model predicts approximately 19 kL (5 kgal) of this waste type to be in this tank (Agnew et al. 1995). A detailed analysis of the ferrocyanide processing records (Borsheim and Simpson 1991) and flow sheet simulant characterization studies (Jeppson and Wong 1993) estimate the volume of ferrocyanide sludge remaining in the tank to be roughly 25 kL (6.7 kgal). The ferrocyanide waste is expected to contain large quantities of sodium, iron, nickel, calcium, uranium, cesium and nitrate. Because the ferrocyanide scavenging process binds the aqueous cesium to the sludge as a precipitant, the quantity of cesium included in the layer of scavenging waste is large enough to be significant and the activity of this layer is expected to be much greater than the first cycle or PUREX cladding waste layers.

Beginning in May 1955, unscavenged uranium recovery (UR) waste already stored in 200 East Area underground tanks at the Hanford Site was routed to the 244-CR vault for scavenging (refer to Figure 2-4). The 244-CR vault facility contained stainless steel tanks with chemical addition, agitation, and sampling capabilities. The pH of the waste was adjusted with nitric acid (HNO_3) and/or sodium hydroxide (NaOH) to pH 9.3 ± 0.7, and ferrocyanide [$Fe(CN)_6^{-4}$] and nickel (Ni^{2}) ions were added (generally 0.005 M each) to precipitate ^{137}Cs. If laboratory analysis of the feed tank indicated additional ^{90}Sr decontamination was necessary, calcium nitrate was also added (Sloat 1955). There was also an effort to scavenge cobalt-60 (^{60}Co) with sodium sulfide (Na_2S) (Jeppson and Wong 1993). The scavenged waste was then routed to another tank for settling, sampling, and decantation to a crib. The settling tanks for this "In-Farm scavenged" waste were 241-C-108, 241-C-109, 241-C-111, and 241-C-112. Waste fractions resulting from these operations are expected to exhibit significant similarity in chemical content and physical properties.

The In Farm precipitate comprises 26% of the total ferrocyanide material added to the Hanford Site tank farms. This material is expected to possess a much higher ferrocyanide concentration than the more prevalent U Plant material, that comprises 66% of the total ferrocyanide material. Analytes that differentiate ferrocyanide waste from other wastes are nickel, calcium, and ^{137}Cs. Over time, additional gravity settling may have compressed the waste layers, increasing the concentration of some of these analytes. Radiation and high pH conditions from later waste additions to the tanks has been shown to degrade (age) the ferrocyanide wastes (Lilga et al. 1993 and 1994). When ferrocyanide wastes age, the energetics and total CN^- content will be reduced over time but the Ni and ^{137}Cs concentrations will remain relatively the same as when the wastes were originally introduced in to the tanks. The aging phenomenon has been observed in tanks 241-C-112 (Simpson et al. 1994a) and 241-C-109 (Simpson et al. 1994b).

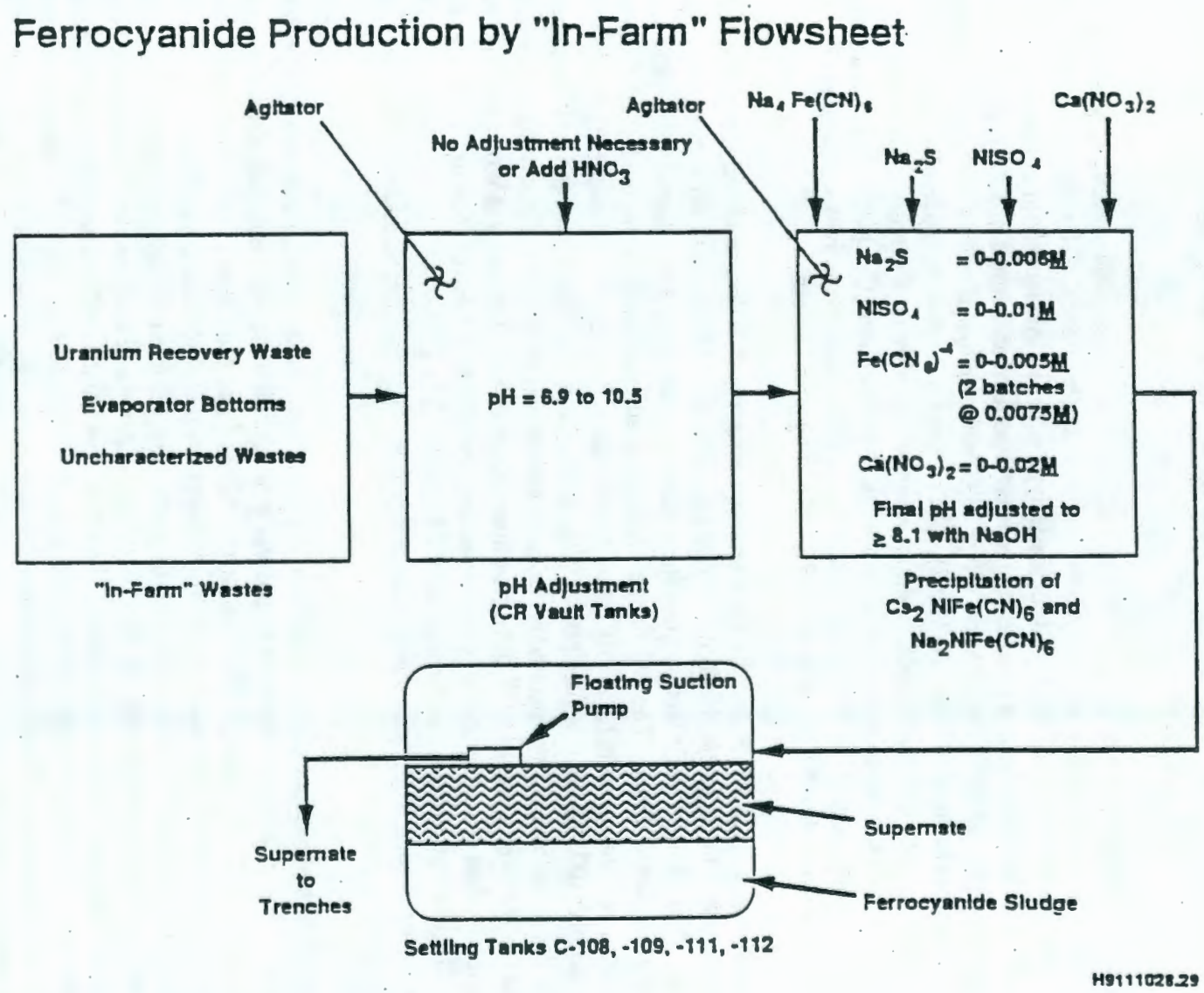


Figure 2-4. In Farm Ferrocyanide Scavenging Flowsheet

2.3.2.3 PUREX Cladding Waste. The PUREX cladding waste is expected to be the top layer of the waste and initially was approximately 150 mm (6 inches) in thickness. This waste is highly flocculent and may have compressed significantly over time. The PUREX cladding waste should be rich in aluminum, sodium nitrates, nitrites, and uranium. The inventory of uranium present in this layer is expected to be lower than the ferrocyanide scavenging waste layer but significantly higher than the first cycle bismuth phosphate waste layer. Cesium and strontium are present in the cladding waste, but the quantities are such that the activity in this layer will be the relatively low. The cladding waste layer can further be distinguished from the other two layers by the absence of iron and nickel (contained in ferrocyanide scavenging waste) and the presence of a small to moderate amount of phosphate (not contained in scavenging waste, but present in large quantities in first cycle waste).

2.3.2.4 Other Waste Type. If significant quantities of Hot Semi-Works waste are present, the TOC, strontium-90 (^{90}Sr), and possibly lead (Pb) levels should be higher. Increased manganese concentration may indicate the presence of organic wash waste, since permanganate was used to wash the PUREX solvent. Organic wash, hot semi-works and uranium recovery wastes were not identified as significant contributors in the HTCE tank layer model.

2.3.2.5 Estimated Tank Composition. Table 2-4 shows an estimate of the expected waste constituents and their concentrations based on the Tank Layering Model and the Hanford Defined Wastes (Brevick et al. 1995). Concentrations of elements and compounds are presented in both moles per liter and parts per million (ppm). These concentrations are then converted into total tank inventories in kilograms for each constituent. The radiological components of the waste are presented in terms of Curies per liter (Ci/L) or microcuries per gram (μCi/g). Total inventory is presented in Ci.

2.4 SURVEILLANCE DATA

Tank 241-C-111 surveillance activities include surface level measurements (liquid and solid), temperature monitoring inside the tank (waste and vapor space), and leak detection well (drywell) monitoring for radioactivity outside the tank. Five drywells are identified for Tank 241-C-111. These data are significant because they provide the basis for determining tank integrity. No tanks in C Farm have liquid observation wells for monitoring interstitial liquid levels.

Table 2-4 HTCE Tank Content Estimate

Single-Shell Tank 241-C-111			
Solids Composite Inventory Estimate*			
Physical Properties			
Total Solid Waste	2.97E+05 kg (57 kgal)		
Heat Load	0.165 kW (564 BTU/hr)		
Bulk Density	1.38 (g/cc)		
Void Fraction	0.717		
Water wt%	70.1		
TOC wt% C (wet)	0.158		
Chemical Constituents	**mole/L**	**ppm**	**kg**
Na^{+1}	4.25	7.09E+04	2.11E+04
Al^{+3}	2.33	4.56E+04	1.35E+04
Fe^{+3} (total Fe)	0.478	1.94E+04	5.76E+03
Cr^{+3}	6.11E-03	231	68.6
Bi^{+3}	5.86E-02	8.89E+03	2.64E+03
La^{+3}	0	0	0
Ce^{+3}	0	0	0
Zr (as $ZrO(OH)_2$)	6.50E-03	431	128
Pb^{+2}	0	0	0
Ni^{+2}	7.09E-02	3.02E+03	899
Sr^{+2}	0	0	0
Mn^{+4}	0	0	0
Ca^{+2}	8.45E-02	2.46E+03	731
K^{+1}	0	0	0
OH^{-1}	8.97	1.11E+05	3.29E+04
$NO3^{-1}$	0.650	2.93E+04	8.69E+03
$NO2^{-1}$	0.273	9.11E+03	2.71E+03
$CO3^{-2}$	8.46E-02	3.68E+03	1.09E+03
$PO4^{-3}$	0.898	6.19E+04	1.84E+04
$SO4^{-2}$	2.92E-02	2.04E+03	606
Si (as SiO_3^{-2})	0.101	2.06E+03	614
F^{-1}	0.255	3.52E+03	1.05E+03
Cl^{-1}	1.39E-02	356	106
$C_6H_5O_7^{-3}$	0	0	0
$EDTA^{-4}$	0	0	0
$HEDTA^{-3}$	0	0	0
NTA^{-3}	0	0	0
$glycolate^{-1}$	0	0	0
$acetate^{-1}$	0	0	0
$oxalate^{-2}$	0	0	0
DBP	0	0	0
NPH	0	0	0
CCl_4	0	0	0
hexone	0	0	0
$Fe(CN)_6^{-4}$	3.13E-02	6.76E+03	1.83E+03
Radiological Constituents			
Pu		0.176 (μCi/g)	0.874 (kg)
U	5.21E-02 (M)	9.01E+03 (μg/g)	2.68E+03 (kg)
Cs	0.162 (Ci/L)	118 (μCi/g)	3.50E+04 (Ci)
Sr	5.62E-04 (Ci/L)	0.408 (μCi/g)	121 (Ci)
*Composite inventory excludes supernatant, diatomaceous earth, and cement.			
Unknowns in tank inventory are assigned by Tank Layer Model (TLM).			

2.4.1 Surface Level Readings

The tank 241-C-111 surface level is monitored quarterly with a manual tape through riser 8. The liquid waste volume is measured with a manual tape surface level gauge, while the solid waste volume is measured using a sludge level measurement device. Tank 241-C-111 was classified as an assumed leaker in 1968. In 1982, a level adjustment was performed on the tank data and an intrusion prevention process was initiated. The supernatant was pumped from the tank, and interim stabilization was completed in March 1984. Surface level measurements have remained consistent for the past 3 years, ranging from 406 mm (16 in) to 387 mm (15.25 in). The baseline surface level is 406 mm (16.5 in.) and has a maximum allowable increase of 51 mm (2 in). No criteria have been established for surface level decreases because the tank has been stabilized and no free liquid remains. Figure 2-5 presents a graphical representation of actual surface level measurements.

2.4.2 Internal Tank Temperatures

Tank 241-C-111 has two operable thermocouple (TC) trees, an original TC tree and a new TC tree installed in July 1995. The original TC tree has 12 thermocouples; TCs 1 through 9 are evenly spaced every 600 mm (2 ft) along the tree starting approximately 732 mm (28.8 in) off the centerline bottom of the tank. There is a 1.2 m (4 ft) gap between TCs 9 and 10, and TCs 10 and 11. No elevation information is available for TC 12.

Tank 241-C-111 was connected to the Tank Monitor and Control System (TMACS) in September 1994 for continuous temperature monitoring. The new TC tree is scheduled for connection to TMACS in August 1995. Temperature measurements from 1989 to the present are similar for TCs 1 through 11. Data are available for TC 12 from 1990 to 1993. Reviews of the Tank 241-C-111 surface level history during this period indicate that all of the TCs were located in the vapor space.

The average temperature is 23 °C (73 °F) with a minimum of 11 °C (52 °F) and a maximum temperature of 41 °C (106 °F). The tank temperature follows a seasonal, cyclic pattern. Temperature readings since January 1975 are available, along with graphs and thermocouple heights where available (Brevick, 1994). Plots of the thermocouple readings are provided in Figure 2-6.

2.4.3 Tank 241-C-111 Photographs

The 1970 series of Tank 241-C-111 photographs are hazy across the majority of the montage. The waste surface appears to be covered with a bluish liquid, while the walls of the tank have a layered color pattern. Visible equipment has been identified and labeled. Equipment visible within the photographs includes recirculating dip tubes, a pump, a temperature probe, spare nozzles, an overflow inlet nozzle, an outlet nozzle, and an old float. The photographs were taken prior to the tank leaking and subsequent saltwell pumping and interim stabilization; therefore, the picture does not represent the current tank contents.

