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Name: K. M. Hodgson

Signature

Name: T. T. Tran, LATA

Signature 07/24/95

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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-AZ-101. This report supports the requirements of Tri-Party Agreement Milestone M-44-08.

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EXECUTIVE SUMMARY

This tank characterization report summarizes the information on the historical uses, status, and the sampling and analysis results of waste stored in the double-shell underground storage tank 241-AZ-101. This report supports the requirement of the *Hanford Federal Facility Agreement and Consent Order*, milestone M-44-08 (Ecology et al. 1994).

Tank 241-AZ-101 is located in the AZ Tank Farm in the 200 East Area of the Hanford Site. The tank, which went into service in 1976, is one of four double-shell tanks designated as aging waste tanks. It was constructed to store neutralized current acid waste, a high-level waste that originated from the reprocessing of irradiated nuclear fuel in the PUREX Plant. Tank 241-AZ-101 first received water in the fourth quarter of 1976. During the next seven years, the tank received a mixture of evaporator feed, double-shell slurry feed, complexed, noncomplexed, and dilute noncomplexed waste from PUREX miscellaneous streams. From 1984 through 1986, tank 241-AZ-101 received aging waste from the PUREX plant exclusively. The remainder of the fill history of tank 241-AZ-101 consists of a series of small additions of water and dilute noncomplexed waste from tanks 241-AY-102 and 241-AZ-102.

A description and status of the tank are summarized in Tables ES-1 and ES-2 and Figures ES-1 and ES-2. Because the tank is active and could be receiving or transferring waste, the volume of supernate and composition of the supernate will likely change. The tank, which has a design capacity of 3,790 kiloliters (kL) (1,000 kilogallons [kgal]), presently contains

3,630 kL (960 kgal) of waste in the form of supernate and sludge. When last measured, it contained 3,500 kL (925 kgal) of supernate (March 1995) and 130 kL (35 kgal) of sludge (September 1990).

This report summarizes three sampling and analysis events. Sludge composition and properties are based upon core samples taken from the tank in April and May 1989. Supernate composition is based on grab samples taken in March 1995 to evaluate waste compatibility. The core samples were taken before the data quality objective process was implemented; therefore, the data may not fully comply with the recent requirements of the safety screening and waste compatibility data quality objectives.

Even though the fuel content of the waste has not been measured by differential scanning calorimetry, the total organic carbon, and the historical uses of the tank suggest that excessive fuel is not present. If the sludge is sampled again, the analyses should include an evaluation of the fuel content by differential scanning calorimetry to confirm the fuel estimates based on historical information and total organic carbon analysis. About 96 percent of the waste is supernate, and the moisture level of the driest sludge is 41.1 percent water, well above the 17 percent safety screening minimum (Babad and Redus 1994). The heat generated by radioactivity in the tank is estimated to be 241,600 British thermal units per hour (Btu/hr)(70,700 watts). The maximum heat load limit for this tank is 4.0E+06 Btu/hr. The maximum temperature of the tank ranged from 74.4 to 84.4 °C (166 to 184 °F) for December 1993 through December 1994. The $^{239/240}Pu$ levels in the sludge were significantly lower than the criticality safety criterion. Based upon this information, the waste does

Table ES-1. Tank 241-AZ-101.

Tank Description	
Type	Double shell
Constructed	1971 to 1977
In-Service	1976[1]
Diameter	23 meters (m) or 75 feet (ft)
Usable depth	11 m (35 ft)
Design capacity	3,790 kiloliters (kL) or 1,000 kilogallons (kgal)
Bottom shape	Flat
Ventilation	Operating exhauster
Tank Status	
Total waste volume (March 1995)	3,630 kL (960 kgal)
Sludge volume (September 1990)	130 kL (35 kgal)
Supernatant volume (March 1995)	3,500 kL (925 kgal)
Surface level (March 1995)	886 centimeters (349 inches)
Maximum temperature (December 1993 to December 1994)	74.4 °C - 84.4 °C (166 °F - 184 °F)
Integrity	Sound
Sampling Dates	
Two samples	October 1987
Two core samples	April/May 1989
Four grab samples	March 1995
Service Status	
Active service	

[1]The tank received only water during 1976.

Table ES-2. Double-Shell Tank 241-AZ-101 Concentrations and Inventories for Major Analytes of Concern (from Table 4-2).

Physical Properties	Sludge Results[1]		Liquid Results[2]	
Density (g/milliliter [mL])	Core 1 1.28 Core 2 1.67		1.19	
Percent Water[3]	Core 1 41.1 Core 2 45		73.8 (Gravimetric) 73.0 (Thermogravimetric)	
pH	13.6		13.6	
Heat Load	241,600 British thermal units per hour (70,700 watts)			
Chemical Constituents	Sludge Concentration (μg/g)	Sludge Inventory (kg)	Liquid Concentration (μg/g)	Liquid Inventory (kg)
Metals				
Al (Aluminum)	24,200	5,320	7,830	32,600
Cd (Cadmium)	4,920	1,070	---	---
Fe (Iron)	87,200	19,100	< 8.40	< 35.0
K (Potassium)	5,700	1,260	---	---
Mn (Manganese)	2,650	4,260	---	---
Na (Sodium)	79,000	17,300	80,000	333,000
Si (Silicon)	5,150	1,130	---	---
U (Uranium)	4,910	1,070	---	---
Zr (Zirconium)	30,900	6,720	---	---
Ions				
NO_2^- (Nitrite)	43,200	9,410	47,700	199,000
NO_3^- (Nitrate)	45,800	10,100	55,500	231,000
SO_4^{2-} (Sulfate)	16,900	3,320	12,900	53,900
Organics				
Total Organic Carbon (μg C/g)	9,180	2,030	866	3,600
Radionuclides	μCi/g	Ci	μCi/g	Ci
^{241}Am	302	66,600	< 0.0253	< 10.5
^{144}Ce	20.8	3,750	---	---
^{137}Cs	1,480	319,000	1,340	5.57E+06
^{239}Pu	3.58	781	< 3.53E-05	< 0.147
^{240}Pu	1.01	222		
^{106}Ru	37.4	6,800	---	---
^{90}Sr	33,400	6.02E+06	---	---

Notes:

Ci = curies
kg = kilograms
μCi/g = microcuries per gram
μC/g = micrograms of carbon per gram
μg/g = micrograms per gram

[1]Based on 1989 Sampling and Analysis
[2]Based on 1995 Sampling and Analysis
[3]Based on weight percent total solids determination

Figure ES-1. Tank 241-AZ-101

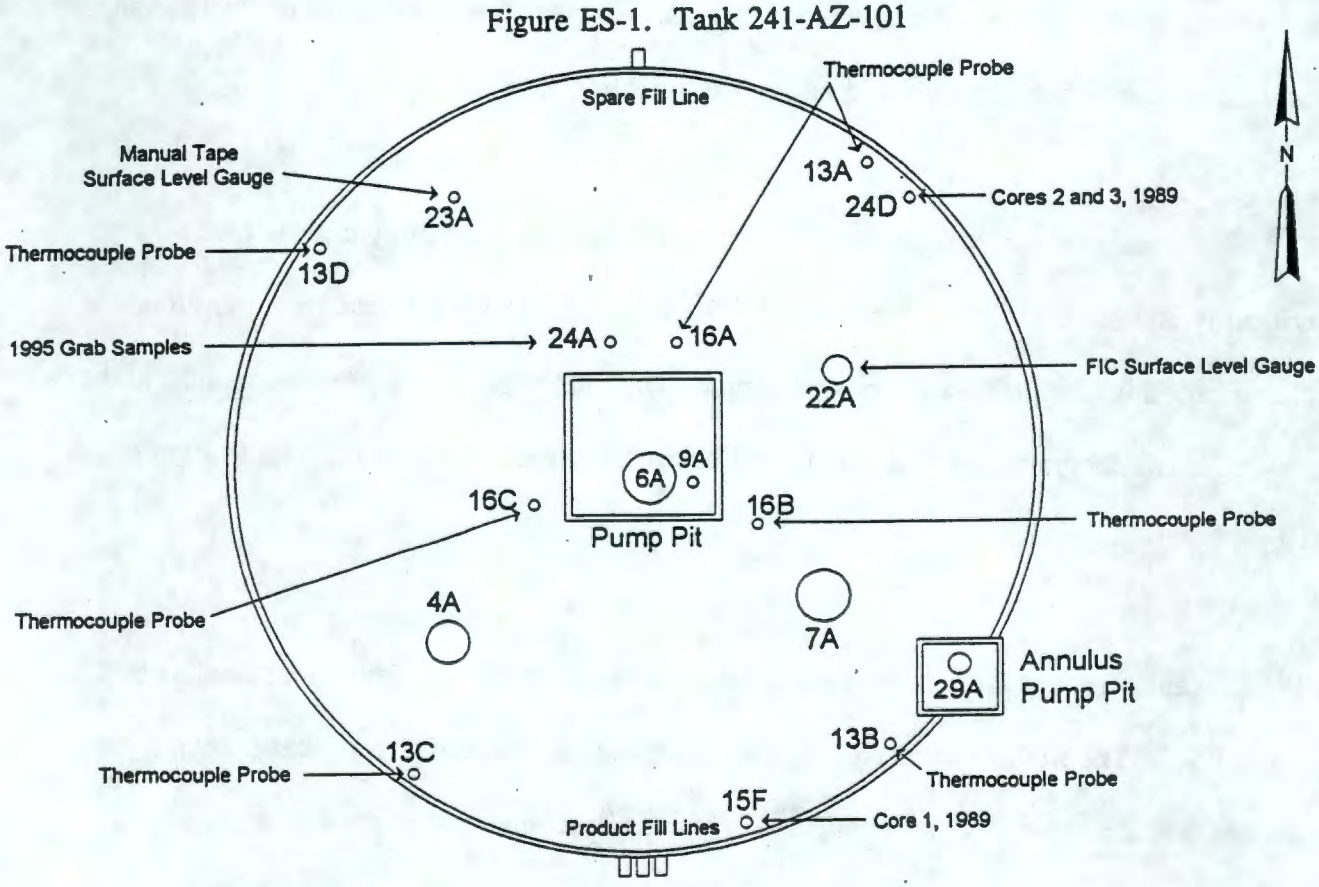
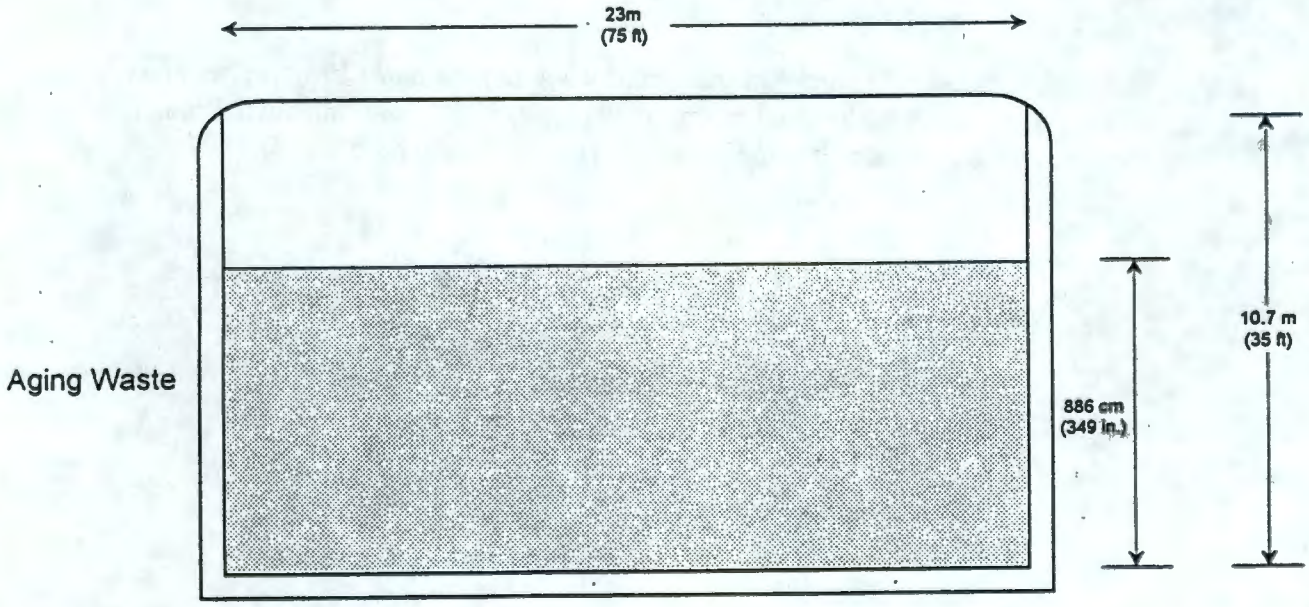


Figure ES-2. Waste Profile of Tank 241-AZ-101.