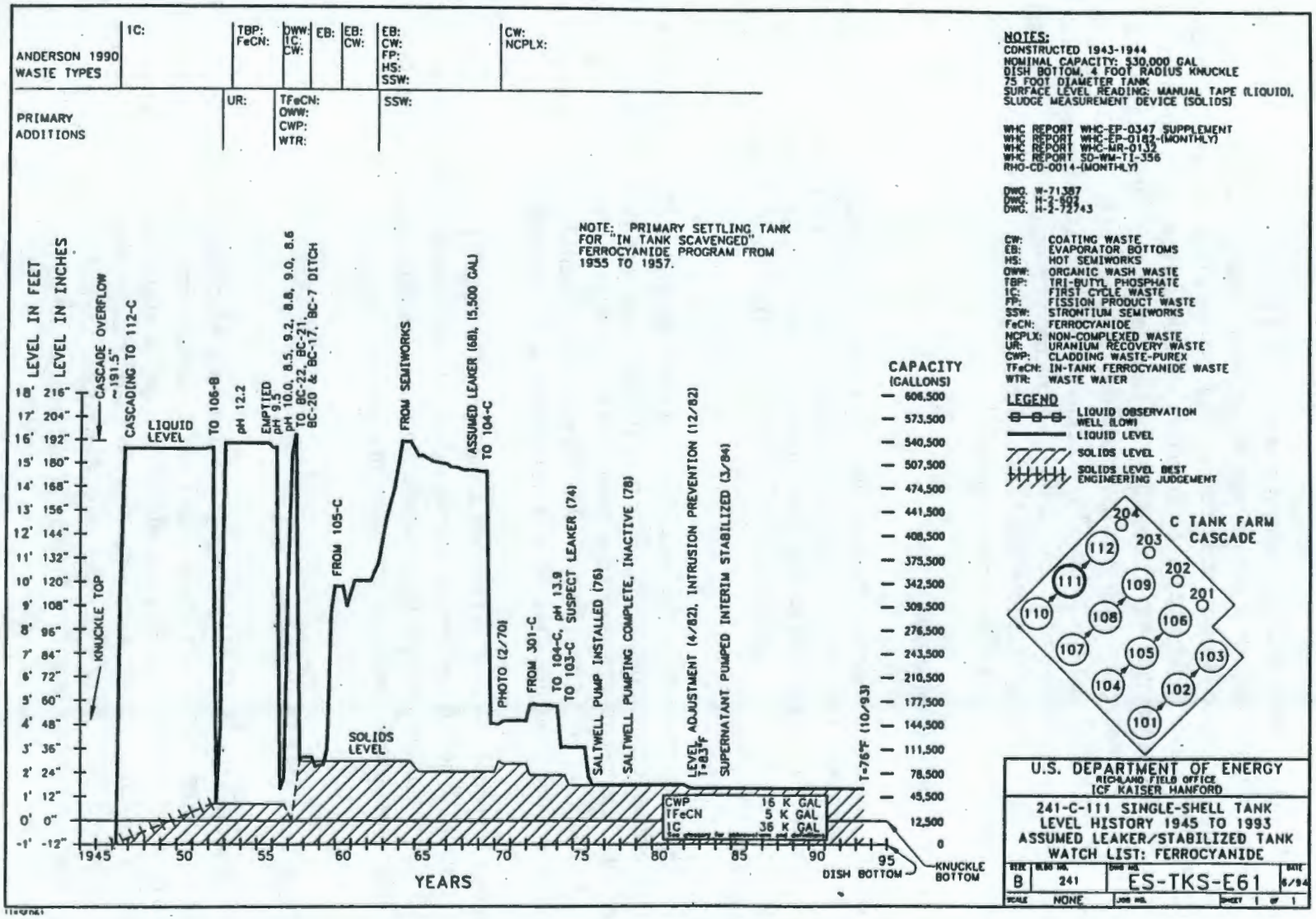


Figure 2-5 Tank 241-C-111 Surface Level History

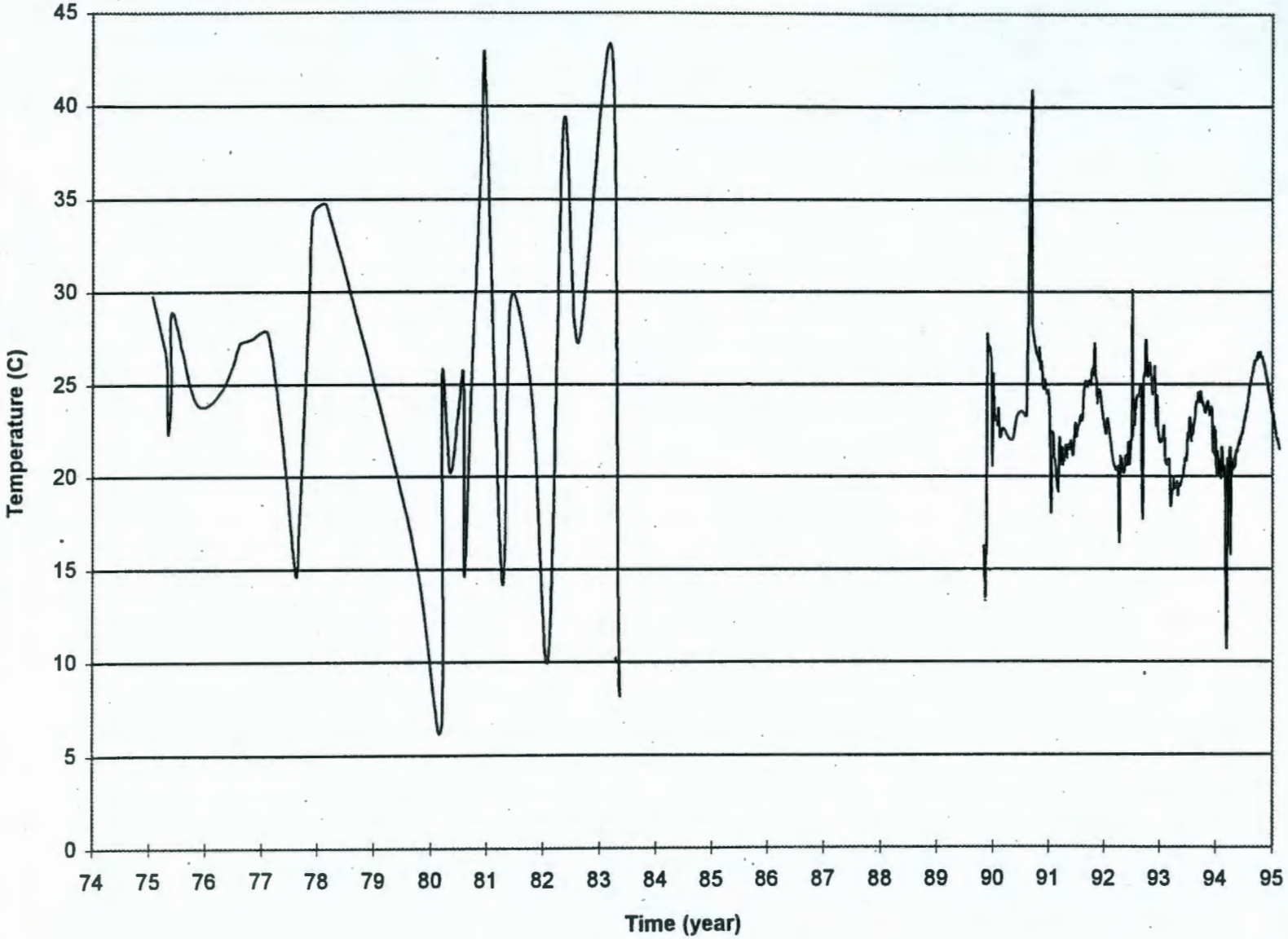


Figure 2-6. Tank 241-C-111 Temperature Plot

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3.0 TANK SAMPLING OVERVIEW

This section describes the samples taken from the waste in Tank 241-C-111. The samples include a supernate sample obtained in 1975, three push-mode core samples taken in April of 1994, and four auger samples taken in January and March of 1995. Only the push-mode and auger samples will be used for characterization of the tank waste since the supernatant from which the 1975 sample was taken has since been transferred out of Tank 241-C-111. The 1994 and 1995 samples were taken to meet the requirement for the ferrocyanide and safety screening DQOs (Meacham et al 1994, Babad and Redus 1994). These sampling events were performed in accordance with the *Tank 241-C-111 Tank Characterization Plan* (Bell 1994, Schreiber 1994, and Schreiber 1995). Sampling and analysis procedures are discussed in detail in the *Tank Characterization Reference Guide* (De Lorenzo et al. 1994).

3.1 DESCRIPTION OF 1975 SUPERNATE SAMPLING EVENT

A supernatant sample was taken from Tank 241-C-111 in 1975 and analyzed for a limited number of constituents (Van Vleet 1993). The analytical results are listed in Appendix B. The supernatant has since been transferred out of Tank 241-C-111 so these analytical results are not used to characterize the waste.

3.2 DESCRIPTION OF 1994 CORE SAMPLING EVENT

Three cores were taken from Tank 241-C-111 during April of 1994. Core 58 was obtained on April 11, 1994 from riser 6. The shipment of core 58 also included a field blank to measure contamination during transport and handling. Core 59 was taken on April 22, 1994 from riser 3. Core 60, requested because of the low recoveries of cores 58 and 59, was obtained on April 29, 1994 from riser 6 (Rice 1994). The waste was expected to be soft so the push-mode sampling method was used for all three core samples (Bell 1994). Table 3-1 lists some of the pertinent information concerning the 1994 core sampling effort. Because the cores were expected to be only one segment in length, no hydrostatic fluid was used during sampling. The tank was sampled to satisfy the criteria for safety screening of Hanford waste tanks (Babad and Redus 1994) and resolution of the ferrocyanide safety issue (Meacham et al. 1994). The sampling and analytical requirements from the two DQOs have been integrated in the *Tank 241-C-111 Tank Characterization Plan* (Bell 1994).

Besides the lower than expected sample recovery described in the next section, only one anomaly was encountered during push-mode core sampling. The sampler for core 58 hit a hard layer about 2 inches before the end of the sampler stroke. No other sampling anomalies were reported. Note that the drill string dose rate for core 59 was nearly zero at the time of sampling, strongly suggesting low sample recovery.

3.2.1 Sample Handling (1994)

Core 58 was shipped to the 222-S Laboratory on April 12, 1994 and extruded on April 14, 1994. Approximately half of the core 58 sample fell out of the sampler as it was being transferred to the extruder inside the hot cell. This indicates that the sampling valve was open during the transfer. The fallen sample was collected and placed in the sample tray along with the rest of the extruded sample. Core 59 was shipped to the 222-S Laboratory on April 22, 1994 and extruded on April 25, 1994. Core 60 was transferred to 222-S Laboratory on April 29, 1994 and extruded on May 2, 1994. No analyses were completed on core 60 per the instructions of the Ferrocyanide Program Office and the sample was archived for possible future study (Rice 1994).

Table 3-1. 241-C-111 Core Sampling Information

Sample Number	Cask Number	Core	Drill String Dose Rate (mR/hr)	Riser Number	Sample Date
NA	1005-C	NA	NA	NA (Field Blank)	4/11/94
94-001	1007-C	58	60	6	4/11/94
94-002	C-1029	59	<0.5	3	4/22/94
94-003	C-1028	60	110	6	4/29/94

The sample lengths of the push-mode cores taken from Tank 241-C-111 were all substantially less than expected. Table 3-2 describes the weights, lengths, expected lengths, and percent recoveries of the core samples. Approximately 2.4 g of liner liquid were also recovered from core 58 but was discarded since such a small volume would not be useful for analysis. The yields were all below the limit for sufficient sample as defined in the *Tank 241-C-111 Tank Characterization Plan* (Bell 1994) which requires that all requested analyses be performed and that at least 10 g of material be archived for further use. The insufficient sample mass of the 1994 core samples also precluded partitioning of the samples into segment, quarter segment, composite, or drainable liquid fractions. Each core sampled was homogenized in its entirety and analyzed in accordance with the *Tank 241-C-111 Tank Characterization Plan* (Bell 1994). A rock appeared during the homogenization of core 58 weighing approximately 8 g which was archived with no further analyses. Cores 58 and 60 were similar in appearance as would be expected since both cores were taken from riser 6. Both cores were dark brown, clay-like, with little or no drainable liquid present. Core 59 was crusty in texture, and off-white in color, with no drainable liquid. Based on its appearance, core 59 was classified by the laboratory as a saltcake. The features of the core samples are presented in Table 3-2. Discrete layers could not be determined within the small sample volumes.

Table 3-2. Tank 241-C-111 1994 Core Sample Description

Core	Weight g	Length cm (in)	Expected Length cm (in)	% Recovery	Color	Texture
58	26.5	3.8(1.5)	23 (9)	17%	dark-brown	clay-like
59	1.7	NR	20 (8)	0%	off-white	crusty
60	19.7	2.5(1.0)	15 (6)	17%	dark-brown	clay-like

Notes:
NR = not reported

3.2.2 Analysis of 1994 Core Samples

All analyses were performed at the 222-S Laboratory and reported in the *216-Day Report for Tank 241-C-111* (Rice 1994). Procedure titles and numbers can be found in Appendix C. Analytical results are listed in Appendix A. Table 3-3 summarizes the analytical tests performed on the core samples. There are no analytical results for core 60 since the sample was archived directly following extrusion. A limited number of analyses were conducted on core 59 (TGA, DSC, Alpha Total, and GEA only) because of the limited amount of available sample (Bratzel 1994, Cash 1994). No material from core 59 remained after the completion of these analyses. Results from fusion and acid digestion methods were compared for nickel and ^{90}Sr, and it was determined that fusion digestion was sufficient to quantify these constituents in ferrocyanide waste. Fusion preparations for the ICP analyses for nickel were performed in a zirconium rather than a nickel crucible to prevent contamination and bias of the samples.

Table 3-3. Tank 241-C-111 Core Sample Analyses

Analyses	Core 58	Core 59	Core 60
TGA	X	X	
DSC	X	X	
Alpha Total	X	X	
ICP (Ni only)	X		
Cyanide	X		
TOC	X		
GEA	X	X	
Strontium-90	X		

3.3 DESCRIPTION OF 1995 AUGER SAMPLING EVENT

Auger samples were taken in January and March of 1995. Table 3-4 lists some pertinent information concerning the sampling events. Auger samples were requested because of the low sample recoveries of the 1994 push-mode sampling attempts (Schreiber 1995). Augers 95-AUG-002 and 95-AUG-003 were taken on January 17, 1995 from riser 2. Because of poor recoveries of the first two auger samples, a second sampling event took place on March 25, 1995. Auger 95-AUG-016 was taken from riser 6 while auger 95-AUG-017 was taken from riser 3. Auger 95-AUG-016 had good sample recovery. All samples were taken using 500 mm (20 inch) augers except Auger 96-AUG-002 which was taken using a 250 mm (10 inch) auger.

Table 3-4. Tank 241-C-111 1995 Sampling Information

Sample Number	Cask Serial Number	Riser Sampled	Expected Sample Length in	Dose Rate Through the Drill String mR/hr
95-AUG-002	C1052	2	8	1
95-AUG-003	C1034	2	7	15
95-AUG-016	1014C	6	12	2,000 (uncorrected)
95-AUG-017	1007C	3	12.75	5

Notes:
cm = centimeter
mR/hr = milliroentgen/hour

3.3.1 Handling of 1995 Auger Samples

Auger samples 95-AUG-002 and 95-AUG-003 were received by the 222-S Laboratory on January 17, 1995. Both samples were extruded the following day. No sample was recovered from sample 95-AUG-002 and only 3.56 g of sample were recovered from 95-AUG-003. No homogenization was performed in order to preserve moisture and sample material. Samples 95-AUG-016 and 95-AUG-017 were received by the 222-S Laboratory on March 17, 1995 and extruded on March 31, 1995. The amounts of material recovered from these samples are listed in Table 3-5. As can be seen in Table 3-5, sample 95-AUG-016 was subsampled into quarter segments, but only 3 of the 4 quarter segments had enough recovery for chemical analysis. Auger 95-AUG-017 was described as off-white in color with a dry and crumbly texture. Auger 95-AUG-016 was described as a dark brown paste. The bottom 10 cm (4 in) of the auger sample were darker than the upper 20 cm (8 in.) Some crumbly tan solids were seen beneath the dark brown paste.

Table 3-5. Tank 241-C-111 1995 Auger Sample Description

Sample Number	Subsample Number	Jar Number	Mass (g)	Description
95-AUG-016	Segment Portion D (Flutes 14-18)	6681	73.6	Dark brown paste
	Segment Portion C (Flutes 10-13)	6682	120	
	Segment Portion B (Flutes 1-9)	6683	82.0	
95-AUG-017	Whole Segment	6679	47.3	Dry, crumbly, off-white color

Notes:
g = gram

3.3.2 Analysis of 1995 Auger Samples

The 1995 auger samples were analyzed in accordance with the *Tank 241-C-111 Tank Characterization Plan* (Schreiber 1995) and additional guidance from the Westinghouse-Hanford Company Characterization Program (Bratzel 1995). The results were reported in the *60-Day Safety Screen Results and Final Report for Tank 241-C-111, Auger Samples 95-AUG-002, 95-AUG-003, 95-AUG-016, and 95-AUG-017* (Rice 1995). Procedure titles and numbers can be found in Appendix C. Analytical results are listed in Appendix A. Table 3-6 summarizes the tests performed on the auger samples. No analyses were performed on auger 95-AUG-002 since no material was recovered.

Sample 95-AUG-003 did not require testing for additional fuel sources since the notification limits for the screening tests were not exceeded (Bratzel 1995). Sample 95-AUG-017 resembled saltcake type waste and was visually classified by the laboratory as a saltcake type waste. Therefore, total alpha and ICP (Ni) analyses were not performed in accordance with the ferrocyanide DQO (Meacham et al. 1994).

Table 3-6. Tank 241-C-111 Auger Sample Analyses

Analyses	95-AUG-002	95-AUG-003	95-AUG-016	95-AUG-017
TGA		X	X	X
DSC		X	X	X
Alpha Total			X	
TOC			X	
Cyanide			X	
ICP (Ni only)		X	X	

Sample 95-AUG-016 was to be analyzed for total alpha, nickel, and cyanide on the half-segment level. However, because fusion preparations were performed on the quarter segment level, it was convenient and efficient to perform these analyses on the quarter segment level as well. In addition, total organic carbon was analyzed on the quarter segments.

Similar to the results observed from Core 59, auger 95-AUG-017 exhibited 0% free water loss during the TGA which would be expected since core 59 and auger 95-AUG-017 were both taken from riser 3.

Fusion preparations for the ICP analyses for nickel were performed in zirconium rather than nickel crucibles to prevent contamination and bias of the samples.

3.4 Waste Level and Total Volume Determination

The total waste volume reported in Hanlon (1995) for this tank is 216 kL (57 kgal). This value was determined from a single waste-level measurement taken from riser 8 and corresponds to a waste level of 41.10 cm (16.18 inches) of waste above the tank sidewall bottom. Waste levels are typically reported in waste height above the bottom base of the tank wall and there are 4,098 L of waste for every cm of waste height in a 22.9 m (75 ft) diameter tank. This corresponds to 2,750 gallons of waste per inch. There is a 30.5 cm (12 in) dished bottom below the bottom of the tank sidewall. This dished bottom contains approximately 47,312 L (12,500 gallons) of waste. The general convention for determining waste volumes in 22.9 m (75 ft) diameter tanks with dished bottoms is as follows:

$$Waste\ Volume = Waste\ Height\ (cm)\ x\ 4{,}098\ \frac{L}{cm} + 47{,}312\ L$$

$$Waste\ Volume = Waste\ Height\ (inches) \times 2{,}750\ \frac{gallons}{inches} + 12{,}500\ gallons$$

This method assumes that the tank has a level waste surface. However, most waste surfaces are uneven and the total waste volume can deviate significantly. The tank surface photographs are usually a good indicator of the surface level variable and the accuracy of the single-point waste volume determination method. Unfortunately, the surface photograph for tank 241-C-111 is poor and does not provide any indication of the surface topography. Therefore, alternative methods have been employed to verify the tank waste volume.

Zip cord measurements are generally taken from a riser prior to initiating waste sampling to better determine the waste level immediately below the riser. A zip cord measurement is taken by lowering a conductivity probe down a riser. When the probe contacts the waste, the circuit is completed and the operator marks the length of the cord. This information combined with knowledge of the riser elevation and the tank sidewall bottom elevation allows for the determination of the waste level. Zip cord measurements were obtained before both auger and core samples were taken from risers 3 and 6. In addition, the surface level is routinely measured in riser 8. Table 3-7 summarizes the waste-level measurements available for this tank.

Comparing the average waste levels observed underneath the three risers would indicate that there is a fairly large gradient from one side of the tank to the next. A further examination of the waste surface was conducted by entering the relative riser positions and average waste level into a computer modeling program. The Cartesian coordinates of the three risers was determined with the centerline of the tank being the origin. The average waste height was converted to feet to be in consistent units with the Cartesian coordinates. Data inputted into the computer model are presented in Table 3-7.

The computer model employs a method known as kriging to extrapolate the three data points to the remainder of the tank. The results of the model can be presented as either a contour map (see Figure 3-1) or as a surficial diagram (see Figure 3-2). The contour map shows a two-dimensional view of the diameter of the tank with the contour lines representing the waste level above the tankwall bottom in units of feet. The contour lines range from 0.95 ft to 1.95 ft with a .05 ft interval. The asterisks mark the position of the risers from where the surface levels where measured. The surficial diagram presents a three dimension view of the estimated waste surface. The vertical (Z) axis represents waste level above the tank sidewall bottom in units of feet and the other two axis (X and Y) represent horizontal position. The surficial diagram presents a dramatic gradient from riser 3 to risers 6 and 8. The sharpness of the gradient is somewhat distorted because the scale of the X and Y axis is considerably smaller than for the Z axis. The estimated waste level differs by approximately 30.5 cm (1 ft) across the 22.8 m (75 ft) diameter tank with a gradient of roughly 1.41 cm of drop per m (0.17 in./ft). This observed gradient may be explained by the fact that the side of the tank with the greater surface level is the same side of the tank as the tank inlet nozzle. The lower side of the tank corresponds with the exit nozzle. It has been observed in other tanks that solids tend to accumulate near the inlet points. The computer model also calculated the volume underneath the surface to be

Table 3-7. Waste Level Measurements for Tank 241-C-111

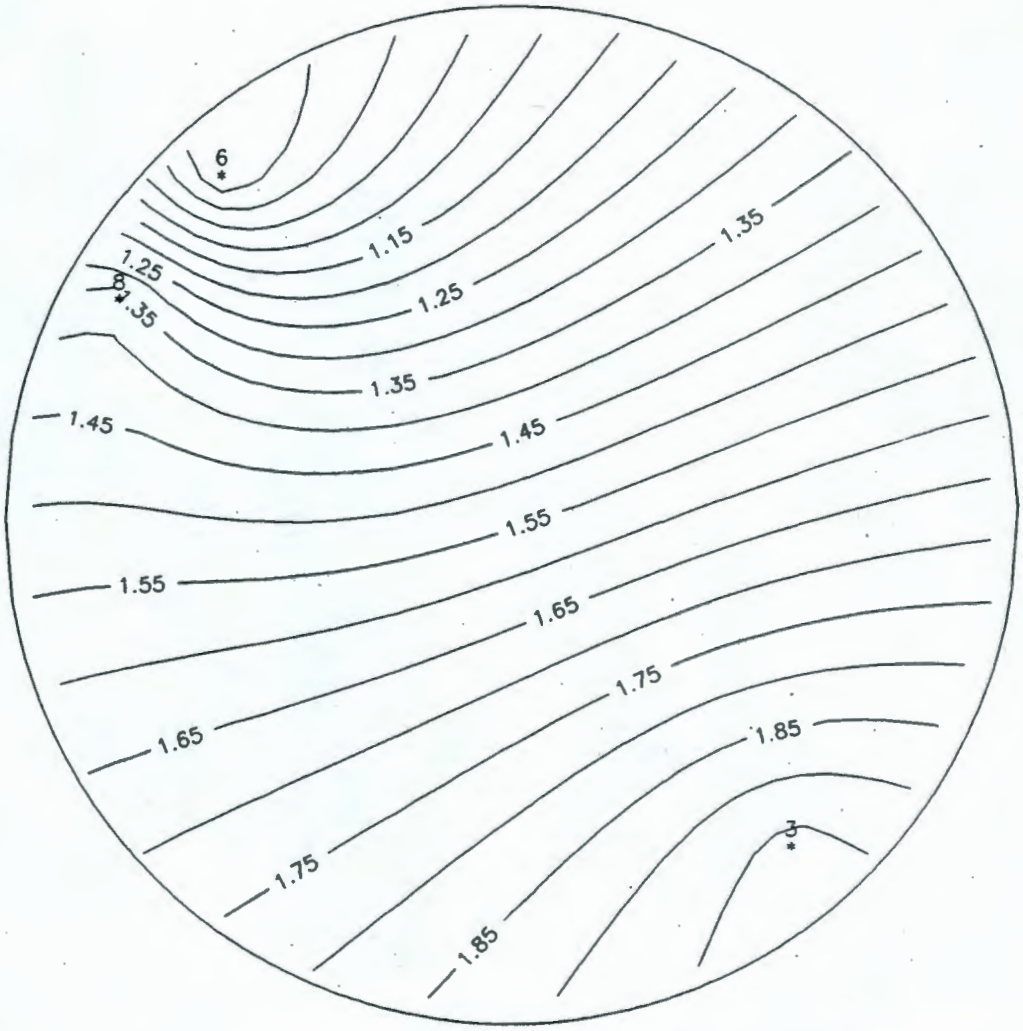
Riser Number	Sampling Method	Waste Level Above Tank Sidewall Bottom (Inches)	Average Waste Height Beneath Riser (Inches)
3	Auger	20.4	23.6
	Core 59	26.8	
6	Auger	10.38	10.76
	Core 58	10.9	
	Core 60	11.0	
8	FIC (7/2/95)	16.5	16.5

Table 3-8. Data Input Parameters for Surface Level Model

Riser	X Coordinate (ft)	Y Coordinate (ft)	Z Coordinate Average Waste Height (ft)
3	20.45	-24.72	1.97
6	-21.31	25.57	0.90
8	-28.98	16.36	1.38

6,667.12 ft^3 or 49.87 kgals. When combined with the 12.5 kgals in the dished bottom, the total tank waste volume estimated by the model was 62.37 kgals (236 kL).

The waste volume can also be estimated by averaging the waste level measured underneath each of the three risers and using the waste volume equations presented earlier in this section. The average of the three waste levels presented in Table 3-7 is 1.42 ft or 17.0 inches. This equates to approximately 59.2 kgal or 224 kL of waste.



Contour lines in units of feet above tank sidewall bottom

Figure 3-1. Contour Map of Waste Surface Level in Tank 241-C-111

The three methods of determining the waste volume range from a low of 216 kL (57 kgal) reported by Hanlon (1995) to 236 kL (62 kgal) calculated by the surface model. The different methods only differ by a 20 kL (~5 kgal) and represents roughly a 9 % deviation in total tank volume. These minor differences do not warrant changing the volume estimate reported in Hanlon because the Hanlon estimates are widely used across the Hanford site as the "official" volume estimates. The volume estimate used for the remainder of this TCR will be 216 kL (57 kgal). However, the gradient observed in the tank must also be recognized and the contour/surficial modeling of the waste surface shall be used for that purpose.

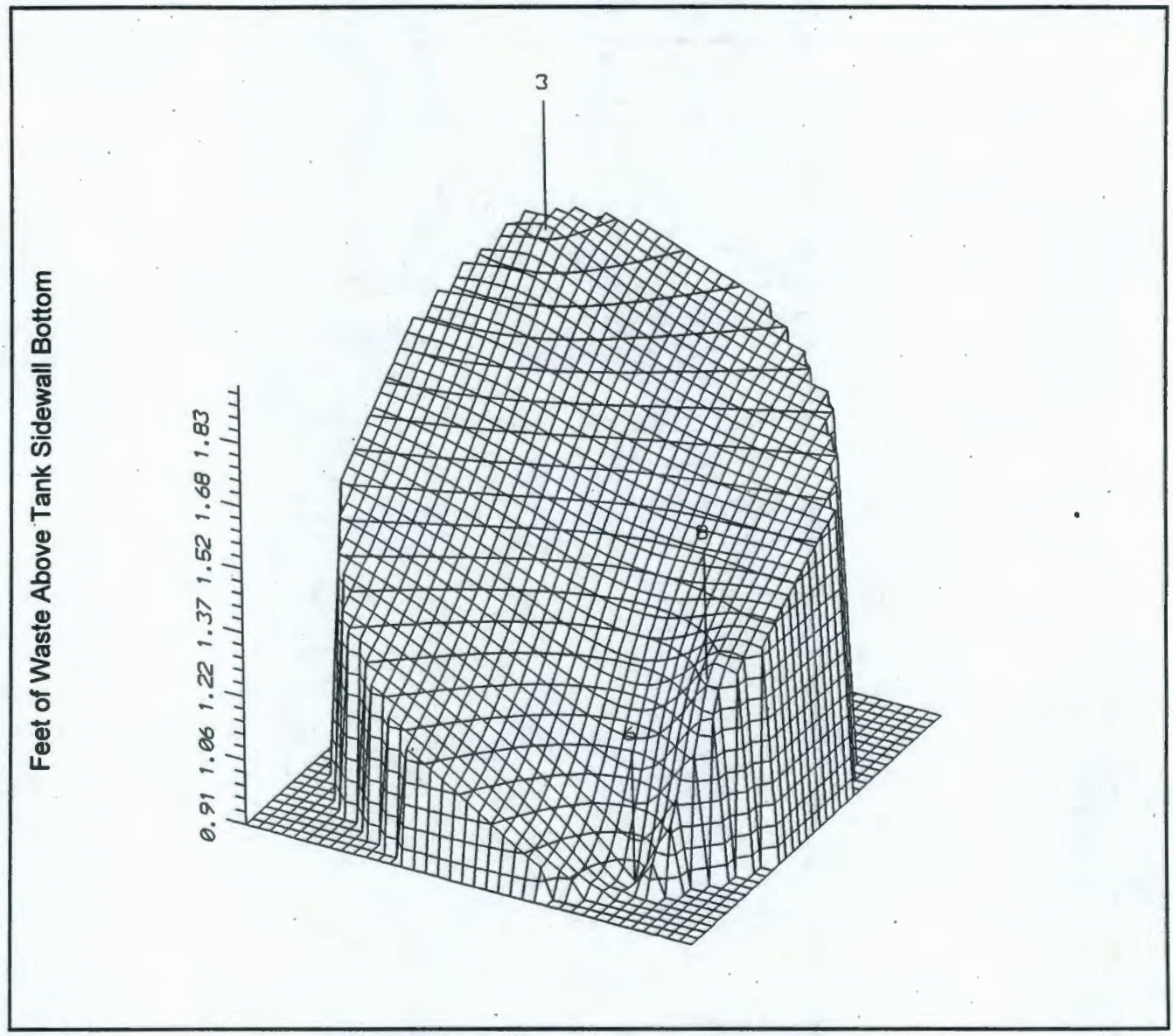


Figure 3-2. Surficial Diagram of Waste Surface in Tank 241-C-111

4.0 ANALYTICAL RESULTS AND WASTE INVENTORY ESTIMATES

4.1 OVERVIEW

Chapter 4 summarizes the sampling and analytical results from each of the sampling events described in Chapter 3 and reported in the Appendices. This chapter uses several values from the data sets presented to arrive at a single, best estimate for the total amount of the analytes in the tank based on the total waste volume in the tank. The sources for the data and its interpretation are principally the data packages associated with the sampling and analytical efforts for this particular tank. The summary tables and appropriate appendices listing these data are summarized in Table 4-1.

Table 4-1. Analytical Presentation Tables

Analysis	Tabulated Result Location
Chemical Composition Data Summary	Table 4-2
Analytical Data for Metals	Table A-1
Analytical Data for Radionuclides	Table A-2
Analytical Data for Percent Water	Table A-3
Analytical Data for Total Organic Carbon	Table A-4
Analytical Data for Cyanide	Table A-5

Inventory estimates for Tank 241-C-111 are based on the average results obtained for a particular analyte from 1994 core sampling and 1995 auger sampling, where appropriate. As a basis for data treatment core 58, core 59, and 95-AUG-003 were all considered equivalent for the purposes of quantitative data analysis. The mean values used for the inventory estimates are presented in Table 4-2. Because of the availability of the data, inductively coupled plasma (ICP) results from core 58 (riser 6) and 95-AUG-003 (riser 2) were assessed together. Total alpha and gamma energy analyses (GEA) for cesium-137 for Core 58 (riser 6) and core 59 (riser 3) were also assessed together, since the auger samples did not provide all this information. Thermogravimetric analyses (TGA) were conducted for all three riser locations, and a quantitative assessment was performed utilizing all three sets of data. Total alpha analyses were conducted twice on core 59. The data assessment performed had several assumptions:

- The tank is relatively shallow, therefore auguring and coring represent appropriate means of sampling and the results from each can be treated equivalently with respect to statistical analyses.