Total Tank Volume: 3,790 kL (1,000 kgal)
Current Waste Volume (Mar. 1995): 3,630 kL (960 kgal)
Sludge Volume (Mar. 1995): 130 kL (35 kgal)
Supernate Volume (Mar. 1995): 3,500 kL (925 kgal)

R-D

not appear to have any immediate safety concerns; however, this report does not include any tank head space vapor sampling and analysis information for evaluation.

The 1995 supernate analysis indicates that the liquid meets compatibility criteria for criticality and corrosion. The supernate $^{239/240}Pu$ and ^{241}Am levels are below the transuranic classification limit of 100 nanocuries per gram. The total organic carbon concentration in the supernate is 1.03 grams per liter (g/L), well below the organic complexant classification of 10 g/L.

The concentration and tank inventory for the centrifuged sludge and liquid are summarized in Table ES-2. The sludge contained high concentrations of aluminum, iron, manganese, sodium, and zirconium. Concentrations of nitrate, nitrite, and sulfate are also high.

REFERENCES

Ecology, EPA, DOE, 1994, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

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LIST OF TERMS

BPLCS	Dilute, non-complexed waste from B Plant strontium processing
CAW	Current acid waste
CPLX	Complexed waste
DN	Dilute, non-complexed waste
DQO	Data Quality Objective
DSC	Differential Scanning Calorimetry
DSSF	Double-shell slurry feed
DST	Double-shell tank
DSTWCD	Double-shell Tank Waste Characterization Database
EVAP	Evaporator feed
FIC	Food Instrument Corporation
GEA	Gamma energy analysis
HLW	High-level waste
HWVP	Hanford Waste Vitrification Plant
ICP	Inductively Coupled Plasma (Atomic Emission Spectroscopy)
IDL	Instrument detection limit
NCAW	Neutralized current acid waste
NCPLX	Noncomplexed waste
PNL	Pacific Northwest Laboratory
PUREX	Plutonium Uranium Extraction (Facility)
PXMSC	Dilute, noncomplexed waste from PUREX miscellaneous streams
PXNAW	Aging waste from PUREX high-level waste
RPD	relative percent difference
TC	Total Carbon
TGA	Thermogravimetric analysis
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
WHC	Westinghouse Hanford Company

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1.0 INTRODUCTION

This tank characterization report overviews double-shell tank 241-AZ-101 and its waste contents. It estimates concentrations and inventories for the waste components based upon the latest sampling and analysis activities and background tank information.

Since 1983, approximately 20 samples have been taken from tank 241-AZ-101. This report describes the results of the three most recent sampling events: the first includes one sludge and one supernatant sample taken in 1987; the second was performed in 1989 using the push-mode core sampling method; and the third includes four grab samples taken in 1995 to evaluate waste compatibility in preparation for receipt of liquid waste from other sources and for process testing purposes. The *Tank AZ-101 Sludge Washing Test* (MacClean 1995) has been developed to obtain information for testing in tank 241-AZ-101 and 241-AZ-102 the process, equipment, and instruments needed for in-tank waste processing. This report supports the requirements of the *Hanford Federal Facility Agreement and Consent Order*, milestone M-44-08 (Ecology et al. 1994).

This report overviews relevant tank sampling and analysis efforts and contains observations about waste characteristics. Because waste is being transferred into and out of this tank, estimates of supernate volumes and composition will change. Sludge volume and composition is not expected to change as significantly as the supernate. These estimates are best available for concentration and bulk inventory data for the waste contents based upon the latest sampling data and background tank information.

1.1 PURPOSE

The purpose of this report is to summarize the information about the use and contents of tank 241-AZ-101. Report information will help to assess issues associated with safety, operations, environmental and process development activities. The report is also a reference point for more detailed information about tank 241-AZ-101.

1.2 SCOPE

The 1987 and 1989 samples were taken to obtain analytical information. Chemical, radiochemical, and physical properties were measured on the supernate and sludge phases of these samples. Other than total organic carbon, no specific organic analyses were performed.

The 1995 supernatant grab samples were taken to support tank operations in assessing the compatibility of tank 241-AZ-101 supernate with other waste for transfer purposes. The technical basis for this compatibility assessment is described in the Data Quality Objectives for the Waste Compatibility Program (Carothers 1994).

This report does not include any information on vapor space sampling and analysis to determine the composition of the tank head space gases. In addition, this report does not assess safety issues in accordance with the *Tank Safety Screening Data Quality Objectives* (Babad and Redus 1994). A sampling event to address safety issues under the *Tank Safety Screening Data Quality Objectives* is expected to occur in fiscal year 1997.

2.0 HISTORICAL TANK INFORMATION

Tank 241-AZ-101 is in active service and is expected to receive additional transfers that will alter the volume and composition of tank contents. The current volume status of the tank is provided in routinely updated reports (Hanlon 1995). Tank history includes tank design information, waste transfer history, waste temperature, and level surveillance information.

2.1 TANK STATUS

Tank 241-AZ-101 is currently categorized as a structurally sound, non-Watch List tank with no associated unreviewed safety questions. All tank monitoring instruments are in compliance with documented standards with the exception of erratic radiation readings from the pit leak-detection system (Hanlon 1995). The out-of-service Food Instrument Corporation gauge for surface-level readings has recently been replaced by an ENRAF* surface level instrument.

The tank contains a total volume of 3,630 kiloliters (kL) or 960 kilogallons (kgal) of aging waste or neutralized current acid waste (NCAW), which is high-level, first-cycle solvent extraction waste from the Plutonium and Uranium Extraction (PUREX) plant. This volume is equivalent to 886 centimeters (cm) (349 inches [in.]) of waste as measured from the tank bottom. Based upon the latest solid volume update (September 30, 1990) the waste is comprised of 3,500 kL (925 kgal) of supernatant liquid and 130 kL (35 kgal) of sludge (Hanlon 1995).

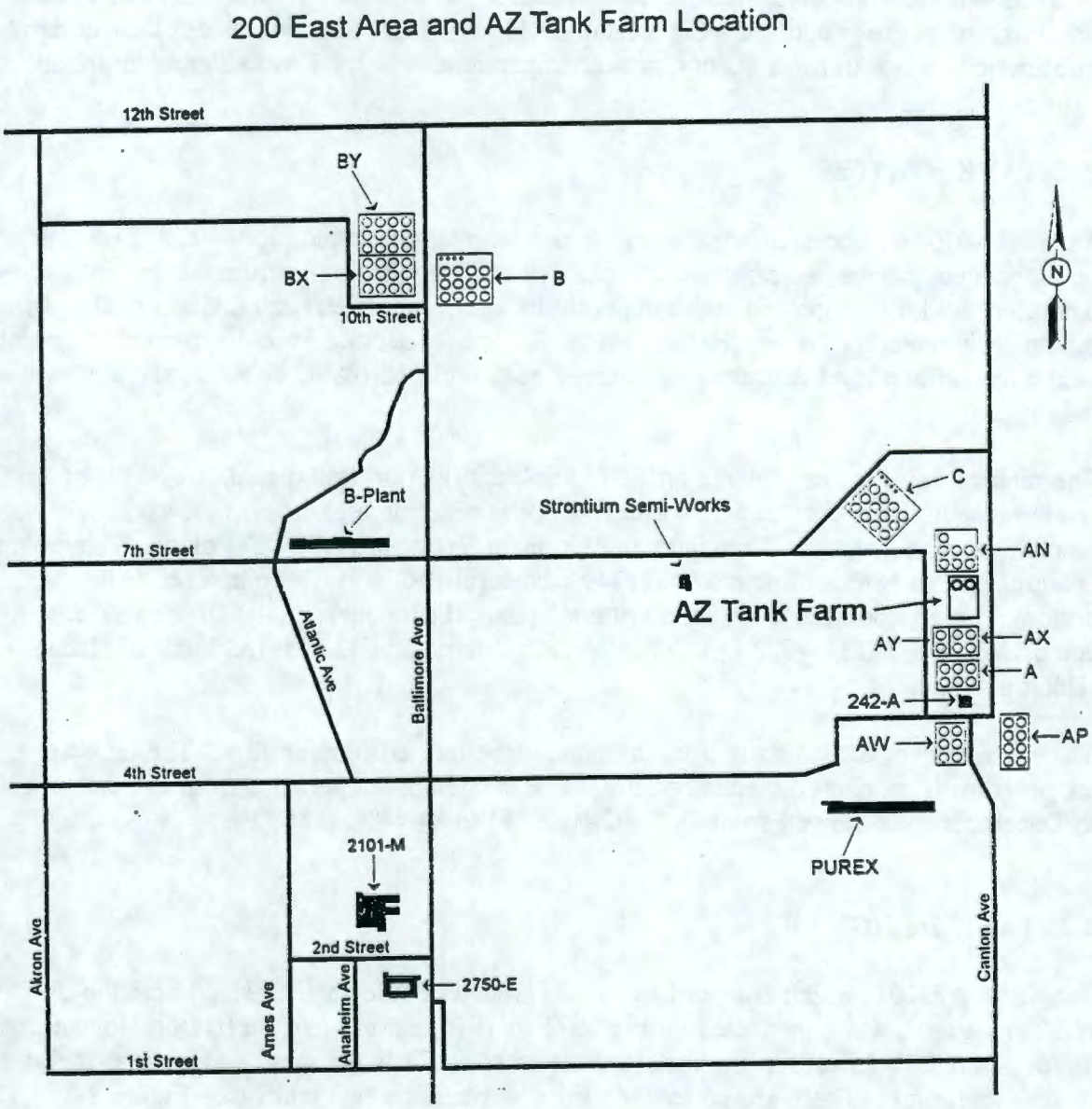
The surface level is read daily using a manual tape located in riser 23A. The tank waste temperature is monitored manually daily. The maximum temperature from December 1993 to December 1994 ranged from 74.4 °C (166 °F) to 84.4 °C (184 °F).

2.2 TANK DESIGN

Tank 241-AZ-101, which is one of two underground double-shell tanks comprising the AZ Tank Farm, was constructed during 1971 to 1976 and put into service on November 30, 1976. Tank 241-AZ-101 is the eastern-most tank, and it is the same elevation as the other double-shell tank. There are no cascade lines between the two tanks (see Figure 2-1). The tank received only water in 1976. A minimum amount of liquid was required in the tanks to operate the ventilation system. The ventilation systems create a negative pressure in the tanks and without the liquid could cause the steel liner to separate from the concrete shell. For this reason water was placed in many new tanks prior to the addition of waste.

* ENRAF is a registered trademark of ENRAF, Inc.

Figure 2-1. 200 East Area Location of the AZ Tank Farm.



Tank 241-AZ-101 is a tank-in-tank design consisting of a heat-treated, stress-relieved steel liner inside a nonstress-relieved steel liner that is surrounded by a reinforced concrete shell. To accommodate high-heat generating wastes, airlift circulators, steam coils, and exhaust condensers were installed to minimize the probability of integrity loss. Maximum design temperatures for the tank are 179 °C (355 °F) for sludge, 104 °C (220 °F) for vapor, and 127 °C (260 °F) for liquid. The tank has a design storage capacity of 3,790 kL (1,000 kgal); however, safety considerations restrict the maximum operating capacity to 3,710 kL (980 kgal). The tank has a diameter of 23 meters (m) (75 feet [ft]) and a usable depth of 11 m (35 ft). Instruments used to monitor the pressure, temperature, liquid level, sludge level, and other bulk tank characteristics access tank 241-AZ-101 through risers (Bell 1994). Riser locations are shown in Figure 2-2 (not all risers are shown) and the configuration of a typical double-shell tank is shown in Figure 2-3. For more information about the AZ Tank Farm and double-shell tanks, see the *Tank Characterization Reference Guide* (De Lorenzo et al. 1994).

2.3 PROCESS KNOWLEDGE

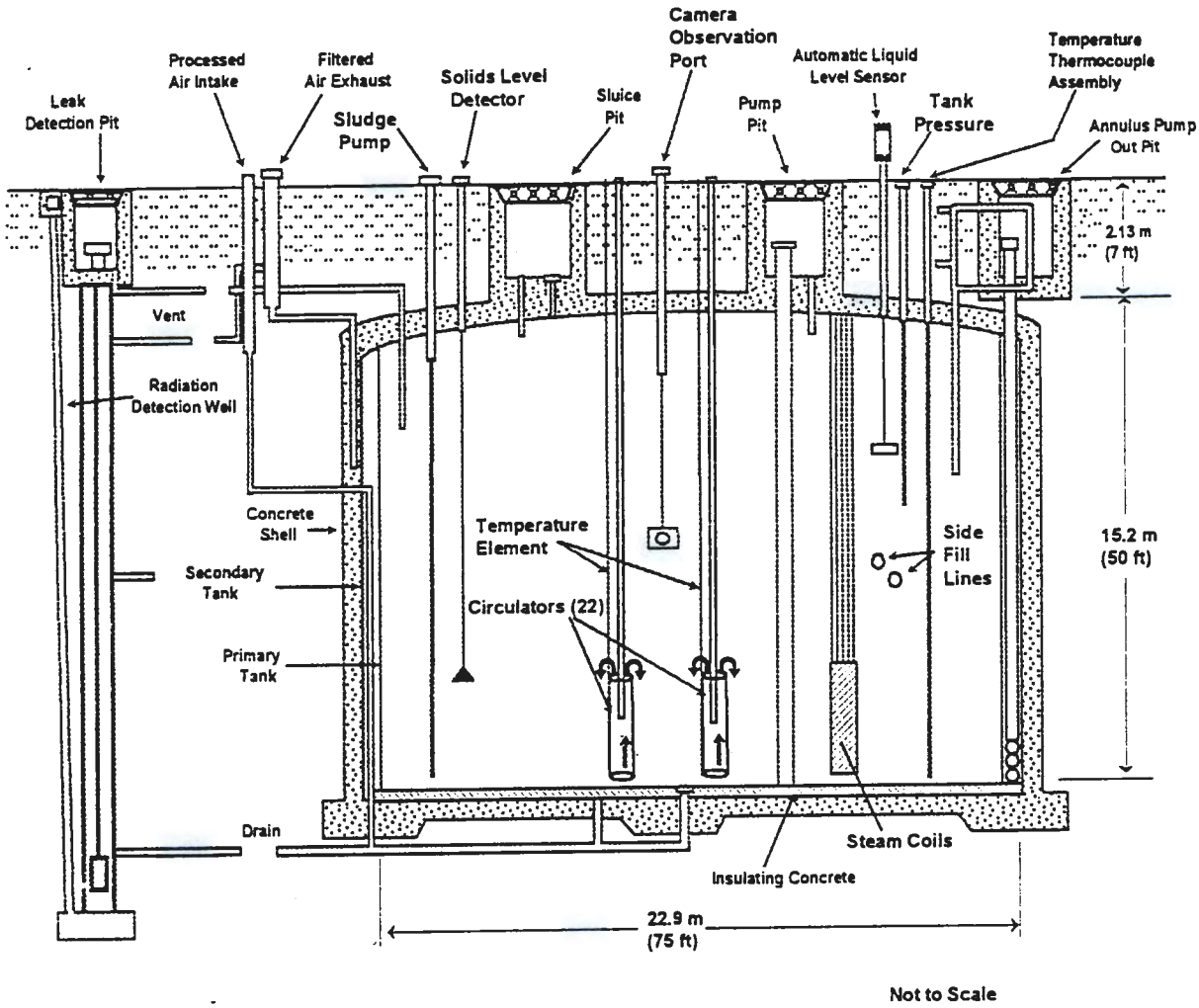
2.3.1 Waste Transfer History

Tank 241-AZ-101 first received water in the fourth quarter of 1976. During the next four years, the tank received a mixture of Evaporator Feed, double-shell slurry feed, complexed and noncomplexed waste. In 1980 the waste volume was 3,010 kL (795 kgal) (Anderson 1990). Tank 241-AZ-101 provided waste feed to the 242A evaporator-crystallizer during three campaigns: 81-1, 82-1, and 83-1. During campaign 81-1, the feed solution was processed in one pass to a double-shell slurry feed concentration. The product was slurried to tanks 241-AX-101 and 241-A-101 for temporary storage; the final supernate was pumped to tank 241-AW-103 (Teats 1982). During campaign 82-1, the feed solution was processed in two passes, and the final product was transferred to tank 241-AW-101 for temporary storage. During campaign 83-1, the feed solution was processed in two passes to a double-shell slurry feed concentration. The final product was slurried to tank 241-AN-104 (Certa 1983).

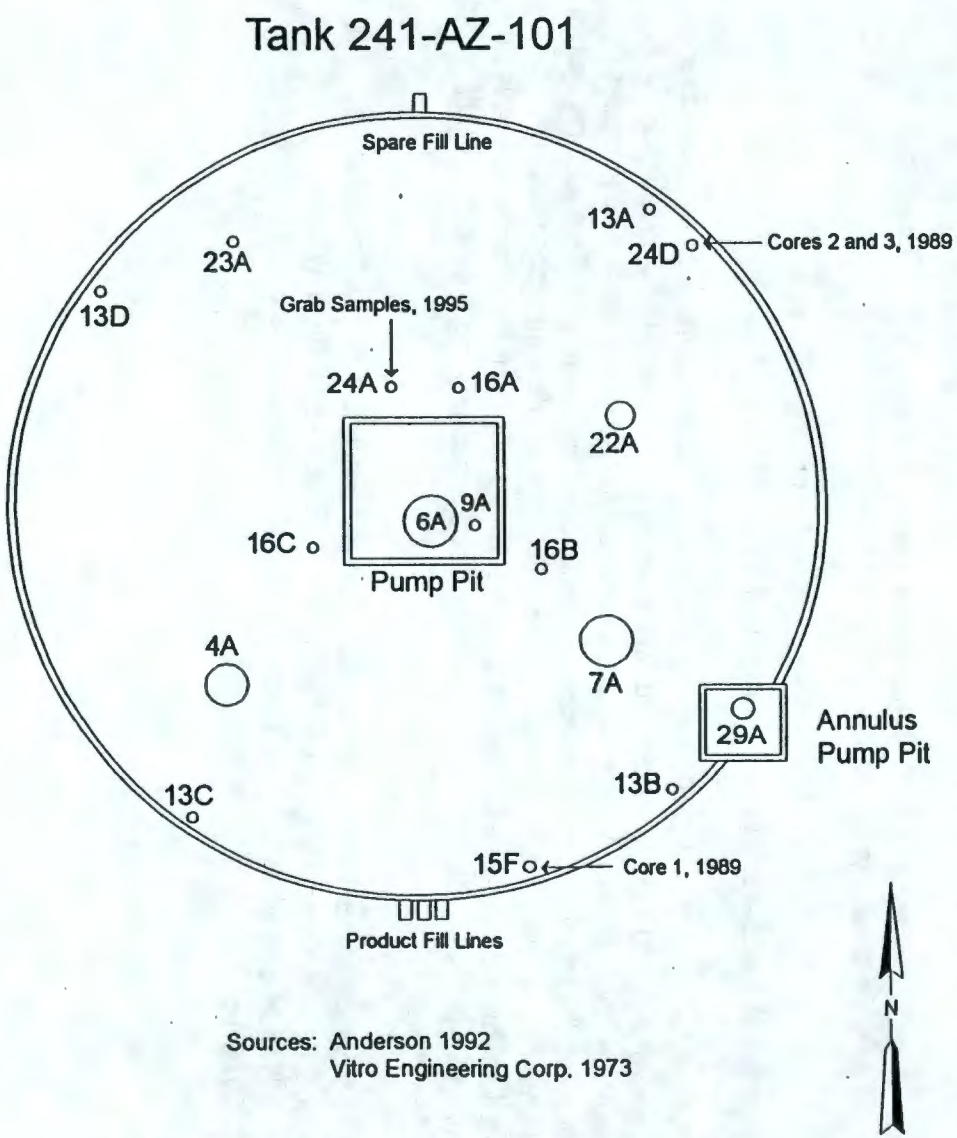
During the subsequent two years, dilute noncomplexed waste was received or transferred as follows. A receipt of 1,101 kL (291 kgal) was received from tank 241-SY-102 in the second quarter of 1982. Two receipts totaling 2,900 kL (766 kgal) were received from tank 241-AY-102 in the second quarter of 1983. A transfer of 927 kL (245 kgal) was made to tank 241-AW-102 in the fourth quarter of 1982, and a transfer of 3,410 kL (901 kgal) was made to tank 241-AW-102 in the third quarter of 1983. A loss of 155 kL (41 kgal) occurred by evaporation in the third quarter of 1983. Finally, the tank was emptied in the third quarter of 1983.

Figure 2-2. Riser Configuration of Tank 241-AZ-101.

Typical Aging Waste Double-Shell Tank Configuration for AZ Tanks.



9613456.0295



Sources: Anderson 1992
Vitro Engineering Corp. 1973

No.	Dia.	Description and Comments
4A	20"	Tank Ventilation
6A	42"	Pump Pit
7A	42"	Steam Coils
9A	4"	Pump Pit Drain
13A	4"	Thermocouple Probe
13B	4"	Thermocouple Probe
13C	4"	Thermocouple Probe
13D	4"	Thermocouple Probe
15F	6"	Sludge Measurement Port; Sampling Riser
16A	4"	Thermocouple Probe
16B	4"	Thermocouple Probe
16C	4"	Thermocouple Probe
22A	16"	FIC Gauge
23A	4"	Manual Tape
24A	6"	Sludge Measurement Port; Sampling Riser
24D	6"	Sludge Measurement Port; Sampling Riser
29A	12"	Annulus Pump

241-AZ Tank Farm

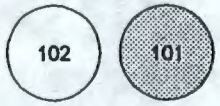


Figure 2-3. Basic Design of a Double-Shell Tank.

A period of approximately three years followed during which tank 241-AZ-101 received aging waste exclusively from the PUREX plant. The tank had a volume of 3,060 kL (808 kgal) in the first quarter of 1986. Tank 241-AZ-101 reached its maximum aging waste fill in March 1986 (WHC 1988). The current classification of the waste in tank 241-AZ-101 is NCAW, a high-level waste originating from the reprocessing of irradiated nuclear fuel in the PUREX Plant. After undergoing several extraction processes in the PUREX Plant, the high-level waste was partially denitrated with sugar. The denitrated waste was referred to as current acid waste (CAW). Sodium hydroxide was then added to the CAW, and the resulting NCAW was transferred to a double-shell tank for storage. Neutralized current acid waste, which is a waste type with a high fission product inventory, contained significant decay heat and could self-boil. Tank 241-AZ-101 is one of four double-shell tanks, which are designated aging waste tanks and were constructed especially for the storage of NCAW. The other aging waste tanks are tanks 241-AY-101, 241-AY-102, and 241-AZ-102.