- Layers are expected to exist; but they are also expected to be horizontally homogeneous within an individual layer.

- The tank has no observable drainable liquid thus moisture measurements from the auger should not be any more biased than the core sample measurements

The analysis of variance performed (ANOVA) specifically tested for horizontal and vertical variability. The Relative Standard Deviations (RSDs) appropriate to these analyses are specified in Table 4-2. Results for strontium-90 and TOC were available only for core 58. Therefore statistical analyses could not be performed, and a simple Relative Percent Difference (RPD) between the sample and its duplicate is provided in Table 4-2.

No inventory estimate was given for analytes below the detection limit. If at least one value was above the detection limit, the inventory calculated was based on the concentrations that were above the detection limit. Because of very high background levels, no inventory estimates were calculated for the potassium results from the potassium fusion, or for the zirconium results from the fusion which utilized a zirconium crucible. The actual calculation of the tank inventory estimates is described in Section 4.2, and Appendix A.

4.2 DATA PRESENTATION

A summary of the data obtained from the analyses of the solids samples derived from the sludge in Tank 241-C-111 is presented in Table 4-2. The first column, 'Analyte Method', is the method used to determine the analyte concentration. The second column, 'Number of Samples', is the total number of samples for each measured analyte. The third column 'Percent Non-Detect Samples' is the ratio of samples which yielded results below the detection limit to the total number of samples for a particular analyte, multiplied by 100.

Columns four and five contain data taken from Appendix A of this report. The fourth column, 'Mean', is the average of the appropriate sample results (core 58, core 59, and 95-AUG-003). It can be comprised of the core and auger values, two separate core values; or in one case, measurements from all three. This value is a simple (non-weighted) mean. Column five, 'RSD', lists the relative standard deviation (the standard deviation divided by the mean multiplied by 100) of the sample results, obtained from the analysis of variance (ANOVA). Column five, where appropriate, provides the 'RPD', the Relative Percent Difference (difference divided by the mean, multiplied by 100). Individual RPD values for all samples are given in the Appendix A tables. Column six, 'Projected Inventory', is the product of the concentration of the analyte and the amount of the waste in the tank (57 kilogallons [kgal] or 216 kiloliters [kL]), and an estimated density of 1.30 kg/L. Because there are no direct measurements of density for any of the wastes from this tank, the density value is based on waste measurements from what is considered an analogous tank, 241-C-109 (Simpson et al. 1993).

Table 4-2. Chemical Composition Data Summary from Tank 241-C-111

Analyte Method	Number of Samples	Percent non-detect Samples	Mean	RSD	Projected Inventory
METALS		%	µg/g	%	kg
ICP.Al	4	0	1.28E+05	9.43	3.58E+04
ICP.Bi[1]	2	0	1.65E+03	NA	4.62E+02
ICP.Ca	4	0	1.17E+04	44.4	3.28E+03
ICP.Cd[1]	2	50	3.76E+01	NA	1.05E+01
ICP.Ce[1]	2	0	5.76E+02	NA	1.61E+02
ICP.Cr[1]	2	0	2.22E+02	NA	6.22E+02
ICP.Cu	4	0	6.57E+01	***	1.84E+02
ICP.Fe	4	0	5.47E+04	1.86	1.53E+04
ICP.La[1]	2	0	4.32E+02	NA	1.21E+02
ICP.Pb	4	0	5.73E+03	4.31	1.60E+03
ICP.Mg	4	0	1.54E+03	***	4.31E+02
ICP.Mn	4	0	3.07E+02	***	8.60E+01
ICP.Nd[1]	2	0	6.11E+02	NA	1.71E+02
ICP.Ni	4	0	2.07E+04	4.04	5.80E+03
ICP.P	4	0	1.11E+04	103	3.11E+03
ICP.Si	4	0	8.92E+03	4.5	2.50E+03
ICP.Na	4	0	2.70E+04	64.9	7.56E+03
ICP.Sr	4	0	1.96E+02	***	5.50E+01
ICP.S[1]	2	100	9.78E+02	NA	2.74E+02
ICP.Ti	4	0	2.00E+02	***	5.60E+01
ICP.U	4	0	1.51E+04	94.6	4.23E+03
ICP.Zn[1]	2	0	1.51E+02	NA	4.23E+01
PHYSICAL PROPERTIES		%	%	%	kg
TGA.% H_2O	7	0	2.11E+01	67	5.91E+04
RADIONUCLIDES		%	µCi/g	%	Ci
APC.total alpha	6	0	8.84E-01	176	2.48E+02
GEA.^{137}Cs	4	0	43.2	139	1.21E+04
		%	µCi/g	%	Ci
BPC.^{90}Sr	2	0	4.16E+03	1	1.16E+06
TOTAL CARBON		%	µg/g	%	kg
Total Organic Carbon	2	0	1.25E+03	5	3.50E+02
Total Cyanide		%	µg/g	%	kg
Total Cyanide	2	0	3.76E+01	3	1.06E+01

Table 4-2. Chemical Composition Data Summary from Tank 241-C-111

Notes:
*** No statistical analyses were performed on these analytes because they were less than 2,000 up/g
NA No statistical analyses were performed due to lack of necessary information
[1] The means and projected inventories for these analytes were based on only core 58

Abbreviation:
RPD = relative percent difference
ICP = inductively coupled plasma
GEA = gamma energy analysis
TGA = thermogravimetric analysis
RSD = relative standard deviation
APC = alpha proportional counting
BPC = beta proportional counting

Fusion digestion data for potassium and zirconium were not considered because the digestion was carried out in a zirconium crucible with potassium hydroxide and cross-contamination makes these results suspect.

4.3 PHYSICAL PROPERTIES

4.3.1 Thermogravimetric Analyses

The percent water content of the waste was measured using a thermogravimetric method. Thermogravimetric analysis measures the mass of a sample while the temperature of the sample is increased at a constant rate. A gas, usually air or nitrogen, is passed over the sample during heating. Any decrease in the weight of a sample represents a loss of gaseous matter from the sample either through evaporation or through a reaction that forms gaseous products. The results are presented in Table 4-3. As can be seen in the table, the first transition for the core 59 sample occurred in a temperature range of 208 to 342 degrees Celsius (°C). This is consistent with the description of the core 59 waste as "crusty, with no drainable liquid," whereas the core 58 sample was described as "clay-like," had no drainable liquid, and exhibited a first transition at a temperature range of 35 to 120°C. A note on the chemist's worksheet states that the weight loss for the core 59 sample was not from water, but does not identify a possible constituent to account for the weight loss. In chapter 5, interpretation regarding the behavior of the DSC/TGA will be given in context of the chemical information.

Percent water analyses were performed on the 1995 auger samples using the Perkin-Elmer and the Mettler methods. A nitrogen blanket was used for the tests. Temperature ranges for the transitions and percent water loss values are listed in Table 4-4. The samples exhibited two transitions, with the exception of sample 95-AUG-017 which exhibited one transition. This material was observed to be relatively low in water, and any water that is present is most likely tightly bound. In fact, the 1st transition for core 59 and auger 95-AUG-017 demonstrated zero weight loss in the region of water.

Table 4-3. Tank 241-C-111 Thermogravimetric Analysis - Core 58 and 59

Sample Number[1]	Run	First Transition		Second Transition	
		Range (35-120°C)	Mean wt% Loss	Range (208-342°C)	Mean wt% Loss
C58S1[1] K211[2]	1	30.9	31.7	11.3	10.8
	2	32.5		10.3	
C59S1 K218	1	0	0	27.6	27.6
	2	0		27.6	

Notes:
wt% - weight per cent
[1]Core or customer identification number
[2]Laboratory tracking number

For core 58, core 59, and 95-AUG-003, transition 1 weight losses ranged from 0% to 35.5%. Transition 2 TGA weight losses ranged from 8.97% to 27.6%. In 95-AUG-016, the transition 1 losses were observed to increase as a function of depth and transition 2 losses were observed to decrease. Transition 1 values ranged from 28% to 44.7% and transition 2 losses ranged from 5.71% to 14.7%.

4.3.3 Core 58 and 59 Thermodynamic Properties

The thermodynamic properties of the waste in the tank were measured using differential scanning calorimetry. In a differential scanning calorimetry analysis, heat flow above the usual heat capacity of the substance is measured while the substance is exposed to a linear increase in temperature. While the substance is being heated, air or nitrogen is passed over the waste material to remove any gases being released. The onset temperature for an endothermic or exothermic event is determined graphically.

An exothermic reaction was observed in the core 58 sample, with an enthalpy change of -41.1 joules/gram (J/g), and a duplicate result of -34.5 J/g. The average value, calculated on a dry weight basis, was -55.3 J/g. The reactions occurred in the range of 120 °C to 240 °C with an average peak temperature of 194 °C. All other differential scanning calorimetry measurements were endothermic. The first transition reaction in the sample from core 59, again endothermic, occurred in a temperature range of 260°C to 360°C, with an average peak temperature of 330°C.

Table 4-4. Tank 241-C-111 Thermogravimetric Analysis - 1995 Auger Samples

Sample Number	Run	First Transition		Second Transition	
		Range (35-140°C)	Mean wt% Loss	Range (140-460°C)	Mean wt% Loss
95-AUG-003[1] 95-AUG-122[2]	1	26.5	28.1	8.97	9.58
	2	35.5		7.88	
	3	22.2		11.9	
95-AUG-016 95-AUG-570 2nd Quarter[3]	1	28.0	28.1	14.7	14.5
	2	28.2		14.2	
95-AUG-016 95-AUG-571 3rd Quarter	1	44.7	40.6	5.71	5.80
	2	38.6		5.87	
	3	38.5		5.83	
95-AUG-016 95-AUG-572 Bottom Quarter	1	44.2	44.3	8.50	7.88
	2	44.3		7.25	
95-AUG-017 95-AUG-577	1	0	0	28.4	28.2
	2	0		28.0	

Notes:
wt% = weight per cent
[1]Core or customer identification number
[2]Laboratory tracking number
[3]Sample 95-AUG-016 was subsampled at the quarter segment level.

4.3.4 1995 Auger Sample Thermodynamic Properties

Differential scanning calorimetry analyses yielded no exothermic reactions within the detectable range of the instrument. The first transition exhibited an overall range of 33 to 210 °C, a peak temperature of 130 °C, and a maximum enthalpy change of +1,210 J/g, on a wet basis. Second transition characteristics included a range of 215 to 350 °C, a peak temperature of 301 °C, and a maximum enthalpy change of +1,150 J/g, on a wet basis.

Table 4-5. Differential Scanning Calorimetry Energetic Results (Wet Weight) for Core and Auger Samples

	First Transition			Second Transition		
Run	Range °C	Peak °C	ΔH J/g[1]	Range °C	Peak °C	ΔH J/g[1]
95-AUG-003/95-AUG-122[2]						
1	38-170	104	854	217-325	301	232
2	40-180	121	1,020	260-320	301	67.6
3	42-170	110	1,034	220-320	301	185
95-AUG-016/95-AUG-570/2nd Quarter(B)						
1	33-190	120	760	220-335	290	363
2	35-175	120	649	220-340	292	406
95-AUG-016/95-AUG-571/3rd Quarter©						
1	35-200	126	1,110	220-325	270	113
2	35-210	123	1,050	225-340	272	144
95-AUG-016/95-AUG-572/Bottom Quarter(D)						
1	40-160	124	1,210	215-310	279	1,150
2	40-165	130	1,140	217-305	279	1,150
95-AUG-017/95-AUG-577						
1	---	---	---	232-350	310	1,020
2	---	---	---	215-347	309	1,018

Table 4-5. Differential Scanning Calorimetry Energetic Results (Wet Weight) for Core and Auger Samples

	First Transition			Second Transition		
Run	Range °C	Peak °C	ΔH J/g[1]	Range °C	Peak °C	ΔH J/g[1]
Core 58						
1	38-120	Not Recorded	Endotherm Not Quantified	141-215	190.3	-41.1
2	38-120	Not Recorded	Endotherm Not Quantified	140-210	198.4	-34.5
Core 59						
1	---	---	---	240-340	Not Recorded	Endotherm Not Quantified
2	---	---	---	240-360	Not recorded	Endotherm Not Quantified

Notes:
C = Celsius
ΔH = change in enthalpy
J/g = joule/gram
[1]Negative sign denotes exothermic reaction.
[2]The first number is the customer identification number. The second is the laboratory tracking number.

5.0 INTERPRETATION OF CHARACTERIZATION RESULTS

5.1 ASSESSMENT OF SAMPLING AND ANALYTICAL RESULTS

The purpose of this section is to evaluate sampling and analysis factors that may impact interpretation of the data. These factors are used to assess the overall quality and consistency of the data and to identify any limitations in their use.

5.1.1 Field Observations

Low recoveries for cores 58 and 59 led to the retrieval of a third core, number 60, which also exhibited lower than expected sample mass. Because push-mode core sample recovery was unsatisfactory, auger samples were also taken. Like the core samples, the first set of auger samples also produced lower than predicted samples masses. Finally during the second auger sampling event enough material was obtained to complete the required analyses.

Approximately half of core 58 fell out of the sampler as it was being transferred to the extruder. The fallen sample was scooped up and placed in the sample tray along with the rest of the extruded sample. Since there is no hydrostatic head fluid and samples were homogenized, the overall quality or usefulness of the data is not expected to be impacted. Further discussion of the sampling events can be found in Section 3.

Several limitations of the data exist for tank 241-C-111. First, only one reasonably full segment sample (95-AUG-016) was recovered from one location (riser 6). Thus, the ability to assess the spatial variability of the waste composition at the segment level in the tank and its distribution is not possible, which limits the information available about the tank's contents. (See Chapter 10 of the Tank Characterization Reference guide, Delorenzo et al. 1994). The only possible estimates available for spatial variability of the waste composition in the tank are those obtained from the composite level data, since composite data are available from two locations (riser 2 and 6), and in one case, 3 locations (riser 2, 3, and 6). Second, the shallowness of the tank's waste composition makes proper sampling more difficult, prompting low sample recovery. Third, the samples must be taken through the existing risers, limiting the opportunity to obtain a random sample and therefore biasing the results.

5.1.2 Quality Control Assessment of Analytical Data

Good laboratory practice requires the quantification of possible sources of error (uncertainty) during chemical analysis of the sample. An assessment of these potential errors (uncertainties) provide an indication of the data reliability. Possible sources of error include sample contamination, matrix interferences, analytical method error, and poor instrument calibration.

Error estimates are determined from the analysis of standards, spike recoveries, blanks, and sample duplicate analyses.

The quality control data for this tank has been summarized in Appendix D. Table D-1 presents quality control data for cores 58 and 59 where as Table D-2 reports the quality control data for the auger samples associated with this tank. These tables provide four kinds of QC data for the analytes requested, standard recovery, preparation blank, spike recovery, and RPD.

Laboratory Standards are used to estimate the accuracy of the analytical method and are evaluated prior to each batch of analyses. Laboratory standards contain the analytes of interest at known concentrations. The standard recovery is the percentage of the known concentration that was measured by the analytical instrument. The criterion for standard recovery is 100 ± 10 %. If the standard recovery is above or below this criterion, then the analytical results might be biased high or low, respectively. As shown in Tables D-1 and D-2, all of the requested analytes were within acceptable recovery ranges except total alpha, which consistently had low recoveries around 81%. Therefore, the total alpha results might be biased low.