The remainder of the fill history of tank 241-AZ-101 consists of a series of small additions from tanks 241-AY-102 and 241-AZ-102 and transfers of dilute noncomplexed waste . The tank volume fluctuated because of evaporation with water or dilute solutions being added to makeup losses. Diversion box catch tanks (essentially water) may also have been transferred into the tank. The final waste volume in the tank at the end of 1993 was 3,520 kL (930 kgal).

The waste transfer history of tank 241-AZ-101 is shown in Figure 2-4. The estimated total volumes of specific waste types added to the tank are listed in Table 2-1.

2.3.2 Historical Estimation of the Contents of Tank 241-AZ-101

Since 1983, when tank 241-AZ-101 was classified as an NCAW storage tank, there have been approximately 20 samples taken and 500 analyses performed (WHC 1989b). However, each sampling effort provided sludge or supernate samples, but not both. The amount of suspended solids reported in the supernate samples has varied from 0 to 7 volume percent, an amount equal to the total settled sludge volume. Because the data on sludge depth, suspended solids, and sludge and supernate analyses have not been taken simultaneously, the total sludge volume and analysis cannot be determined accurately from historical data (WHC 1989a).

Tank inventory estimates based upon the Tank Layer Model, the Waste Status and Transaction Record Summary (Agnew 1995), and the Hanford Defined Wastes Types (Agnew 1994) developed by the Los Alamos National Laboratory were not available for tank 241-AZ-101 when this report was compiled.

Figure 2-4. Tank 241-AZ-101 Fill History.

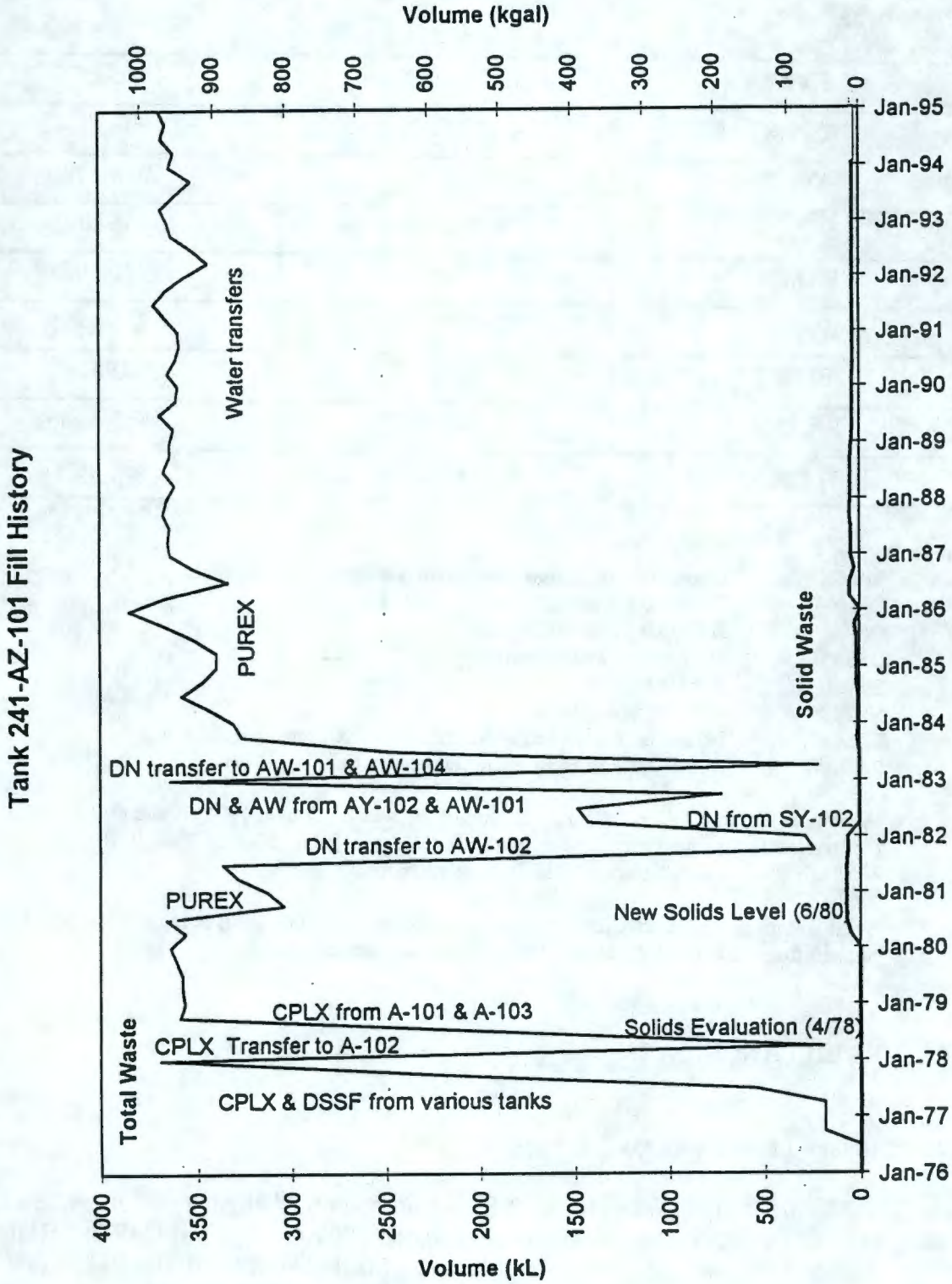


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Table 2-1. Estimated Total Volume of Waste Types Received by Tank 241-AZ-101[1].

Waste Type	Estimated Cumulative Volume (kiloliters [kilogallons])[2]	Years Received
EVAP	2,237 (591)	1976-1977
CPLX	4,012 (1,060)	1978
DSSF	939 (248)	1978-1980
NCPLX	3,202 (846)	1980
PXMSC	265 (70)	1981-1985
WATER	2,684 (709)	1981-1995
BPLCS	80 (21)	1982
PXNAW	2,752 (727)	1983-1986
DN	4,035 (1,066)	1982-1990

Notes:

BPLCS	Dilute, noncomplexed waste from B-Plant strontium processing
CPLX	Complexed waste
DN	Dilute noncomplexed waste
DSSF	Double-shell slurry feed
EVAP	Evaporator feed
NCPLX	Noncomplexed waste
PXMSC	Dilute, noncomplexed waste from PUREX miscellaneous streams
PXNAW	Aging waste from PUREX high-level waste

[1]Agnew, S. F., R. Corbin, T. Duran, K. Jurgensen, and B. Young, 1994, *Waste Status and Transaction Record Summary for the Southeast Quadrant*, WHC-SD-WM-TI-689, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

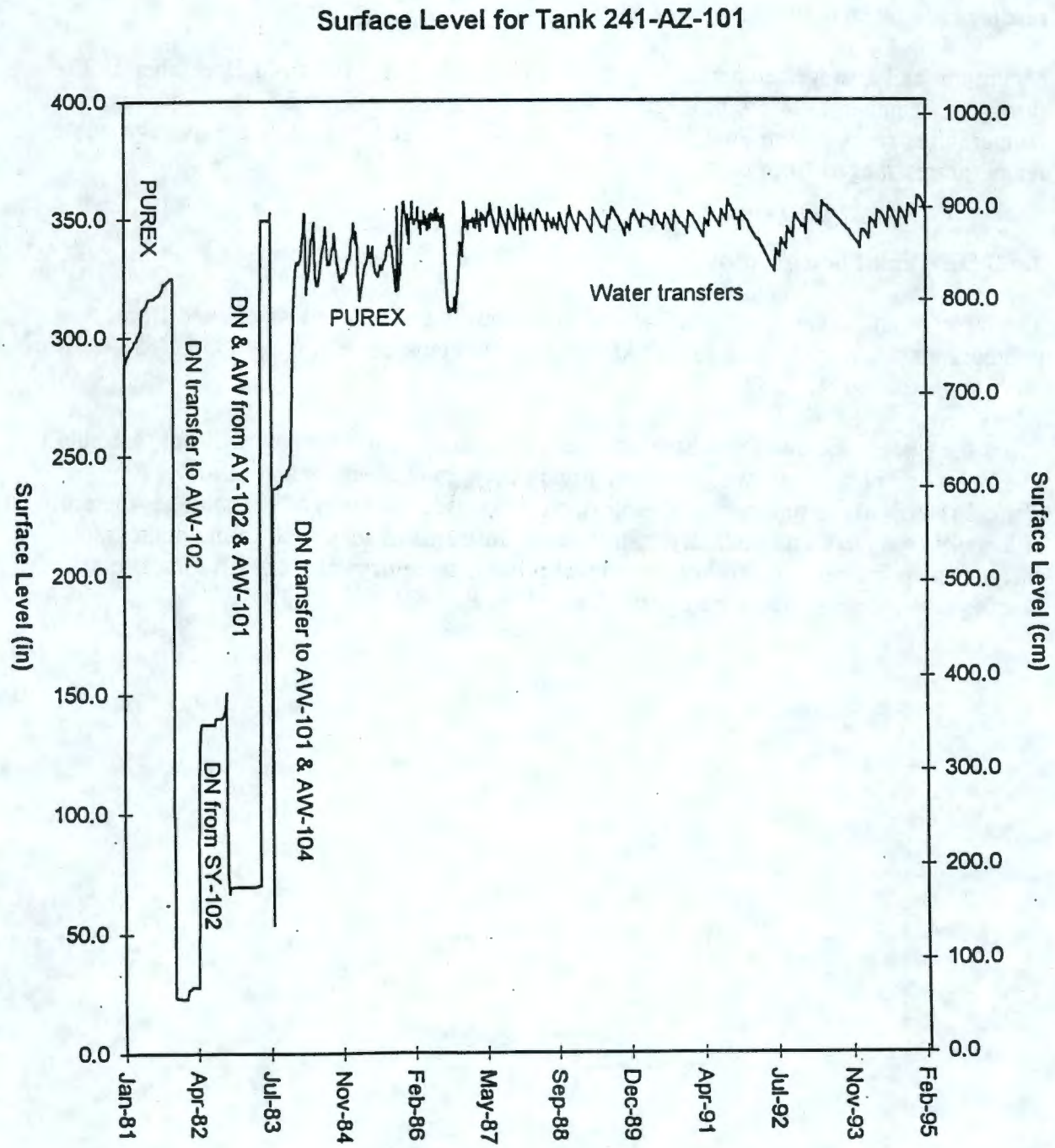
[2]Total volume is greater than the tank capacity of 3,790 kL (1,000 kgal) because waste was routinely pumped from tank 241-AZ-101 to other tanks or the evaporator.

2.4 SURVEILLANCE DATA

2.4.1 Surface-Level Readings

Tank 241-AZ-101 is equipped with an ENRAF Corporation level gauge. Surface level readings are taken daily. The surface level in March 1995 was 886 cm (349 in.) (Hanlon 1995). Figure 2-5 shows the surface-level history of tank 241-AZ-101 since January 1981. The fluctuations observed from 1981 to present are the result of evaporation and intermittent water additions.

Figure 2-5. Tank 241-AZ-101 Surface-Level History.



2.4.2 Internal Tank Temperatures

Thermocouple trees, each consisting of 18 Iron-Constantan (Type J) thermocouples assembled into a pipe measure waste temperatures in tank 241-AZ-101 at various levels, usually every 61 cm (2 ft) (Tran 1993). There are a total of seven thermocouple trees located at risers 13A, 13B, 13C, 13D, 16A, 16B, and 16C (Anderson 1992). Temperature readings are taken daily.