Matrix spike analyses are used to estimate the bias of the analytical method caused by matrix interferences. Spike samples are prepared by splitting a waste sample into two aliquots and adding a known amount of a particular analyte to one aliquot but not to the other. The spike recoveries are calculated as follows:

$$Spike\ Recovery = \frac{(Sample + Spike\ Result) - Sample\ Result}{Spike} \times 100\%$$

The quality control criterion for matrix spikes is 100 ± 10% recovery. If the spike recovery is above or below this criterion, the matrix interferences may be biasing the sample results. Nearly all of the spike recoveries fell within the acceptable tolerance limits. Two total alpha results (95-AUG-016 second quarter segment and core 58, segment 1) and one Ni results (95-Aug-016, third quarter segment) were marginally below the threshold at 89.01%, 89.9%, and 88.0%, respectively. It was felt that these results did not indicate any major matrix interference biases.

Preparation blanks are used to identify any sample contamination that was introduced in the laboratory during the process of sample breakdown, digestion, and dilution. A preparation blank of deionized water is prepared and all sample preparation and analytical procedures that are conducted on the samples are also performed on the blank. The presence of large concentrations of analytes, relative to the concentration of that analyte in the sample, can bias the results. Although there were numerous detections of analytes in the preparation blanks, most of these were orders of magnitude below the concentration of the analyte in the sample. The only exception to this was TOC. TOC was found in all four determinations (see Tables D-1 and D-2). These blank concentrations ranged from 19.1 µg/g to 37.2 µg/g. The average TOC concentration for tank 241-C-111 was 1,250 µg/g. The highest blank concentration represents only 3% of the average sample concentration and is not considered to be a significant bias.

Random analytical error can be estimated by comparing sample and duplicate results. Currently, the RPD is used to quantify this error for each sample-duplicate pair. The Tank Safety Screening DQO set the tolerance limit at 10%. Out of 31 RPD determination, 9 were greater than the 10% threshold. However, only 2 results were greater than 25%. Although over a quarter of the determinations were greater than the threshold, the 10% limit is very stringent and the results are not felt to be greatly biased.

5.1.3 Data Consistency Checks

Data consistency can be verified by inspection of the analytical results for samples taken from the same riser. Major discrepancies between analytical results of samples taken from the same riser would indicate data inconsistency and unreliability. The consistency of the analytical data for tank 241-C-111 cannot be adequately evaluated with the currently available data. Core 59 and auger 95-AUG-017 were taken from the same riser (riser 3) but TGA and DSC are the only two tests common to both samples. By inspection and statistical results, TGA and DSC for these two samples are consistent with each other. However,. TGA and DSC are not consistent with other observations from the tank.. Core 58 and 95-AUG-016 were both taken from riser 6. However, the auger sample was analyzed as quarter segments and the core sampled was composited. The auger sample showed the presence of significant vertical heterogeneity (see Table 5-4) and a comparison of the quarter segment level data to the composite data would not be valid. Vertical trends exist in the data and are presented in Table 5-4.

5.1.3.1 Comparison of Results from Different Methods

Comparison of results from different analytical methods may help identify problems with the data set or may indicate the existence of other chemical species in the sample. There were insufficient data to complete such a comparison for tank 241-C-111.

5.1.3.2 Mass and Charge Balance

The principal objective in performing a mass and charge balance is to determine if the measurements are self-consistent. It is vital that a complete set of anion and metal results are available for an accurate assessment. A complete set of anion results is not available for tank 241-C-111 so mass and charge balances were not completed. However, the fraction of chemical constituents in the waste that have been identified can be estimated based on the available information. The highest concentration result for each constituent, regardless of sample preparation, was used. All concentration information can be found in Appendix A. The water concentration is derived from the average weight percent by multiplying by 10,000 (water = 316,000).

The results indicate, using only metals and water, approximately 63% of the constituents in the tank have been identified. This fraction would increase if assumptions were made concerning the most likely speciation of each constituent (e.g. phosphorous is primarily present as the phosphate ion).

5.3 TANK WASTE PROFILE

An evaluation of the tank waste profile for tank 241-C-111 is limited by the number of analyses and sample points. Thermogravimetric analysis of samples from core 58 showed that the dark brown sludge of core 58 exhibited two transitions, one in the region of water and one above the region of water. The off-white sample of 95-AUG-003 exhibited no transition in the region of free water. It did, however, exhibit a transition in the range of approximately 260-320 °C. Given the observed aluminum content of the tank and the temperature range of the endotherm, it is likely that the weight loss was from dehydration of aluminum hydroxide.

In core 58, obtained from riser 6, there appears to be free water in the waste matrix. Visually, the sample was dark brown and clay-like, and there was a substantial mass loss in the temperature range from ambient to 120 degrees C (suggesting that the mass was free water). The 95-AUG-003 sample, obtained from riser 2, does not appear to have any free water associated with it. Visually, it was off-white, and crumbly, and the TGA did not show any mass loss in the temperature range from ambient to 120 degrees C (suggesting that there was no free water). All of these observations taken together point towards a large horizontal heterogeneity in the tank. Photographs of the tank interior cannot confirm this conclusion, since the latest pictures of the tank interior are obscured by a fog. Also, there was a low amount of bismuth observed in this tank. It is predicted that there is a large amount of bismuth located in the dish of the tank, which cannot be sampled because of the location of the risers. Therefore, the Tank Layering Model cannot be confirmed, and no comments can be made concerning first cycle decontamination waste from the bismuth phosphate process (1C waste). The prediction of the existence of ferrocyanide, however, is confirmed by the samples and the existence of nickel.

Because risers 2 and 3 and riser 6 are located at opposite sides of the tank, common observations between these risers are of interest. A summary of these observations are shown is Table 5-1.

Three core samples, four auger samples, a field blank, and a hot cell blank were taken from three different risers of Tank 241-C-111. For core 58 (riser 6), core 59 (riser 3), and auger 95-AUG-003 (riser 2,) a single segment was recovered and homogenized. Because of the availability of the data, horizontal heterogeneity was analyzed between core 58 (riser 6) and 95-AUG-003 (riser 2) for certain analytes, and between core 58 (riser 60) and core 59 (riser 3) for certain other analytes. Two analytical measurements, the sample and the duplicate, were obtained from each subsample. It is assumed that all subsamples and analytical measurements were analyzed independently of one another. Enough sample was recovered from core 58 to complete an analysis for most analytes of interest, whereas the recovery from core 59 (riser 3) was so low that only analyses of the primary DQO analytes were possible. Since only primary

DQO analyses were directed, the ICP results, with the exception of nickel, are considered for information purposes only. These results were obtained from the data package and may not meet all of the quality control requirements normally applied to ICP analyses where the analyte was specified such as nickel.

Table 5-1. Summary of Common Observations for Risers 2 and 3 and Riser 6

	Riser 2,3	Riser 6
Samples	95-AUG-003	95-AUG-016
	95-AUG-017	Core 58
	Core 59	
Common Observations	Core 59 and 95-AUG-017 White, Dry, Crumbly 95-AUG-003 Brown, Dry, Crumbly	Brown, Wet, Cohesive
	95-AUG-017 and Core 59, no free water observed; weight loss believed to be from the dehydration of aluminum hydroxide 95-AUG-003 free water was detected	Large first transition suggesting free water
	No segment level data to observe vertical heterogeneity	ICP results for 95-AUG-016 suggest vertical heterogeneity
	Horizontal heterogeneity exists between riser 2 and 6 and riser 3 and 6	

A statistical test known as the analysis of variance (ANOVA) was conducted on the analytes shown in Table 5-2 to determine the existence of horizontal heterogeneity across the tank.. The model associated with the ANOVA tests is known as a one-way model. The model is:

$$Y_{ij} = \mu + S_i + A_{ij}$$

where

Y_{ij} = the jth analytical result in the ith core sample
S_i = the deviation from the mean attributed to the location of the core sample i (spatial variability)
A_{ij} = the deviation from the mean attributed to sample j in core sample i

Table 5-2. Horizontal Homogeneity Tests for Tank 241-C-111

Analyte Method	Number of Samples	P-value	Different?
METALS			
ICP.Al	4	.1432	No
ICP.Ca	4	.0074	Yes
ICP.Fe	4	.2487	No
ICP.Pb	4	.0628	No*
ICP.Ni	4	.0299	Yes
ICP.P	4	.0009	Yes
ICP.Si	4	.2771	No
ICP.Na	4	.0034	Yes
ICP.U	4	.0003	Yes
PHYSICAL PROPERTIES			
TGA.% H_2O	7	.0007	Yes
RADIONUCLIDES		%	
APC.total alpha	6	.0001	Yes
GEA.^{137}Cs	4	.0001	Yes

Notes:
ICP = inductively coupled plasma
GEA = gamma energy analysis
TGA = thermogravimetric analysis
P-value = the smallest probability at which the hypothesis of no difference between the two means can be rejected

The ANOVA generates a statistic called a p-value which is compared with a standard significance level ($\alpha = 0.05$). If a p-value is below 0.05, there is sufficient evidence to conclude that the subsample means are significantly different from each other. However, if a p-value is above 0.05, there is not sufficient evidence to conclude that the subsamples are significantly different from each other. The assumptions associated with these tests are 1) the population from which these samples came were normally distributed, and 2) equal variances exist between the two cores (or the core and auger). A two-tailed test was used.

The results of the ANOVA tests are shown in Table 5-2. Based on the results for these twelve analytes, the distribution of waste in the tank appears to be heterogeneous. The asterisk shown for lead indicates that this p-value was close to .05. Since there are little data (and therefore very

few degrees of freedom (see chapter 10 of the Tank Characterization Reference Guide), the ANOVA results are questionable. These differences found in the statistical tests could be caused by the sampling methods (systematic error) or the location of the risers (limits opportunity of obtaining a random sample) through which these samples were taken. The differences found in the statistical tests are further supported by the visually observed differences in the two cores (risers from opposite sides of the tank) from the field observations.

Table 5-3 displays the subsegment analyses for 95-AUG-016. For selected analytes, statistical analyses on the vertical distribution were performed using the same one-way ANOVA model presented previously. Also, tests for linear and quadratic trends as a function of depth were performed. Table 5-4 displays the results of these analyses.

Table 5-3. Subsegment Analyses for Auger-016 of Tank 241-C-111

Analyte Method	Aliquot	2nd Quarter	3rd Quarter	Bottom Quarter
METALS				
ICP.Al	Sample	1.36E+05	4.50E+04	3.62E+04
	Duplicate	2.02E+05	4.72E+04	3.67E+04
ICP.Ca	Sample	2.10E+04	3.55E+04	1.54E+04
	Duplicate	2.75E+04	4.38E+04	1.54E+04
ICP.Fe	Sample	9.94E+03	6.78E+03	4.94E+03
	Duplicate	1.31E+04	8.03E+03	4.95E+03
ICP.Mg	Sample			3.77E+02
	Duplicate			
ICP.Na	Sample	3.25E+04	4.88E+04	1.36E+05
	Duplicate	4.07E+04	5.46E+04	1.37E+05
ICP.Ni	Sample	1.55E+04	2.24e+04	1.15E+04
	Duplicate	2.08E+04	2.73E+04	1.14E+04
ICP.P	Sample	9.46E+03	2.17E+04	5.25E+04
	Duplicate	1.46E+04	2.57E+04	5.27E+04
ICP.S	Sample		1.31E+03	
	Duplicate		1.61E+03	
ICP.Si	Sample	3.90E+03	3.14E+03	3.09E+03
	Duplicate	6.21E+03	3.41E+03	3.10E+03
ICP.Sr	Sample	1.21E+02	1.65E+02	1.07E+02
	Duplicate	1.69E+02	1.93E+02	1.03E+02
ICP.U	Sample	9.90E+03	1.21E+04	1.24E+04
	Duplicate	1.56E+04	1.13E+04	1.27E+04
ICP.Zr	Sample	1.13E+02	1.52E+02	2.20E+02
	Duplicate		1.20E+02	2.45E+02

Table 5-4. Statistical Analyses of the Vertical Distribution for Auger-016 of Tank 241-C-111

Analyte Method	Vertical Difference?	Trend Linear and/or Quadratic	Comments
METALS			
ICP.Al	Yes	Linear	Downward linear trend as function of depth
ICP.Ca	Yes	Quad	Trend not constant; rises and then falls as a function of depth
ICP.Fe	Yes	Linear	Downward linear trend
ICP.Na	Yes	Both	Linear with a large increase between the 3rd and Bottom quarter segments
ICP.Ni	Yes	Quad	Trend not constant; rises and then falls as a function of depth
ICP.P	Yes	Both	Large increases between all quarter segments
ICP.Si	No	None	No discernable trend
ICP.U	No	None	No discernable trend

From the statistical analyses, vertical heterogeneity does exist, as is expected. Aluminum and iron both have downward linear trends as a function of depth. Calcium and nickel show quadratic trends while phosphorous shows a mixture of linear and quadratic trends (not consistent) as a function of depth. Silica and uranium were not vertically heterogeneous, according to the statistical results.

The behavior of the data suggests that there are at least three waste types represented: PUREX coating waste (CWP), first-cycle ferrocyanide-scavenged waste (TFECN). First-cycle bismuth phosphate waste mixed with coating waste (1C/CW) is expected but cannot be confirmed because of low amounts of bismuth in the samples and the fact that it is believed that much of the bismuth is located in the dish of the tank, which cannot be sampled because no risers are available. The nature of the sampling method (auger) further suggests that the integrity of the sample was not maintained, and ferrocyanide waste was partially commingled with the others. One other likely waste type that is indicated in the tank, both from historical sources and the analytical data is Hot Semi-Works waste. The elevated ^{90}Sr content observed is not indicated from any of the principal waste types disposed in this tank. However, because of the limited set

of analyses performed, and the observed heterogeneity (in both vertical and horizontal directions), confirmation of the presence of Hot Semiworks waste is not possible.

5.4 COMPARISON OF ANALYTICAL AND TRANSFER HISTORY INFORMATION

A comparison of the historical transfer based tank content information to the sampling and analytically derived tank content information was performed and is presented as Table 5-6. The first column presents the analytes included in the comparison. Because of the limited suite of safety screening analyses, only 16 analytes had both historically and analytically derived estimates of concentration. The second and third columns respectively present the HTCE and analytically derived estimates for analyte concentration. These data were extracted from Tables 2-5 and 4-2. With exception to water, which is presented as weight percent (wt%), all chemical constituents are presented in units of parts per million (ppm) which is the same as μg/g. The radiological constituent concentrations are presented in units of μCi/g. It must be noted that only total alpha was measured on the waste samples. An assumption was made for the purposes of comparison that all alpha radiation was generated by Pu. In addition, the P and total CN^- measured on the samples were converted to PO_4^{-3} and $Fe(CN)_6^{-4}$, respectively, to allow additional data points for comparison. The fourth column presents the relative magnitude of the difference between the two estimating methods. This difference is presented in the form of a ratio between the HTCE estimate and the analytically derived estimate. The comparison ratio was calculated as follows:

$$\textit{Comparison Ratio} = \frac{\textit{Higher Estimate}}{\textit{Lower Estimate}}$$

A negative sign in front of the ratio implies that the HTCE estimate was lower than the sampling derived estimate. The last two columns on the table present the HTCE based and the sampling based inventories.

Of the 16 analytes included in the comparison, only 4 analytes differed by less than a factor of 2.5 and nearly half the analytes (7) differed by greater than a factor of 4. Exactly half of the analytes (8) were predicted in higher concentrations by the HTCE relative to the sampling based estimate and half were estimated lower. The three most notable discrepancies between the two estimation methods were Ni, $Fe(CN)_6^{-4}$, and ^{90}Sr. The HTCE estimated that Ni would be only a minor constituent of this tank's waste (3,020 ppm). However, the sampling and analysis found Ni to be present as one of the most prevalent elements in percentage quantities (2% or 20,700 ppm). The HTCE also predicted that appreciable amounts of ferrocyanide would be present (6,760 ppm) but the sampling and analysis found very little (208 ppm). This discrepancy is explained by the ferrocyanide aging process (Lilga et al. 1993, 1994). The most glaring difference was the ^{90}Sr estimate. The HTCE predicted only 0.41 μCi/g whereas the sampling and analysis found approximately 4,160 μCi/g. The ^{90}Sr estimates differed by a factor of 10,200. This is likely from the presence of Hot Semi-Works waste that was not predicted by the Tank Layering Model.