Maximum and average temperature readings for tank 241-AZ-101 from December 1993 through December 1994 are plotted in Figure 2-6. During this period, the maximum waste temperatures ranged from 74.4 °C (166 °F) to 84.4 °C (184 °F) while the average waste temperatures ranged from 60 °C (140 °F) to 71.7 °C (161 °F).

2.4.3 In-Tank Photographs

The most recent montage of tank 241-AZ-101 (see Figure 2-7) was assembled from photographs taken in August 1983. At that time, the tank contained 2,460 kL (650 kgal) of noncomplexed waste.

Since the waste type and level have changed, the current waste surface will not resemble the 1983 photographs. However, the photographs show in-tank equipment clearly.
Tank 241-AZ-101 is one of four double-shell tanks used for aging waste storage; therefore, it is heavily equipped with auxiliary instruments. Instruments identified in the photographs include three temperature probes, four level probes, three drywells, air lift circulators, heating coils, drains, risers, and ports (Brevick et al. 1994).

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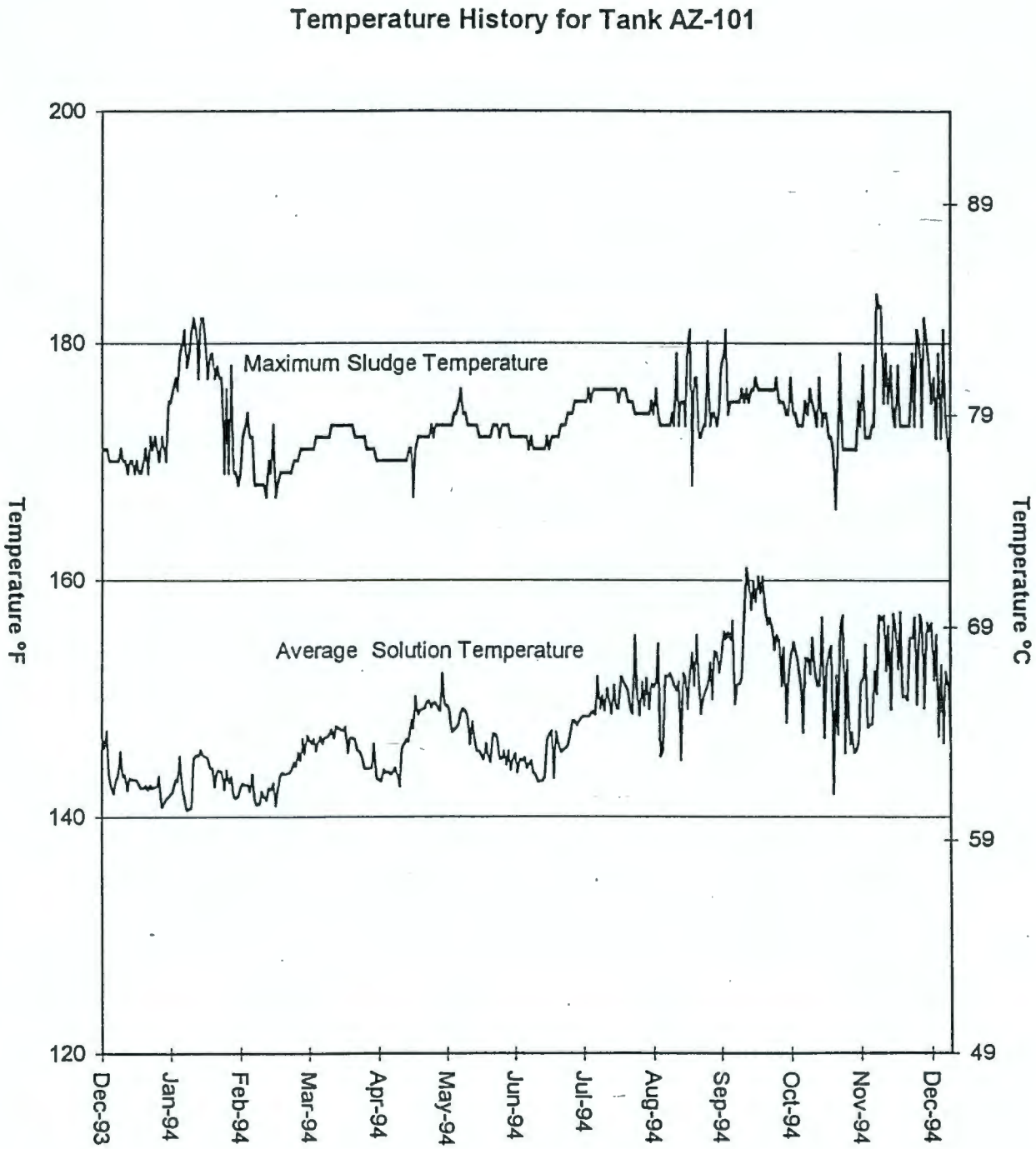
Figure 2-6. Tank 241-AZ-101 Temperature History.



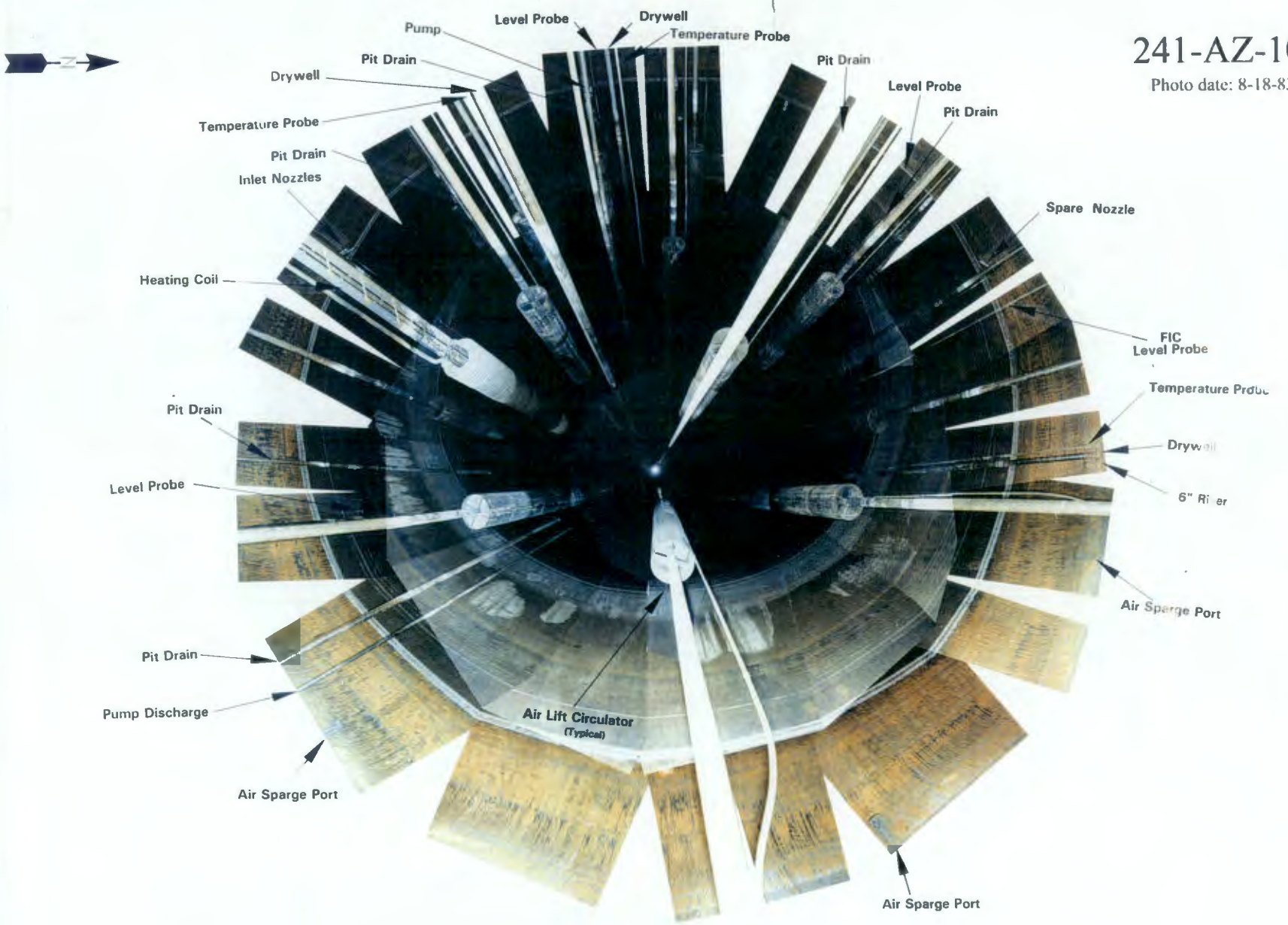


Figure 2-7. Tank 241-AZ-101 In-Tank Photo Montage.

3.0 TANK SAMPLING OVERVIEW

This section describes three sampling and analysis events for tank 241-AZ-101. One sludge sample and one supernate sample were taken in 1987 (see Appendix C for results). Three samples were taken using the push-mode core sampling method in 1989 (see Appendix A). Four grab samples were recovered in 1995 to evaluate waste compatibility in preparation for transfer of liquid waste and for process testing(see Appendix B). For further description of the sampling procedures, refer to the *Tank Characterization Reference Guide* (De Lorenzo et al. 1994).

3.1 DESCRIPTION OF 1987 SAMPLING EVENT

In October 1987, one sludge sample and one supernate sample were taken from tank 242-AZ-101. Both samples were clear, bright yellow liquids with a trace of brown solids (approximately 0.15 percent centrifuged solids by volume) (WHC 1987).

3.1.1 Sample Handling and Analysis (1987)

A description of the samples is provided in Table 3-1. Results from analyses of these samples are tabulated in Appendix C. To analyze the solids from tank 241-AZ-101, all solids from the sludge and supernate samples were combined. The total combined centrifuged solids volume was only 0.06 milliliter and the total sample volume was 40 milliter. Solids were washed with water, then dissolved in nitric acid. Only the acid wash was submitted for analysis. The concentrations of ions in the water wash were too small and the associated errors too large to draw firm conclusions about the composition of the solids. A sample of the supernate solution was submitted without dilution for analysis.

Table 3-1. Description of 1987 Samples.

Sample Identification	Sample Description
T-3493	Clear, bright yellow liquids with a trace of brown solids. The brown solids were combined with trace of brown solids in sludge sample T-3494.
T-3494	Clear, bright yellow liquids with a trace of brown solids. Solids analysis for tank 241-AZ-101 was accomplished by combining solids from T-3493 and T-3494 (total volume was only 0.06 mL).

3.2 DESCRIPTION OF 1989 SAMPLING EVENT

Tank 241-AZ-101 was sampled in April and May 1989 using the push-mode core sampling method. Three core samples were taken. The first two cores each contained two segments; the third core contained only one segment. The first core was taken from riser 15F; the second and third cores were taken from riser 24D.

The average sludge depth of tank 241-AZ-101, measured before the sampling event, was calculated to be 17 inches. Based upon this information, the first core was intended to include waste samples from 19 to 38 inches above the tank bottom, consisting of primarily supernate, and from 0 to 19 inches above the tank bottom, consisting primarily of solids. The first segment of waste was obtained 0 to 17 inches above the tank bottom. When the sampler for the second segment was at the tank bottom, it was discovered that the actual riser height was 21 inches lower than expected. Because the sampler could not be pushed or rotated, it was filled with waste using suction. This meant that stratification of the waste would not be preserved. Taking this into account, it was expected that both segments would contain mostly solids. However, the first segment contained only supernate, and the second segment contained primarily solids. These problems were corrected before the remaining two cores were obtained. Table 3-2 describes the samples recovered from the 1989 sampling event.