Table 5-5. Comparison of HTCE vs Sampling Estimates of Concentration and Inventory

	Concentration			Inventory	
	HTCE	Sampling	Ratio	HTCE	Sampling
Chemical Constituent	PPM	PPM		Kg	Kg
Na	70,900	27,000	2.62	21,100	7,560
Al	45,600	128,000	-2.80	13,500	35,800
Fe	19,400	54,700	-2.82	5,760	15,800
Cr	231	222	1.04	69	622
Bi	8,890	1,650	5.39	2,640	462
Ni	3,020	20,700	-6.90	899	5,800
Ca	2,460	11,700	-4.76	731	3,280
PO_4^{-3} (P)	61,900	33,966	1.82	18,400	NA
Si	2,060	8,920	-4.33	614	2,500
U	9,010	15,100	-1.67	2,680	4,230
$Fe(CN)_6^{-4}$	6,760	208	32.50	1,830	43
TOC	1,580	1,250	1.26	NA	350
H20 (WT%)	70.0%	21.1%	3.32	NA	59,100
Radiological Constituents	µCi/g	µCi/g	%	Ci	Ci
Pu (total Alpha)	0.18	0.88	-5.02	874	248
Cs	118	43	2.73	3,500	12,100
Sr	0.41	4,160	-10,200	121	1,160,000

5.5 EVALUATION OF PROGRAM REQUIREMENTS

The sampling and analysis of core samples taken in 1994 and auger samples taken in 1995 were performed to meet the requirements of ferrocyanide and safety screening DQOs. Evaluation of data in terms of operational, environmental, or process development requirements is not possible.

5.5.1 Safety Evaluation

Data criteria identified in the safety screening DQO (Babad and Redus 1994) and the ferrocyanide DQO (Meecham et al 1994) are used to assess the safety of the waste in Tank 241-C-111.

The ferrocyanide DQO requires samples for Tank 241-C-111 to be taken from two widely spaced risers. Four sampling efforts (obtaining 3 core and four auger samples) were required to obtain sufficient sample material to complete analyses. Samples obtained from risers 2, 3, and 6 are from opposite sides of the tank and meet the widely spaced riser criteria. Differential scanning calorimetry analyses were endothermic with one exception: core 58 exhibited an exothermic reaction of -41.1 J/g, with a -34.5 J/g value for the duplicate (the results given are based on a wet weight). The respective corresponding dry weight results were -60.1 J/g and -50.4 J/g. This clearly satisfies the criterion for ferrocyanide tanks requiring energetics to be less than -481 J/g (-115 cal/g). The average moisture content for this tank is 21.2%. The ferrocyanide safety limit for moisture content is dependent on fuel content. Current estimates of fuel content as $Na_2NiFe(CN)_6$, based on the average cyanide measurement of 37.6 µg/g from Table 4-2, is 0.01% (dry basis) and falls into the "safe" region of less than 8 WT% fuel for ferrocyanide tanks (Meacham et al. 1994). Since cyanide is known to degrade, the $Na_2NiFe(CN)_6$ inventory (10,451 kg) that was estimated to have been placed in the tank (Borsheim and Simpson 1991) was compared to the inventory estimate based upon the sampling and analysis data of 28.1 kg. These calculations indicated that the tank is currently considered safe and that most of the original ferrocyanide that was placed in the tank has been degraded. Calculations illustrating these points are shown below:

$$\text{Current Fuel Content} = \frac{37.6\ \mu g\ CN^-}{g\ waste} \cdot \frac{1\ g}{10^6\ \mu g} \cdot \frac{316.7\ g\ Na_2NiFe(CN)_6}{156\ g\ CN^-} \cdot \frac{1}{1 - .211\ (Wt\%H_2O)} = 0.01\ wt\%\ (Dry\ Basis)$$

$$\text{Current Fuel Inventory} = \frac{0.0010\ g\ Na_2NiFe(CN)_6}{g\text{-}waste} \cdot \frac{1.3g\text{-}waste}{ml\text{-}waste} \cdot \frac{1000\ ml}{L} \cdot 216{,}000\ L\text{-}waste \cdot \frac{1\ kg}{1000\ g} = 28.1\ kg$$

The safety screening DQO makes additional assessment regarding the tanks safety for interim storage. Although Core sample 59, segment 1, and 95-AUG-017 had moisture contents lower than the notification limit of 17% as stated for organics in the Safety Screening Data Quality Objective, all remaining moisture measurements and the average water content were above the limit. This indicates that the measurements of the moisture content for these samples exceeds the limiting content of 17% identified in the safety screening DQO. Two additional factors used in assessing the safety of the waste are the heat generation level and temperature of the waste. Heat in the tanks is typically generated by radioactive components of the waste. The primary contributors to heat generation in the 241-C-111 waste are assumed to be ^{137}Cs and ^{90}Sr. The amount of heat resulting from radioactivity in the tank was calculated and is displayed in Table 5-6. The estimated heat load for the tank is 7.83E+03 Watts (2.67E+04 British Thermal Units/hour [BTU/hr]). This calculated heat load can be compared to other estimates of heat load in this tank. McLaren (1994) estimated 1600 Watts and Crowe et al. (1993) predicts 1900 Watts. Based on the tank temperatures, the lower heat load estimates are probably more accurate. All three estimates are well below the 40,000 BTU/hr criterion used to distinguish a high heat tank from a low heat tank (Bergmann 1991). The recorded tank temperature for the last several years has ranged from a minimum of approximately 10.7° C (51°F) to a maximum of approximately 40.9° C (105.6° F).

Table 5-6. Tank 241-C-111 Projected Heat Load

Radionuclide	Ci	BTU/hr	Watts
^{137}Cs	1.21E+04	1.95E+02	5.70E+01
^{90}Sr	1.16E+06	2.65E+04	7.77E+03
Total		2.67E+04	7.83E+03

Notes:
Ci = curie

The potential for criticality is assessed using either total alpha or plutonium analysis. The safety screening criterion is 1 gram/liter (g/L); total alpha, however, is measured in μCi/g rather than g/L. To convert the notification limit for total alpha into a number more readily comparable to total alpha results, it was assumed that all alpha decay originates from ^{239}Pu. Assuming a tank density of 1.30 g/mL and using the specific activity of ^{239}Pu (0.0615 Ci/g), the decision criterion was converted to 47.3 μCi/g as shown:

$$\left(\frac{1\ g}{L}\right)\left(\frac{1\ L}{10^3\ mL}\right)\left(\frac{1\ mL}{density\ 1.3\ g}\right)\left(\frac{0.0615\ Ci}{1\ g}\right)\left(\frac{10^6\ \mu Ci}{1\ Ci}\right) = \frac{47.3\ \mu Ci}{density\ g}$$

The total alpha results (0.884 μCi) are well below this limit. Table 5-7 summarizes the results of the analyses required by the DQO, sorted by sampling point. The table also provides the relative percent differences between the original sample and its duplicate.

The tank headspace has been characterized but the vapor sampling and analysis data and its interpretation are included in a separate report (Huckaby, 1995). The analysis of Tank 241-C-111 does not fully address the safety screening requirements because Core 59 Segment 1 and 95-AUG-017 was below the minimum notification limit for water content for an organic safety issue tank (Babad and Redus 1994). However, all of the other moisture measurements and the average water content were above the notification limit and the tank has a minimal fuel content. Historical tank content information, in combination with sampling and analysis data, indicate that safety issues regarding fuel level, water content, heat, and criticality are not violated.

5.5.2 Operational Evaluation

Tank 241-C-111 contains no supernatant and is therefore not a candidate for operational analyses.

5.5.3 Environmental Evaluation

Tank 241-C-111 was not characterized to designate the waste or evaluate environmental compliance issues. It was characterized to meet specified requirements regarding safe management and storage of the waste and worker safety. Specific organic (volatile or semi-volatile) analyses were performed on the tank in 1994 (Huckaby 1995). The 1994 core samples of the waste in the tank show that notable concentrations of chromium and lead with some uranium are present.

5.5.4 Process Development Evaluation

Analyses of the sludge in the tank for metal constituents are important for evaluating the disposal waste form that will be produced in the vitrification process and for identifying components that may affect the treatment and disposal process. Because the sludges may be blended, washed, and treated before disposal, there are no specific criteria at this time for the parameters measured. No analyses were performed on water soluble fractions of the waste; therefore, no solubility information was obtained. Physical properties, solubilities, chemical constituents, etc., needed for the disposal programs will be defined in the appropriate DQOs..

Table 5-7. Safety Screening DQO Decision Variables and Criteria

Safety Issue	Primary Decision Variable	Decision Criteria Threshold	Auger or Core Location	Analytical Value	RPD (%)
Core 58					
Ferrocyanide/ Organic	Total Fuel Content	-481 J/g (-115 cal/g)	Segment 1	-55.3 J/g	17.5
Organic	Percent Moisture	17 WT%	Segment 1	31.7 WT%	5.04
Criticality	Total Alpha	47.3 µCi/g (1 g/L)[1]	Segment 1	2.45 µCi/g	11.9
Flammable Gas	Flammable Gas	N/A	---	---	
Core 59					
Ferrocyanide/ Organic	Total Fuel Content	-481 J/g (-115 cal/g)	Segment 1	No exotherms observed	
Organic	Percent Moisture	17 WT%	Segment 1	0	0
Criticality	Total Alpha	47.3 µCi/g (1 g/L)[1]	Segment 1	0.123 µCi/g	3.3
Flammable Gas	Flammable Gas	N/A	---	---	
95-AUG-003					
Ferrocyanide/ Organic	Total Fuel Content	481 J/g (115 cal/g)	Whole Segment	No exotherms observed	
Organic	Percent Moisture	17 WT%	Whole Segment	28.1 WT%	24[1]
Criticality	Total Alpha	47.3 µCi/g (1 g/L)[1]	---	---	---
Flammable Gas	Flammable Gas	N/A	---	---	

[1]Relative Standard Deviation (RSD) of three sample results

Table 5-7. Safety Screening DQO Decision Variables and Criteria

Safety Issue	Primary Decision Variable	Decision Criteria Threshold	Auger or Core Location	Analytical Value	RPD (%)
95-AUG-016					
Ferrocyanide/ Organic	Total Fuel Content	-481 J/g (-115 cal/g)	Second quarter	No exotherms observed	
			Third quarter		
			Bottom quarter		
Organic	Percent Moisture	17 WT%	Second quarter	28.1 WT%	0.36
			Third quarter	40.6 WT%	8.75[1]
			Bottom quarter	44.3 WT%	0.23
Criticality	Total Alpha	47.3 µCi/g (1 g/L)[1]	Second quarter	0.748 µCi/g	17.8
			Third quarter	0.392 µCi/g	6.12
			Bottom quarter	0.396 µCi/g	5.31
Flammable Gas	Flammable Gas	N/A	---	---	
95-AUG-017					
Ferrocyanide/ Organic	Total Fuel Content	-481 J/g (-115 cal/g)	Whole Segment	No exotherms observed	
Organic	Percent Moisture	17 WT%	Whole Segment		1.42
Criticality	Total Alpha	47.3 µCi/g (1 g/L)[1]	---	---	---
Flammable Gas	Flammable Gas	N/A	---	---	

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6.0 CONCLUSIONS AND RECOMMENDATIONS

Three sets of samples have been taken of the waste in Tank 241-C-111. The three sets of samples consist of a supernate sample obtained in 1975, three push-mode core samples taken in April of 1994, and four auger samples taken in January and March of 1995. Only the two more recent sets of samples were used for characterization of the tank waste since the supernatant from which the 1975 sample were taken has since been transferred out of Tank 241-C-111. The 1994 and 1995 samples were ferrocyanide tank and safety screening samples. These sampling events were performed in accordance with the *Tank 241-C-111 Tank Characterization Plan* (Bell 1994, Schreiber 1994, and Schreiber 1995). Sampling and analysis procedures are discussed in detail in the *Tank Characterization Reference Guide* (De Lorenzo et al. 1994).

The core sample recoveries of the three core samples was poor. The two cores (58 and 60) taken from riser 6 collected on 17% of the expected waste and core 59 (riser 3) captured nearly 0% (1.7 g) of the waste anticipated. The poor recoveries prompted another round of sampling using the auger sampling method. The first two auger samples collected from this tank (95-AUG-002 and 95-AUG-003) also did not obtain large quantities of sample prompting yet another round of two augers (95-AUG-016 and 95-AUG-017). Only auger 95-AUG-016 captured an appreciable amount of sample material. The data available are consistent with expected characteristics of the three waste types (PUREX Cladding waste, ferrocyanide scavenged waste, and first cycle bismuth phosphate waste) predicted to be in the tank based upon historical process knowledge. The data also suggest the presence of a fourth waste type, Hot Semi-Works waste, that was known to have been placed in the tank but was no longer predicted to remain by the Tank Layering Model.

The surface level of tank 241-C-111 was measured from three different risers. These measurements indicate that the waste surface differs by approximately 30 cm (1 ft) from one side of the tank to the other with an approximate gradient of 1.41 cm per m (0.17 in. per ft.). A contour map and surficial diagram of the surface was developed based upon the three surface level measurements. The waste volume estimated for the tank based upon the three measurements did not differ significantly from the estimate of 216 kL (57 kgal) reported in Hanlon (1995). Therefore, the Hanlon estimate has been validated and used in this report.

The sampling and analysis data were compared to the historical tank content estimates (HTCE) (Brevick et al. 1995). Of the 16 analytes included in the comparison, only 4 analytes differed by less than a factor of 2.5 and nearly half the analytes (7) differed by greater than a factor of 4. Because of the disparities between the two estimation methods and the apparent presence of a waste type (Hot Semiworks waste) not predicted by the Tank Layering Model nor included in the HTCE, it is recommended that the HTCE not be used for this tank. Instead, the sampling and analysis based tank content estimates (Table 4-2) should be considered the best source of information on the waste.

The analytical data collected from this tank met all of the criteria identified in the tank safety screening DQO (Babad 1994) and the ferrocyanide DQO (Meacham et al 1994). Samples were collected and analyzed from three widely spaced risers (Risers 2, 3 and 6). It has been shown that the inventory of ferrocyanide has degraded over time from 10,451 kg to only 28.1 kg. The DSC measurements did not identify any exothermic reactions above the 481 J/g criteria and the TGA analyses indicate that the average water content is above the 17% minimum threshold. Although the TGA Core 59 Segment 1 and 95-AUG-017 (both taken from Riser 3) were below the minimum notification limit (17%) for water content, all of the other moisture measurements were above the notification limit and the tank has a minimal fuel content. The calculated heat load and estimated plutonium content are both well below the respective criteria of 40,000 BTU/hr and 1 g/l. The tank headspace has been characterized but the vapor sampling and analysis data and its interpretation are included in a separate report (Huckaby, 1995). Historical tank content information, in combination with sampling and analysis data, indicate that safety issues regarding fuel level, water content, heat, and criticality are not violated.

The data are consistent with the waste types thought to be present (with the addition of Hot Semiworks waste) and does not suggest that there are any safety issues associated with this tank for interim safe storage. Because of the very small total volume of waste, this tank will not be a significant driver for the retrieval, pretreatment, or disposal programs and further sampling efforts to provide a more complete understanding of this tank are not recommended.

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APPENDIX A. ANALYTICAL RESULTS FROM AUGER AND CORE SAMPLING OF TANK C-111

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APPENDIX A. ANALYTICAL RESULTS FROM AUGER AND CORE SAMPLING OF TANK C-111

INTRODUCTION

Appendix A presents the chemical and radiological characteristics of Tank 241-C-111 in a tabular form, in terms of the specific concentrations of metals, radionuclides, and physical properties.

The data table for each analyte lists laboratory sample identification, a description of where the sample was obtained, an analytical concentration for each sample, an evaluated concentration which is the mean of the appropriate analytical concentrations (for this tank, the most appropriate concentration values were those derived from direct or fusion digested samples), a relative percent difference for each sample category, and a projected tank inventory for the particular analyte using the highest concentration as a base. The data are listed in scientific notation.

TABLE DESCRIPTION

The tables are divided into groups dependent on the characteristics of the analytes.

Analyte Characteristic	Table Number
Metals	Table A-1
Radionuclides	Table A-2
Physical Properties	Table A-3
Total Organic Carbon	Table A-4
Cyanide	Table A-5

Standard abbreviations are used to describe analytical methods.

Metals:	ICP - Inductively Coupled Plasma (generic for all metals unless otherwise known)
Radionuclides:	GEA - Gamma Energy Analysis
	APC - Alpha Proportional Counting
	BPC - Beta Proportional Counting
Physical Properties:	TGA - Thermogravimetric Analysis

COLUMN HEADINGS

The "Analyte" column contains, in addition to the name of the analyte or physical characteristic, information about the method of measurement, and where applicable, information about the method of digestion.

Digestion methods will be denoted for those analytes that were digested by more than one method. Digestion methods used are abbreviated: a - acid digestion; and f - potassium hydroxide fusion, followed by acid digestion. Analytes may also be measured directly on an undigested sample and these are abbreviated: d-direct.

The analyte and method are presented as follows: "method.analyte," or, (where applicable) "method.digestion.analyte." For example, the specific concentration of ^{137}Cs was measured by direct gamma energy analysis and is listed "GEA.d.137Cs" A specific concentration of Pb was determined by the inductively coupled plasma method which was preceded by acid digestion, and is listed as "ICP.a.Pb."

The "Sample Number" column lists the laboratory sample from which the analyte was measured; this identification number is different from the number assigned to the samples at the tank farm. Sampling rationale, locations, and descriptions of sampling events are contained in Section 3.0.

Column three describes the core that each sample was derived from. Core 60 was not analyzed due to insufficient material, while GEA, TGA, total alpha, and DSC analyses were performed on core 59. All analyses were performed on core 58 (Rice 1994).

"Result" is the specific concentration of the analyte determined at different sampling points. For all analyses, duplicate sample results appear in the table following the primary sample result. 'ND' is used to indicate results less than the detection limit.

"Mean" is the average between the primary sample and its duplicate.

Column 6 ,"Relative Percent Difference", is the absolute value of the difference between the sample result and duplicate result divided by the mean and multiplied by 100.

Column 7, "Projected Inventory", is the product of the concentration of the analyte and the volume of the waste in the tank (57 kgal or 216 kL).

For selected analytes, a "Comp Mean" (composite mean) is provided along with an RPD and a Projected Inventory. These are the means using the composite data that was utilized in the statistical analyses, the RPD between those means, and the Projected Inventory associated with those means.

<u>Formula:</u>

(Total Waste Volume)(Result)(Density)(Conversion Factors) = Projected Inventory

(216,000 L)(Result µg/g)(1.30 g/mL)(1,000 mL/L)(kg/1E+09 µg) = Projected Inventory

Table A-1. Tank 241-C-111 Analytical Data: Aluminum

Analyte	Sample Number	Sample ID	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Al	K211-8755	58	1.21E+05	1.22E+05	1	
	K211-8855	58	1.22E+05			
ICP.f.Al	k211-6755	58	1.45E+05	1.37E+05	12	
	k211-6855	58	1.29E+05			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.Al	S95T000123	95-AUG-003	1.18E+05	1.18E+05	0.2	
	S95T000123	95-AUG-003	1.18E+05			
	S95T000573	95-AUG-016	1.36E+05	1.69E+05	39	
	S95T000573	95-AUG-016	2.02E+05			
	S95T000574	95-AUG-016	4.50E+04	4.61E+04	4.8	
	S95T000574	95-AUG-016	4.72E+04			
	S95T000575	95-AUG-016	3.62E+04	3.65E+04	1.4	
	S95T000575	95-AUG-016	3.67E+04			
				Comp Mean		
				1.28E+05	15	3.58E+04

Table A-1. Tank 241-C-111 Analytical Data: Bismuth

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		Core	µg/g	µg/g	%	kg
ICP.a.Bi	K211-8755	58	2.09E+03	2.13E+03	3	
	K211-8855	58	2.16E+03			
ICP.f.Bi	K211-6755	58	1.69E+03	1.65E+03	5	
	K211-6855	58	1.60E+03			
				Comp Mean		
				1.65E+03	5	4.62E+02

Table A-1. Tank 241-C-111 Analytical Data: Cadmium

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		Core	µg/g	µg/g	%	kg
ICP.a.Cd	K211-8755	58	ND			
	K211-8855	58	ND			
ICP.f.Cd	K211-6755	58	ND	3.76E+01	---	
	K211-6855	58	3.76E+01			
				Comp Mean		
				3.76E+01	---	1.05E+01

Table A-1. Tank 241-C-111 Analytical Data: Calcium

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Ca	K211-8755	58	9.07E+03	9.11E+03	1	2.56E+03
	K211-8855	58	9.14E+03			
ICP.f.Ca	K211-6755	58	8.65E+03	8.03E+03	16	
	K211-6855	58	7.40E+03			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.Ca	S95T000123	95-AUG-003	1.52E+04	1.54E+04	1.8	
	S95T000123	95-AUG-003	1.55E+04			
	S95T000573	95-AUG-016	2.10E+04	2.43E+04	26.7	
	S95T000573	95-AUG-016	2.75E+04			
	S95T000574	95-AUG-016	3.55E+04	3.97E+04	20.9	
	S95T000574	95-AUG-016	4.38E+04			
	S95T000575	95-AUG-016	1.54E+04	1.54E+04	0	
	S95T000575	95-AUG-016	1.54E+04			
				Comp Mean		
				1.17E+04	63	3.28E+03

Table A-1. Tank 241-C-111 Analytical Data: Cerium

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Ce	K211-8755	58	7.95E+02	7.99E+02	1	
	K211-8855	58	8.03E+02			
ICP.f.Ce	K211-6755	58	5.67E+02	5.76E+02	3	
	K211-6855	58	5.85E+02			
				Comp Mean		
				5.76E+02	3	1.61E+02

Table A-1. Tank 241-C-111 Analytical Data: Chromium

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Cr	K211-8755	58	1.31E+02	1.33E+02	2	
	K211-8855	58	1.34E+02			
ICP.f.Cr	K211-6755	58	1.16E+02	1.15E+02	2	
	K211-6855	58	1.14E+02			
				Comp Mean		
				1.15E+02	2	6.22E+02

Tank A-1. Tank 241-C-111 Analytical Data: Copper

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Cu	K211-8755	58	7.23E+01	6.62E+01	19	
	K211-8855	58	6.00E+01			
ICP.f.Cu	K211-6755	58	7.52E+01	7.38E+01	4	
	K211-6855	58	7.23E+01			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.Cu	S95T000123	95-AUG-003	5.75E+01	5.76E+01	0.2	
	S95T000123	95-AUG-003	5.76E+01			
				Comp Mean		
				6.57E+01	24.7	1.84E+02

Table A-1. Tank 241-C-111 Analytical Data: Iron

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Fe	K211-8755	58	6.20E+04	6.26E+04	2	1.76E+04
	K211-8855	58	6.31E+04			
ICP.f.Fe	K211-6755	58	5.67E+04	5.56E+04	4	
	K211-6855	58	5.45E+04			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.Fe	S95T000123	95-AUG-003	5.35E+04	5.38E+04	1.2	
	S95T000123	95-AUG-003	5.40E+04			
	S95T000573	95-AUG-016	9.94E+03	1.15E+04	27	
	S95T000573	95-AUG-016	1.31E+04			
	S95T000574	95-AUG-016	6.78E+04	7.41E+04	17	
	S95T000574	95-AUG-016	8.03E+04			
	S95T000575	95-AUG-016	4.94E+04	4.95E+03	0.2	
	S95T000575	95-AUG-016	4.95E+04			
				Comp Mean		
				5.47E+04	3.3	1.53E+04

Table A-1. Tank 241-C-111 Analytical Data: Lanthanum

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		Core	µg/g	µg/g	%	kg
ICP.a.La	K211-8755	58	5.01E+02	5.09E+02	3	
	K211-8855	58	5.17E+02			
ICP.f.La	K211-6755	58	4.27E+02	4.32E+02	2	
	K211-6855	58	4.37E+02			
				Comp Mean		
				4.32E+02	2	1.21E+02

Table A-1. Tank 241-C-111 Analytical Data: Lead

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		Core	µg/g	µg/g	%	kg
ICP.a.Pb	K211-8755	58	6.02E+03	6.07E+03	2	
	K211-8855	58	6.12E+03			
ICP.f.Pb	K211-6755	58	5.98E+03	5.91E+03	3	
	K211-6855	58	5.83E+03			
		Auger	µg/g	µg/g	%	kg
ICP.f.Pb	S95T000123	95-AUG-003	5.49E+03	5.55E+03	1.6	
	S95T000123	95-AUG-003	5.60E+03			
				Comp Mean		
				5.73E+03	6.3	1.60E+03

Table A-1. Tank 241-C-111 Analytical Data: Magnesium

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		Core	µg/g	µg/g	%	kg
ICP.a.Mg	K211-8755	58	5.60E+02	5.13E+02	18	
	K211-8855	58	4.66E+02			
ICP.f.Mg	K211-6755	58	4.58E+02	4.34E+02	11	
	K211-6855	58	4.10E+02			
		Auger	µg/g	µg/g	%	kg
ICP.f.Mg	S95T000123	95-AUG-003	2.67E+03	2.64E+03	2.3	
	S95T000123	95-AUG-003	2.61E+03			
				Comp Mean		
				1.54E+03	144	4.31E+02

Table A-1. Tank 241-C-111 Analytical Data: Manganese

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
Solid		Core	µg/g	µg/g	%	kg
ICP.a.Mn	K211-8755	58	1.94E+02	1.97E+02	3	
	K211-8855	58	1.99E+02			
ICP.f.Mn	K211-6755	58	1.85E+02	1.77E+02	9	
	K211-6855	58	1.69E+02			
		Auger	µg/g	µg/g	%	kg
ICP.f.Mn	S95T000123	95-AUG-003	4.34E+02	4.37E+02	1.4	
	S95T000123	95-AUG-003	4.40E+02			
				Comp Mean		
				3.07E+02	84.7	8.60E+01

Table A-1. Tank 241-C-111 Analytical Data: Neodymium

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		Core	µg/g	µg/g	%	kg
ICP.a.Nd	K211-8755	58	7.99E+02	7.74E+02	1	
	K211-8855	58	7.48E+02			
ICP.f.Nd	K211-6755	58	6.02E+02	6.11E+02	3	
	K211-6855	58	6.20E+02			
				Comp Mean		
				6.11E+02	3	1.71E+02

Table A-1. Tank 241-C-111 Analytical Data: Nickel

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Ni	K211-8755	58	2.13E+04	2.15E+04	2	
	K211-8855	58	2.17E+04			
ICP.f.Ni	K211-6755	58	1.99E+04	2.01E+04	2	
	K211-6855	58	2.02E+04			
	S95T000123	95-AUG-003	2.11E+04	2.13E+04	1.4	
	S95T000123	95-AUG-003	2.14E+04			
	S95T000573	95-AUG-016	1.55E+04	1.82E+04	29	
	S95T000573	95-AUG-016	2.08E+04			
	S95T000574	95-AUG-016	2.24E+04	2.49E+04	19.7	
	S95T000574	95-AUG-016	2.73E+04			
	S95T000575	95-AUG-016	1.15E+04	1.15E+04	.87	
	S95T000575	95-AUG-016	1.14E+04			
				Comp Mean		
				2.07E+04	5.8	5.80E+03

Table A-1. Tank 241-C-111 Analytical Data: Phosphorus

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.P	K211-8755	58	6.95E+03	6.87E+03	2	
	K211-8855	58	6.79E+03			
ICP.f.P	K211-6755	58	3.44E+03	2.98E+03	31	
	K211-6855	58	2.52E+03			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.P	S95T000123	95-AUG-003	1.90E+04	1.92E+04	1.6	
	S95T000123	95-AUG-003	1.93E+04			
	S95T000573	95-AUG-016	9.46E+03	1.20E+04	42.8	
	S95T000573	95-AUG-016	1.46E+04			
	S95T000574	95-AUG-016	2.17E+04	2.37E+04	16.9	
	S95T000574	95-AUG-016	2.57E+04			
	S95T000575	95-AUG-016	5.25E+04	5.26E+04	3.8	
	S95T000575	95-AUG-016	5.27E+04			
				Comp Mean		
				1.11E+04	146	3.11E+03

Table A-1. Tank 241-C-111 Analytical Data: Silicon

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Si	K211-8755	58	1.16E+03	1.22E+03	9	
	K211-8855	58	1.27E+03			
ICP.f.Si	K211-6755	58	9.83E+03	9.31E+03	11	
	K211-6855	58	8.79E+03			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.Si	S95T000123	95-AUG-003	8.52E+03	8.54E+03	.5	
	S95T000123	95-AUG-003	8.56E+03			
	S95T000573	95-AUG-016	3.90E+03	5.06E+03	45	
	S95T000573	95-AUG-016	6.21E+03			
	S95T000574	95-AUG-016	3.14E+03	3.28E+03	16.7	
	S95T000574	95-AUG-016	3.41E+03			
	S95T000575	95-AUG-016	3.09E+03	3.10E+03	2.4	
	S95T000575	95-AUG-016	3.10E+03			
				Comp Mean		
				8.92E+03	8.6	2.50E+03

Table A-1. Tank 241-C-111 Analytical Data: Sodium

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Na	K211-8755	58	4.39E+04	4.41E+04	1	
	K211-8855	58	4.43E+04			
ICP.f.Na	K211-6755	58	4.08E+04	3.94E+04	7	
	K211-6855	58	3.79E+04			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.Na	S95T000123	95-AUG-003	1.47E+04	1.46E+04	1.8	
	S95T000123	95-AUG-003	1.44E+04			
	S95T000573	95-AUG-016	3.25E+04	3.66E+04	22	
	S95T000573	95-AUG-016	4.07E+04			
	S95T000574	95-AUG-016	4.88E+04	5.17E+04	11	
	S95T000574	95-AUG-016	5.46E+04			
	S95T000575	95-AUG-016	1.36E+04	1.37E+04	0.7	
	S95T000575	95-AUG-016	1.37E+04			
				Comp Mean		
				2.70E+04	92	7.56E+03

Table A-1. Tank 241-C-111 Analytical Data: Strontium

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Sr	K211-8755	58	1.54E+02	1.53E+02	1	
	K211-8855	58	1.52E+02			
ICP.f.Sr	K211-6755	58	1.44E+02	1.41E+02	4	
	K211-6855	58	1.38E+02			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.Sr	S95T000123	95-AUG-003	2.50E+02	2.50E+02	0	
	S95T000123	95-AUG-003	2.50E+02			
	S95T000573	95-AUG-016	1.21E+02	1.45E+02	33	
	S95T000573	95-AUG-016	1.69E+02			
	S95T000574	95-AUG-016	1.65E+02	1.79E+02	16	
	S95T000574	95-AUG-016	1.93E+02			
	S95T000575	95-AUG-016	1.07E+02	1.05E+02	3.8	
	S95T000575	95-AUG-016	1.03E+02			
				Comp Mean		
				1.96E+02	56	5.50E+01

Table A-1. Tank 241-C-111 Analytical Data: Sulfur

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.S	K211-8755	58	1.11E+03	1.10E+03	2	
	K211-8855	58	1.09E+03			
ICP.f.S	K211-6755	58	1.03E+03	9.78E+02	11	
	K211-6855	58	9.26E+02			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.S	S95T000123	95-AUG-003	<5.25E+02	<5.25E+02	0	
	S95T000123	95-AUG-003	<5.25E+02			
	S95T000574	95-AUG-016	1.31E+03	1.47E+03	21	
	S95T000574	95-AUG-016	1.62E+03			
				Comp Mean		
				9.78E+02	56	2.74E+02