3.2.1 Sample Handling (1989)

The first core sample was sent to the Pacific Northwest Laboratory and extruded in the 325A facility (Peterson et al. 1989). As shown in Figure 3-1, sample preparation included decanting, centrifuging, and compositing processes. Extensive physical, chemical, and radiochemical characterizations were performed. In addition, the composite core was processed through simulated B-Plant pretreatment and Hanford Waste Vitrification Plant (HWVP) feed preparation procedures (Peterson et al. 1989). This report provides the results of the characterization of the first core sample throughout all processing steps that precede the two simulations.

The second core sample was also extruded and analyzed by the Pacific Northwest Laboratory (Gray et al. 1993). By combining different proportions of composite solids and supernate, it was characterized as received, as layer samples, in its composite form, and as three slurries representative of the waste during retrieval. B-Plant pretreatment simulation was also performed but will not be discussed (Gray et al. 1993). The characterization plan for the second core sample is shown in Figure 3-2.

The third core sample consisted of approximately 173 grams of solids and 2.5 grams of drainable liquid. The initial waste pushed out contained chunks of material and was a more fluid waste that did not maintain the cylindrical shape of the sampler upon extrusion (McGrail 1991). The waste was used for Miller Number measurements. The Miller Number is a measure of the abrasiveness of a slurry.

Table 3-2. Description of 1989 Samples[1,2].

Core	Segment	Weight (grams)	Description
1	1	280	Supernate
	2	200	Soft, creamy, and sticky dark brown solids; did not retain cylindrical shape upon extrusion
		118	Drainable liquid
2	1	305[3]	Dark brown solid; sticky at top but dry toward bottom; retained cylindrical shape upon extrusion
	2	208	Dark brown solid
		109	Dark brown drainable liquid
3	1	173	Large hard chunks; did not retain cylindrical shape upon extrusion
		2.5	Drainable liquid

Note:

[1]Peterson, M. E., R. D. Scheele, and J. M. Tingey, 1989, *Final Report - Characterization of the First Core Sample of Neutralized Current Acid Waste from Double-Shell Tank 101-AZ*, Incoming Correspondence no. 8904140 to A. J. DiLiberto, dated September 29, Westinghouse Hanford Company, Richland, Washington.

[2]Gray, W. J., M. E. Peterson, R. D. Scheele, and J. M. Tingey, 1993, *Characterization of the Second Core Sample of Neutralized Current Acid Waste from Double-Shell Tank 101-AZ*, Pacific Northwest Laboratory, Richland, Washington.

[3]Only the solids transferred to a jar were weighed; residual material left in extruder tray was not weighed.

3.2.2 Sample Analysis (1989)

When the two segments of the first core sample were extruded, the solid and liquid phases were weighed, and the physical appearance was described (Peterson et al. 1989). The physical properties measured on the second segment included the shear strength, penetration resistance, density, particle size, settling rate, volume percent centrifuged solids, volume percent settled solids, and weight percent total solids. Both segments were then combined. The physical properties measured on the composite included the following: density, settling rate, volume percent settled solids, weight percent total solids, weight percent oxide, viscosity of the centrifuged supernate at 65 °C and 95 °C, and pH. The centrifuged solids and supernate from the composite core were analyzed for the following chemical and radiochemical properties: Cr^{6+} (supernate only), mercury, elements by inductively coupled argon plasma atomic emission spectroscopy, total carbon, total inorganic and organic carbon, anions by ion chromatography, ^{241}Am, ^{14}C, gamma emitters by gamma energy analysis, ^{3}H, ^{129}I, ^{237}Np, ^{79}Se, ^{90}Sr, ^{99}Tc, thorium, total plutonium and uranium and their isotopes.

K-0

Figure 3-1. Characterization Plan for the First Core Sample.

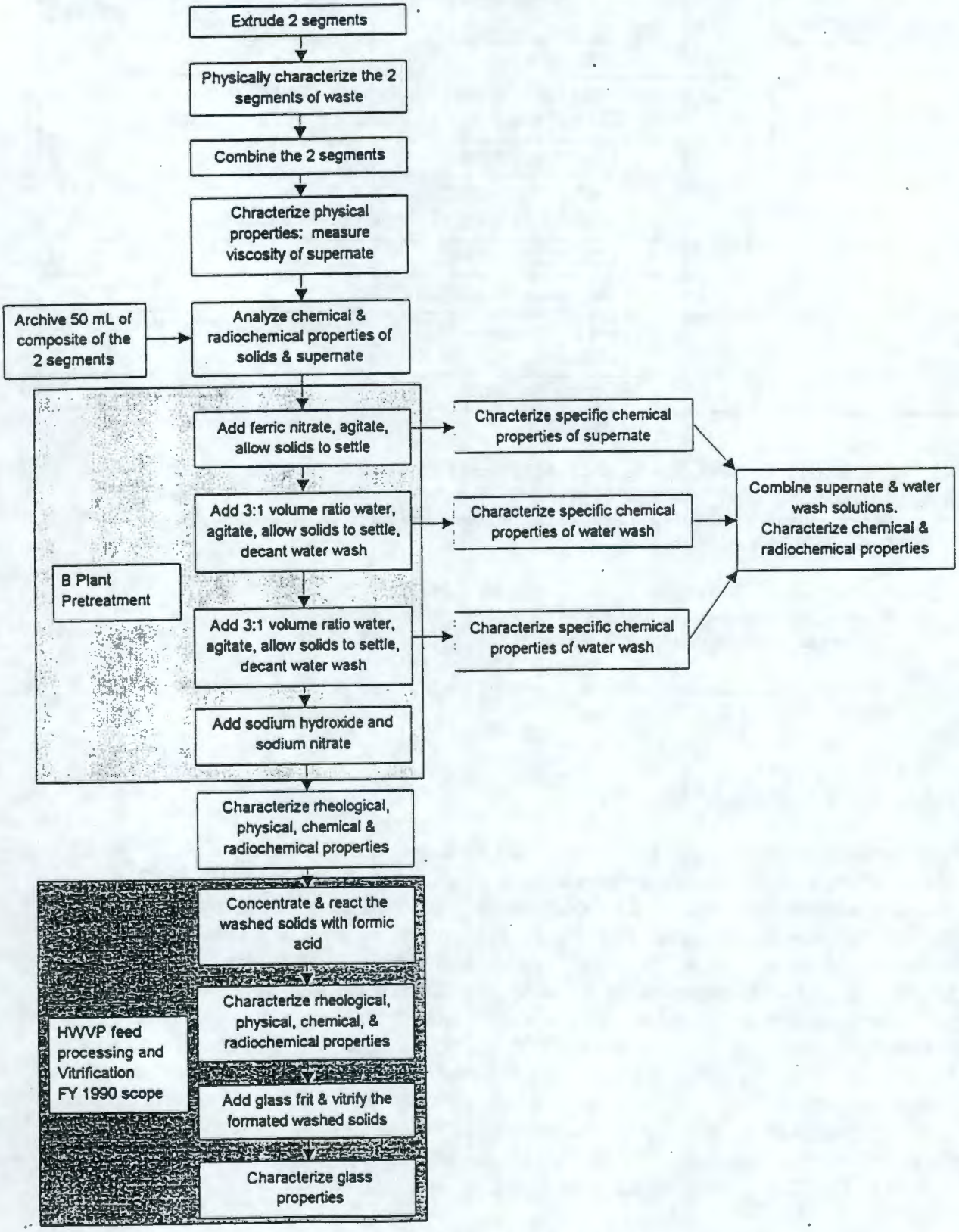
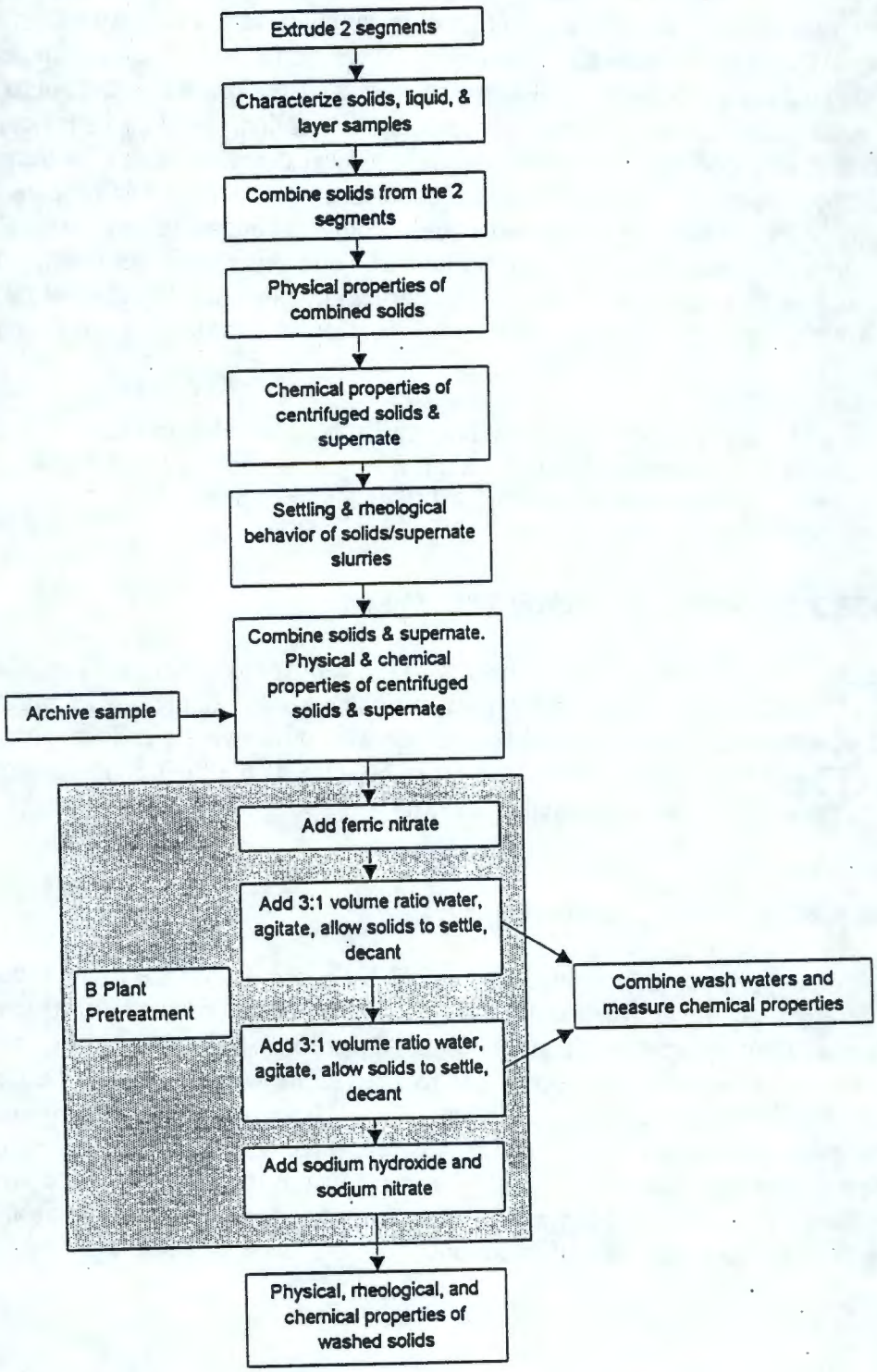


Figure 3-2. Characterization Plan for the Second Core Sample.



Following extrusion, the weight, photograph, and description of each segment of the second core sample were recorded (Gray et al. 1993). Shear-strength and layer samples were selected from the solids, and physical and rheological characterizations were performed on the liquids. Additional physical characterizations were performed on the composite solids. Physical, chemical, and radiochemical analyses were also performed on the solids and supernate obtained from centrifugation of the composite solids. Settling behavior, rheological properties of two waste slurries, and physical characteristics of a third slurry were measured. Following these analyses, a composite core sample was prepared by combining all of the remaining solids and liquids from the composite solids and slurry samples. Physical properties of this composite core were recorded before centrifugation. The physical, chemical, and radiochemical properties of solids and liquids were also measured after centrifugation. The steps in the characterization process are summarized in Figure 3-3.

Two fusions and dissolutions followed by inductively coupled plasma analyses were performed on the large chunk of material taken from the third core sample (McGrail 1991). The remaining waste was used in a modified Miller Number procedure.

3.3 DESCRIPTION OF 1995 SAMPLING EVENT

On March 3, 1995, four grab samples from varying depths (see Table 3-3) were taken from riser 24A of tank 241-AZ-101 using a typical weighted-bottle sampler. The purpose was to determine whether the waste would be compatible with other wastes and for process testing (Carothers 1994). No field/trip blank was taken because of the high concentration levels expected in the analyte results (Schreiber 1995).

3.3.1 Sample Handling and Analysis (1995)

Samples were shipped to and received by the 222-S Laboratory on the same day they were taken. The three supernate grab samples were analyzed in accordance with the requirements of Schreiber (1995); the results are tabulated in Appendix B. No physical description of the samples was available (Rollison 1995). The fourth sample was assumed to be a sludge sample based on the depth from which it was taken. However, on inspection in the laboratory it was discovered that no sludge was recovered in the sample. The fourth sample was for process testing, but since no sludge was recovered the purpose of the sample could not be fulfilled and so the sample was not analyzed. The sample identification numbers and the corresponding laboratory identification numbers are listed in Table 3-4.

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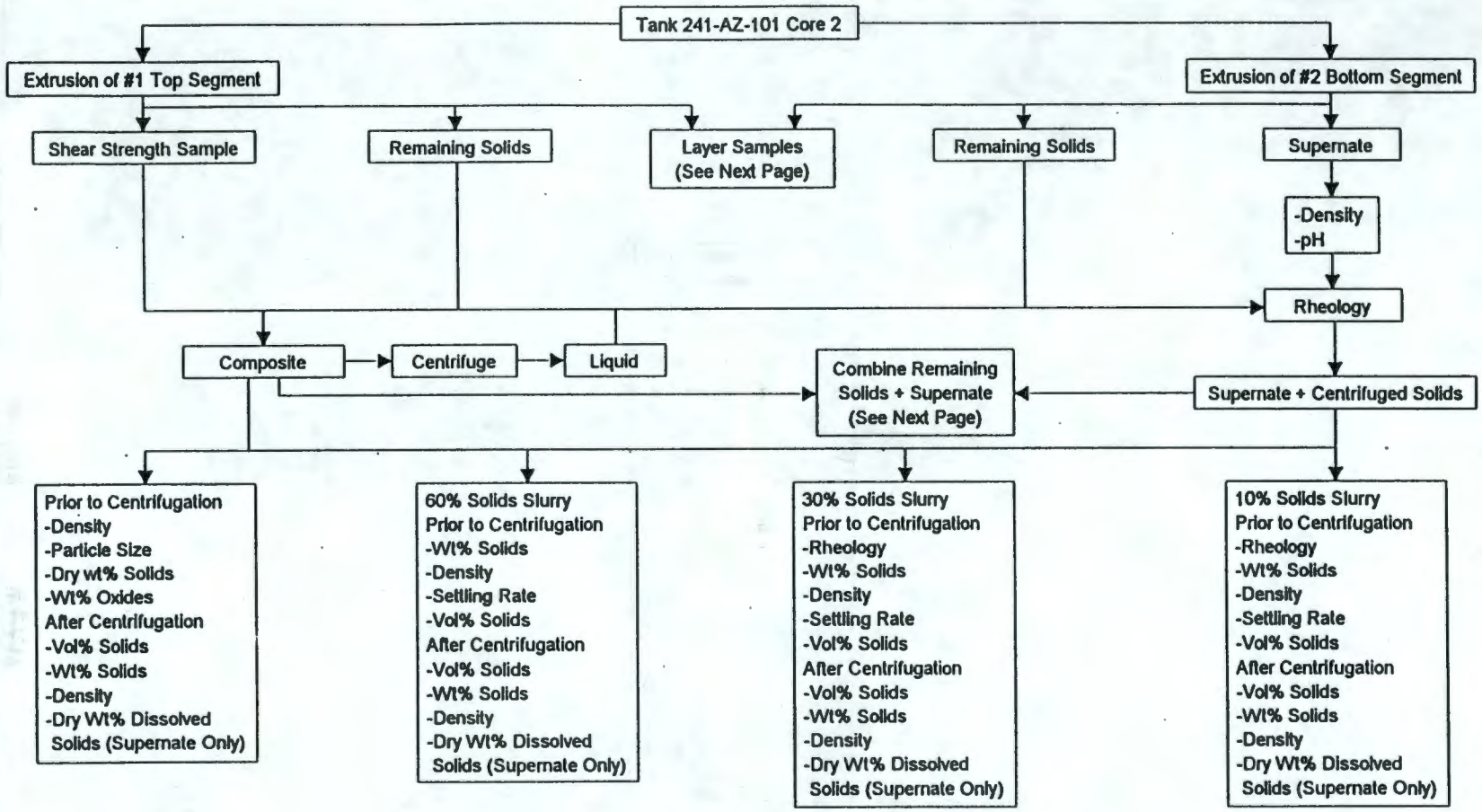

Figure 3-3. Flow Diagram for the Characterization of the Second Core 1989 Sample. (2 sheets)

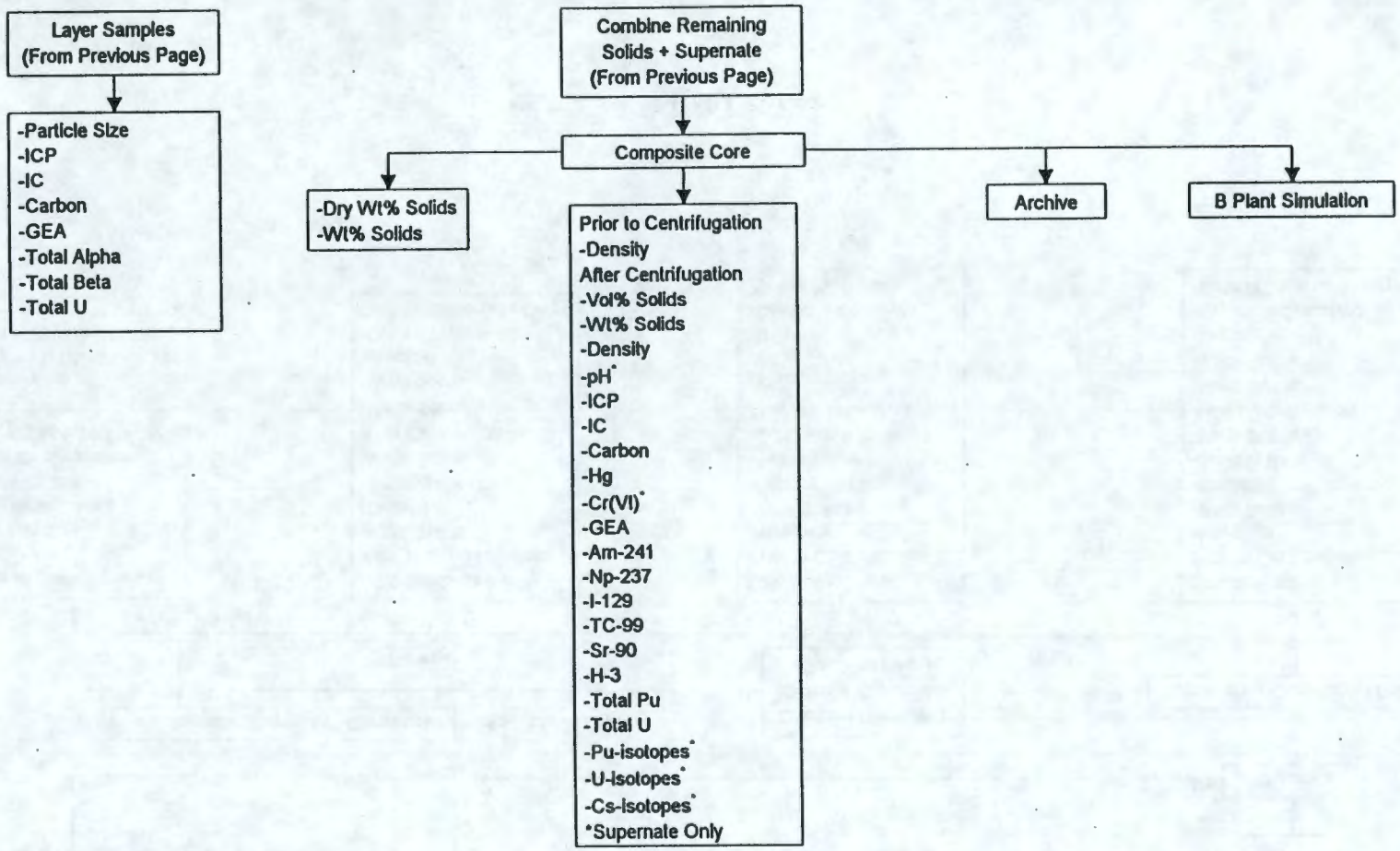

Figure 3-3. Flow Diagram for the Characterization of the Second Core 1989 Sample. (2 sheets)

Table 3-3. Grab Sampling Depths[1].

Sample Number	Sample Type	Sample Location	Sample Depth[2]
AZ-101-1	Supernate	Riser 24A	321 inches
AZ-101-2	Supernate	Riser 24A	491 inches
AZ-101-3	Supernate	Riser 24A	657 inches
AZ-101-4	Sludge	Riser 24A	664 inches

Notes:

[1]Schreiber, R. D., 1995, *Tank 241-AZ-101 Tank Characterization Plan*, WHC-SD-WM-TP-284, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

[2]Sample depth is defined as the distance from the top of the riser to the mouth of the sample bottle.

Table 3-4. Laboratory Sample Identification.

Sample Number	Laboratory ID	Source
AZ-101-1	S95T000278	Undiluted original sample
	S95T000305	Original sample diluted 10X
AZ-101-2	S95T000279	Undiluted original sample
	S95T000306	Original sample diluted 10X
AZ-101-3	S95T000280	Undiluted original sample
	S95T000307	Original sample diluted 10X

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4.0 ANALYTICAL RESULTS AND WASTE INVENTORY

4.1 OVERVIEW

This section summarizes sampling and analytical results from the most recent sludge and supernate samplings. It estimates the analyte concentration for sludge and supernate. In addition, a total inventory for each analyte in the tank is provided based upon the estimated amount of sludge and supernate in the tank. The summary tables and appendices where the data can be found are listed in Table 4-1. Data regarding the physical characteristics of the sludge portion of the waste are discussed in Section 4.3. All sampling events, from which the reported results were derived, are described in Section 3.

Table 4-1. Analytical Data Tables and Appendices.

Analysis	Location
Tank 241-AZ-101 chemical composition summary	Table 4-2
Analytical summary for sludge - 1989 Cores	Appendix A
1995 Grab samples results	Appendix B
1987 Samples results	Appendix C

The sludge composition is based upon the 1989 first and second core sample analyses of tank 241-AZ-101. The data were obtained from Peterson et al. (1989) and Gray et al. (1993) and are summarized in Table 4-2. The calculated analyte concentrations for sludge are a sum of the results obtained from centrifuged solid and centrifuged liquid samples from the sludge (see Appendix A). The values in Table 4-2 are averages of values from the first and second core samples. With regard to the centrifuged solids, the samples designated for inductively coupled plasma and some radiochemical analysis were prepared by two fusion methods. One fusion was performed by potassium hydroxide in a nickel crucible; the other was conducted with sodium peroxide in a zirconium crucible. The results were then reported as averages of the two fusion methods. No comments concerning precision were provided.