Table A-1. Tank 241-C-111 Analytical Data: Titanium

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Ti	K211-8755	58	1.54E+02	1.56E+02	2	
	K211-8855	58	1.57E+02			
ICP.f.Ti	K211-6755	58	2.70E+02	2.49E+02	17	
	K211-6855	58	2.27E+02			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.Ti	S95T000123	95-AUG-003	1.52E+02	1.51E+02	7	
	S95T000123	95-AUG-003	1.50E+02			
				Comp Mean		
				2.00E+02	49	5.60E+01

Table A-1. Tank 241-C-111 Analytical Data: Uranium

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.U	K211-8755	58	4.59E+03	5.14E+03	21	
	K211-8855	58	5.68E+03			
ICP.f.U	K211-6755	58	4.64E+3	4.99E+03	14	
	K211-6855	58	5.33E+03			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.U	S95T000123	95-AUG-003	2.52E+04	2.52E+04	.4	
	S95T000123	95-AUG-003	2.51E+04			
	S95T000573	95-AUG-016	9.90E+03	1.28E+04	45	
	S95T000573	95-AUG-016	1.56E+04			
	S95T000574	95-AUG-016	1.43E+04	1.32E+04	16.7	
	S95T000574	95-AUG-016	1.21E+04			
	S95T000575	95-AUG-016	1.24E+04	1.26E+04	2.4	
	S95T000575	95-AUG-016	1.27E+04			
				Comp Mean		
				1.51E+04	134	4.23E+03

Table A-1. Tank 241-C-111 Analytical Data: Zinc

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
METAL						
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Zn	K211-8755	58	2.08E+02	1.78E+02	34	
	K211-8855	58	1.48E+02			
ICP.f.Zn	K211-6755	58	1.74E+02	1.51E+02	31	
	K211-6855	58	1.27E+02			
				Comp Mean		
				1.51E+02	41	4.23E+01

Table A-1. Tank 241-C-111 Analytical Data: Zirconium

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
Solid		**Core**	**µg/g**	**µg/g**	**%**	**kg**
ICP.a.Zr	K211-8755	58	ND			
	K211-8855	58	ND			
ICP.f.Zr	K211-6755	58	5.06E+02	1.03E+03	102	
	K211-6855	58	1.56E+03			
		Auger	**µg/g**	**µg/g**	**%**	**kg**
ICP.f.Zr	S95T000573	95-AUG-016	1.13E+02	1.13E+02	NA	
	S95T000573	95-AUG-016	NA			
	S95T000574	95-AUG-016	1.52E+02	1.36E+02	24	
	S95T000574	95-AUG-016	1.20E+02			
	S95T000575	95-AUG-016	2.20E+02	2.33E+02	11	
	S95T000575	95-AUG-016	2.45E+02			
				Comp Mean		
				1.03E+02	NA	2.88E+01

Table A-2. Tank 241-C-111 Analytical Data: Total Alpha

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
Radionuclide						
Solid		**Core**	**µCi/g**	**µCi/g**	**%**	**Ci**
APC.f. total alpha	K211-6725	58	2.59E+00	2.45E+00	12	
	K211-6825	58	2.30E+00			
	K218-6725	59	1.21E-01	1.23E-01	3	
	K218-6825	59	1.25E-01			
	K218-6725	59	8.39E-02	8.28E-02	2.7	
	K218-6825	59	8.17E-02			
	S95T000573	95-AUG-016	6.82E-01	7.48E-01	17.8	
	S95T000573	95-AUG-016	8.15E-01			
	S95T000574	95-AUG-016	3.80E-01	3.92E-01	6.12	
	S95T000574	95-AUG-016	4.04E-01			
	S95T000575	95-AUG-016	3.85E-01	3.96E-01	5.31	
	S95T000575	95-AUG-016	4.06E-01			
				Comp Mean		
				8.84E-01	176	2.48E+02

Table A-2. Tank 241-C-111 Analytical Data: Cesium-137

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
Radionuclide						
Solid		**Core**	**µCi/g**	**µCi/g**	**%**	**Ci**
GEA.d.^{137}Cs	K211-6730	58	8.85E+01	8.58E+01	6	
	K211-6830	58	8.30E+01			
	K218-6730	59	7.15E-01	7.25E-01	3	
	K218-6830	59	7.36E-01			
				Comp Mean		
				4.32E+01	139	1.21E+04

Table A-2. Tank 241-C-111 Analytical Data: Strontium-90

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
Radionuclide						
Solid		**Core**	**µCi/g**	**µCi/g**	**%**	**Ci**
Sep/BPC.f.^{90}Sr	K211-6786	58	4.13E+03	4.16E+03	1	
	K211-6886	58	4.19E+03			
Sep/BPC.a.^{90}Sr	K211-8786	58	4.31E+03	4.27E+03	2	
	K211-8886	58	4.22E+03			
				Comp Mean		
				4.16E+03	1	1.16E+06

Table A-3. Tank 241-C-111 Analytical Data: Percent Water

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
Physical Property						
Solid		**Core**	**%**	**%**	**%**	
TGA.d.% H_2O	K211-5712	58	30.8	31.6	5	
	K211-5812	58	32.5			
	K218-5712	59	0	0	NA	
	K218-5812	59	0			
		Auger	**%**	**%**	**%**	**kg**
TGA.d.%.H_2 0	S95T000123	95-AUG-003	26.5	28.1	47[1]	
	S95T000123	95-AUG-003	35.5			
	S95T000123	95-AUG-003	22.2			
	S96T000573	95-AUG-016	28.0	28.1	.82	
	S96T000573	95-AUG-016	28.2			
	S96T000573	95-AUG-016	44.7	41.7	14.8	
	S96T000573	95-AUG-016	38.6			
	S96T000573	95-AUG-016	44.2	44.2	.05	
	S96T000573	95-AUG-016	44.2			
		95-AUG-017	0[2]			
		95-AUG-017	0[2]			
				Comp Mean		
				21.1		5.91E+04

1) This RPD was calculated using the difference of the two extreme concentrations of the three (35.5 and 22.2)
2) Auger 95-AUG-017 was not included in the calculation of the composite mean because it was taken from the same riser as Core 59 (Riser 3).

Table A-4. Tank 241-C-111 Analytical Data: Total Organic Carbon

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
Radionuclide						
Solid		**Core**	**µg C/g**	**µg C/g**	**%**	**kg**
TOC	K211-5718	58	7.09E+02	7.24E+02	4	
	K211-5818	58	7.38E+02			
	S95T000573	95-AUG-016	6.39E+02	6.82E+02	12.5	
	S95T000573	95-AUG-016	7.24E+02			
	S95T000573	95-AUG-016	1.22E+03	1.25E+03	4.80	
	S95T000573	95-AUG-016	1.28E+03			
	S95T000573	95-AUG-016	9.09E+02	9.01E+02	1.78	
	S95T000573	95-AUG-016	8.93E+02			
				Comp Mean		
				7.24E+02	4	3.50E+02

Table A-5. Tank 241-C-111 Analytical Data: Cyanide

Analyte	Sample Number	Sample Identification	Result	Mean	RPD	Projected Inventory
Radionuclide						
Solid		**Core**	**µg CN/g**	**µg CN/g**	**%**	**kg**
Cyanide	K211-5777	58	3.51E+01	3.76E+01	13	
	K211-5877	58	4.00E+01			
	S95T000573	95-AUG-016	9.38E+01	8.87E+01	11.5	
	S95T000573	95-AUG-016	8.36E+01			
	S95T000574	95-AUG-016	1.55E+02	1.53E+02	2.61	
	S95T000574	95-AUG-016	1.51E+02			
	S95T000575	95-AUG-016	1.07E+02	1.06E+02	2.84	
	S95T000575	95-AUG-016	1.04E+02			
				Comp Mean		
				3.76E+01	13	4.28E+01

APPENDIX A REFERENCES

Rice, A.D., 1994, *216-Day Report for Tank 241-C-111*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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APPENDIX B

ANALYTICAL RESULTS

FROM 1975 SAMPLING OF

SINGLE-SHELL TANK 241-C-111

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Table B-1. Analytical Results of 1975 Sampling Effort (Van Vleet 1993).

Sample Type	Supernate
Sample Date	2/19/75
Sample Identification	T-2167
Density (g/mL)	1.30
Volume (kL)	216
Analyte	**Result µg/g**
Al	3.05E+03
NO_2^-	2.08E+04
NO_3^-	7.35E+04
OH^-	1.06E+04

Table B-2. Ferrocyanide Tank Inventory Summary (Brevick et al. 1994).

Chemical Analysis					
$Fe(CN)_6^{-4}$ (kg)	**NO_3^- (kg)**	**NO_2^- (kg)**	**$Fe(CN)_6^{-4}$ in Sludge (L)**	**$Fe(CN)_6^{-4}$ (µg/g)**	**Molar Ratio $Fe(CN)_6^{-4}/NO_3^-/NO_2^-$**
7.00E+03	9.11E+04	2.26E+04	3.71E+05	1.47E+04	1.0/44.7/14.9

APPENDIX B REFERENCES

Brevick, C.H., L.A. Gaddis, and A.C. Walsh, 1994, *Supporting Document for the Northeast Quadrant Historical Tank Content Estimate Report for C-Tank Farm*, WHC-SD-WM-ER-313, Rev. 0, ICF Kaiser Hanford Company, Richland, Washington.

Van Vleet, R.J., 1993, *Radionuclide and Chemical Inventories for the Single-Shell Tanks*, WHC-SD-WM-TI-565, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

APPENDIX C

ANALYTICAL METHODS

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Table C-1. Tank 241-C-111 Analytical Procedures (Rice 1994).

Analyte	Method	Procedure
Percent Water	Thermogravimetric Analysis	LA-560-112 (Mettler) LA-514-114 (Perkin-Elmer)
Energetics	Differential Scanning Calorimetry	LA-515-113 (Mettler) LA-514-114 (Perkin-Elmer)
Total Alpha	Alpha Proportional Counting	LA-508-101 LA-508-114
Total Metals	Inductively Coupled Plasma	LA-505-151 LA-505-161
Cyanide	Microdistillation and Spectrophotometric Determination of Cyanide	LA-695-102
Total Organic Carbon	Coulometry	LA-342-100
Cesium-137	Gamma Energy Analysis	LA-548-121 (Prep) LA-508-052 (Counting)
Strontium-90	Separation and Beta Proportional Counting	LA-220-101

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APPENDIX D

QUALITY CONTROL RESULTS

FOR

CORE AND AUGER SAMPLES

OF 241-C-111

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Appendix D-1 Quality Control results for Core 58 and 59 Samples

	Sample Indentification	Standard Recovery	Preparation Blank	Spike Recovery	RPD
		%			%
DSC	Core 58 Segment 1	101.2	NA	NA	15.2
	Core 59 Segment 1	104	NA	NA	NA
	Hot Cell Blank	95	NA	NA	NA
		%			%
TGA	Core 58 Segment 1	99.6	NA	NA	5.4
	Core 59 Segment 1	98.4	NA	NA	NA
	Hot Cell Blank	98.9	NA	NA	NA
	Field Blank	99.9	NA	NA	0.2
		%	ugCN/g	%	%
CN	Core 58 Segment 1	93.0	<0.02	109.1	13.0
	Field Blank	100.3	<0.03	101.9	NA
		%	UgC/g	%	%
TOC	Core 58 Segment 1	90	19.1	NA	4.01
	Hot Cell Blank	100.3	NA	NA	NA
	Field Blank	95.0	<5.00	100.3	NA
		%	UCig	%	%
Total Alpha	Core 58 Segment 1	81.6	<0.193	89.9	11.9
	Core 59 Segment 1	102.4	<0.0122	96.5	3.25
	Hot Cell Blank	93.3	NA	NA	NA
	Field Blank	90.5	<2.09E-07	101.6	NA

	Sample Indentification	Standard Recovery	Preparation Blank	Spike Recovery	RPD
		%	uCi/g	%	%
Cs-137	Core 58 Segment 1	96.1	<0.551	NA	6.41
	Core 59 Segement 1	105.5	<0.0401	NA	2.88
	Hot Cell Blank	99.5	NA	NA	NA
	Field Blank	98.6	<2.27E-06	NA	0.02
		%	ug Ni/g	%	%
Ni	Core 58 Segment 1	101.5	0.061	104.0	1.49
	Core 59 Segement 1	94.74	<0.02	94.74	1.86
	Hot Cell Blank	99.72	<0.02	NA	NA
	Field Blank	99.72	<0.02	101.4	NA
		%	uCi/g	%	%
Sr-90	Core 58 Segment 1	102	0.192	NA	1.44
	Core 59 Segment 1	99.7	1.17	NA	2.11
	Field Blank	102	<3.42E-06	NA	1.36

Appendix D-2 Quality Control Results for Auger Samples

	Sample Indentification	Standard Recovery	Preparation Blank	Spike Recovery	RPD
		%			%
TGA	95-AUG-003 Whole Segment	99.31	NA	NA	28.9
		%			%
DSC	95-AUG-003 Whole Segment	99.12	NA	NA	NA
		%	Ug Ni/mL	%	%
Ni	95-AUG-003 Whole Segment	102.6	5.52	NA	1.41
		%			%
TGA	95-AUG-017 Whole Segment	100.6	NA	NA	NA
		%			%
DSC	95-AUG-017 Whole Segment	92.09	NA	NA	NA
		%	UgC/g	%	%
TOC	95-AUG-016 2nd Quarter Segment	96.0	23.90	NA	12.5
		%			%
TGA	95-AUG-016 2nd Quarter Segment	99.21	NA	NA	0.82
		%			%
DSC	95-AUG-016 2nd Quarter Segment	95.78	NA	NA	NA
		%	ug CN/g	%	%
CN	95-AUG-016 2nd Quarter Segment	101.4	0.5	97.70	11.5

	Sample Indentification	Standard Recovery	Preparation Blank	Spike Recovery	RPD
		%	ug Ni/mL	%	%
Ni	95-AUG-016 2nd Quarter Segment	101.5	0.146	95.40	29.1
		%	UCi/g	%	%
Total Alpha	95-AUG-016 2nd Quarter Segment	81.76	<0.0379	89.10	17.8
		%	ug C/g	%	%
TOC	95-AUG-016 3rd Quarter Segment	96.0	23.90	98.60	4.80
		%			%
TGA	95-AUG-016 3rd Quarter Segment	99.21	NA	NA	NA
		%			%
DSC	95-AUG-016 3rd Quarter Segment	95.78	NA	NA	NA
		%	ug CN/g	%	%
CN	95-AUG-016 3rd Quarter Segment	101.5	0.430	106.0	2.61
		%	Ug Ni/mL	%	%
Ni	95-AUG-016 3rd Quarter Segment	101.5	0.146	88.0	19.7
		%	UCi/g	%	%
Total Alpha	95-AUG-016 3rd Quarter Segment	81.76	<0.0379	103.8	6.12
		%	ug C/g	%	%
TOC	95-AUG-016 Bottom Quarter Segment	94.33	37.20	NA	1.78

	Sample Indentification	Standard Recovery	Preparation Blank	Spike Recovery	RPD
		%			%
TGA	95-AUG-016 Bottom Quarter Segment	100.6	NA	NA	0.05
		%			%
DSC	95-AUG-016 Bottom Quarter Segment	92.09	NA	NA	NA
		%	ug CN/g	%	%
CN	95-AUG-016 Bottom Quarter Segment	105.8	0.430	NA	2.84
		%	Ug Ni/mL	%	%
Ni	95-AUG-016 Bottom Quarter Segment	101.5	0.146	94.40	0.47
		%	UCi/g	%	%
Total Alpha	95-AUG-016 Bottom Quarter Segment	81.76	<0.0332	90.0	5.31

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