The supernate composition and inventory for the tank was based upon results from the 1995 grab samples (Rollison 1995) (see Appendix B). A simple mean was calculated from the results for each analyte. This composition and inventory may change if transfers into and out of the tank occur.

Table 4-2. Analytical Summary for Waste in Tank 241-AZ-101 (3 sheets).

Analyte	1989 Sludge Sample		1995 Grab Samples (Liquid above Sludge)		
	Calculated Analyte Concentration	Projected Inventory	Liquid Sample Result		Projected Inventory
Metals	µg/g	kg	µg/mL	µg/g	kg
Ag	360	78.2	---	---	---
Al	24,200	5,320	9,320	7,830	32,600
As	506	111	---	---	---
B	264	57.8	---	---	---
Ba	639	139	---	---	---
Be	15.3	3.32	---	---	---
Ca	2,130	467	---	---	---
Cd	4,920	1,070	---	---	---
Ce	1,070	234	---	---	---
Co	< 1,010	< 220	---	---	---
Cr	1,560	343	---	---	---
Cu	380	82.6	---	---	---
Dy	< 875.3	< 16.5	---	---	---
Fe	87,200	19,100	< 10	< 8.40	< 35.0
K	5,700	1,260	---	---	---
La	3,320	724	---	---	---
Li	64.6	14.2	---	---	---
Mg	537	118	---	---	---
Mn	2,650	4,260	---	---	---
Mo	110	24.1	---	---	---
Na	79,000	17,300	95,200	80,000	333,000
Nd	2,380	518	---	---	---
Ni	3,940	855	---	---	---
P	2,550	558	---	---	---
Pb	468	101	---	---	---
Pu	79.0	17.2	---	---	---
Re	51.1	11.0	---	---	---
Rh	383	83.1	---	---	---

Table 4-2. Analytical Summary for Waste in Tank 241-AZ-101 (3 sheets).

Analyte	1989 Sludge Sample		1995 Grab Samples (Liquid above Sludge)		
	Calculated Analyte Concentration	Projected Inventory	Liquid Sample Result		Projected Inventory
Metals	µg/g	kg	µg/mL	µg/g	kg
Ru	780	169	---	---	---
Sb	< 2,380	< 517	---	---	---
Se	1,600	352	---	---	---
Si	5,150	1,130	---	---	---
Sr	436	95.3	---	---	---
Te	1,700	374	---	---	---
Th	1,090	240	---	---	---
Ti	577	127	---	---	---
Tl	< 5,920	< 1,280	---	---	---
U	4,910	1,070	---	---	---
V	22.9	4.97	---	---	---
Zn	357	78.6	---	---	---
Zr	30,900	6,720	---	---	---
Ions	µg/g	kg	µg/mL	µg/g	kg
F^-	2,160	472	1,580	1,330	5,530
Cl^-	125	27.1	174	146	609
Cr(VI)	424	93.9	---	---	---
NO_2^-	43,200	9,410	56,800	47,700	199,000
NO_3^-	45,800	10,100	66,000	55,500	231,000
OH^-	---	---	11,400	9,580	39,900
PO_4^{3-}	610	134	1,310	1,100	4,590
SO_4^{2-}	16,900	3,320	15,400	12,900	53,900
Carbon	µg C/g	kg C	µg/mL	µg/g	kg
Total organic carbon	9,180	2,030	1,030	866	3,600
Total inorganic carbon	5,250	1,150	5,780	4,860	20,200

Table 4-2. Analytical Summary for Waste in Tank 241-AZ-101 (3 sheets).

Analyte	1989 Sludge Sample		1995 Grab Samples (Liquid above Sludge)		
	Calculated Analyte Concentration	Projected Inventory	Liquid Sample Result		Projected Inventory
Radionuclides	µCi/g	Ci	µCi/mL	µCi/g	Ci
^{241}Am	302	66,600	< 0.0301	< 0.0253	< 105
^{14}C	0.002	0.353	---	---	---
^{144}Ce	20.8	3,750	---	---	---
^{242}Cm	0.079	17.8	---	---	---
$^{243/244}Cm$	0.79	144	---	---	---
^{60}Co	4.90	2,080	---	---	---
^{134}Cs	3.71	821	---	---	---
^{137}Cs	1,480	319,000	1,590	1,340	5.57E+06
^{154}Eu	126	22,300	---	---	---
^{3}H	0.013	2.82	---	---	---
^{129}I	0.035	5.82	---	---	---
^{237}Np	0.059	10.3	---	---	---
^{238}Pu	0.60	132	< 4.20E-05	< 3.53E-05	< 0.147
^{239}Pu	3.58	781	---	---	---
^{240}Pu	1.01	222	---	---	---
$^{239/240}Pu$	---	---	< 4.20E-05	< 3.53E-05	< 0.147
^{241}Pu	32.9	7,200	---	---	---
^{106}Ru	37.4	6,800	---	---	---
^{125}Sb	114	19,700	---	---	---
^{79}Se	0.002	0.451	---	---	---
^{90}Sr	33,400	6.02E+06	1.20	1.01	4,200
^{99}Tc	2.73	474	---	---	---

Notes:

C = carbon
Ci = curies
kg = kilograms
µgC/g = microcuries of carbon per gram
µCi/g = microcuries per gram
µCi/mL = microcuries per milliliter
µg/g = micrograms per gram
µg/mL = micrograms per milliliter

The physical analytical results presented in Section 4.3 are based on results from the 1989 core sampling event.

When all results for an analyte were less than the instrument's detection limit, individual concentration values were based on the detection limit and were reported as less than the detection limit. The calculated projected inventory was also reported as a less than value. Where there was one detected and one less than concentration result, the resulting mean was recorded as a detected value as was the calculated projected inventory.

4.2 DATA PRESENTATION

The chemical composition of the sludge and the liquid, which is above the sludge layer, is reported in Table 4-2. The sludge layer results are based on data from two core samples taken in 1989, and the liquid results are based on data from the 1995 grab samples. The second column, "Calculated Analyte Concentration," lists the estimated concentration of each analyte with respect to the entire mass of the sludge. The third column, "Projected Inventory," displays the estimated amount (kilograms) of each analyte in the sludge. The results in these two columns represent averages of the corresponding values for the first and second core samples. The sludge radionculides have been decayed six years (1989 to 1995) from the values given in Appendix A. The last three columns deal with the supernate located above the sludge. The volume of this supernatant liquid waste in tank 241-AZ-101 was 3.50E+06 liters (L) (925,000 gal) when the March 1995 sampling event occurred (Hanlon 1995). This volume and the reported specific gravity 1.19 (Table B-1), were used to calculate the last two columns.

4.3 PHYSICAL MEASUREMENTS

Physical analyses were performed on three of four primary samples and three duplicate samples from the 1995 grab sampling event. The sample analyses produced physical data for percent water by gravimetric analysis, percent water by thermogravimetric analysis, specific gravity, and pH. These data are summarized in Table 4-3 and tabulated in Appendix B.

Extensive physical and rheological characterizations were performed on the 1989 first and second core samples from tank 241-AZ-101. The physical characterization included the following: density, settling rate, volume percent settled solids, volume percent and weight percent centrifuged solids, weight percent total solids, weight percent dissolved solids, weight percent total oxide, pH (first core only), particle size, shear stress versus shear rate (apparent viscosity), shear strength, and penetration resistance. The data associated with the physical properties from the 1989 first and second core sample analyses are listed in Tables 4-4 and Table 4-5, respectively.

Table 4-3. Tank 241-AZ-101 1995 Grab Sample Physical Data (Rollison 1995).

Physical Property	1995 Grab Sample (Supernate)		
Sample Number	S95T000278/ Duplicate	S95T000279/ Duplicate	S95T000280/ Duplicate
Specific Gravity	1.19/ 1.20	1.18/ 1.16	1.20/ 1.19
Gravimetric %H_2O	73.8/ 73.5	73.9/ 73.8	73.9/ 73.9
TGA %H_2O	71.36/ 71.38	73.02/ 73.86	73.17/ 73.31
pH	13.55/ 13.59	13.54/ 13.56	13.55/ 13.58

Table 4-4. Tank 241-AZ-101 1989 First Core Sample Physical Data[1].

Physical Property	Supernate[2]	Solids[3]	Composite Core	Washed Solids[4]	30 Vol% Wash Solids Slurry	Wash Composite
Density (g/mL)	1.2	1.7	1.28	1.04	1.1	NR[5]
Centrifuged solids density (g/mL)	NA	1.8	1.8	1.4	1.4	NR
Vol. % settled solids	0	100	48	58.5	100	NR
Vol. % centrifuged solids	0	74	16	15	31.8	NR
Wt. % dissolved solids in centrifuged supernate	26.9	6.63	23.7	NR	NR	24.6
Wt. % centrifuged solids	0	78.3	22.3	20	40.1	NR
Wt. % total solids	26.9	58.9	34.6	9.4	20	NR
Wt. % oxides	NR	45.6	22.5	6.6	14	NR
pH	13.7	NR	NR	12.6	12.6	13.1

Notes:

[1]Peterson, M. E., R. D. Scheele, and J. M. Tingey, 1989, *Final Report - Characterization of the First Core Sample of Neutralized Current Acid Waste from Double-Shell Tank 101-AZ*, Incoming Correspondence no. 8904140 to A. J. DiLiberto, dated September 29, Westinghouse Hanford Company, Richland, Washington.
[2]Centrifuged Supernate from Core Composite
[3]As-received Solids Prior to Compositing Core
[4]Washed Solids Slurry
[5]NR = Analysis Not Requested

Table 4-5. Tank 241-AZ-101 1989 Second Core Sample Physical Data[1].

Physical Property	Composite Solids[2]	Slurries			Core Composite[3]	Washed Solids[4]
		60% Solids	30% Solids	10% Solids		
Density (g/mL)	1.62	1.51	1.35	13.4	1.67	1.14
Centrifuged solids density (g/mL)	1.73	1.80	1.77	1.79	1.84	1.53
Centrifuged supernate density (g/mL)	1.22	1.14	1.22	1.24	1.22	0.98
Vol. % settled solids	100 [5]	100 [5]	56 [6]	50 [7]	100 [5]	66 [8]
Vol. % centrifuged solids	76	56	27	22	71	28
Wt. % dissolved solids in centrifuged supernate	5.37	10.4	18.5	20.2	NR	NR
Wt. % centrifuged Solids	81	67	36	29	79	38
Wt. % total solids	57	47	41	NM	55	19 [9]
Wt. % oxides	41	NR	NR	NR	43	16 [9]

Notes:

NR = No Analysis Requested
NM = Not Measured

[1]Gray, W. J., M. E. Peterson, R. D. Scheele, and J. M. Tingey, 1993, *Characterization of the Second Core Sample of Neutralized Current Acid Waste from Double-Shell Tank 101-AZ*, Pacific Northwest Laboratory, Richland, Washington.

[2]Blended solids from the two core composites

[3]Blended solids and liquids

[4]Solids slurry remaining after washing the core composite

[5]No Settling Observed

[6]After 121 hours

[7]After 50 hours

[8]After 23 hours; no interim measurements made

[9]These values sightly underestimate the true values because they do not account for the dissolved solids in the centrifuged supernate, which was not measured

In addition to the quantitative characterizations for the 1989 sampling event, the physical appearance of the waste was documented after extrusion and processing steps. The waste was described in terms of its physical state (solution, slurry, or sludge), color, particle size, ability to hold its shape, and other observable characteristics.

4.3.1 Density, Percent Solids, Weight Percent Oxides, and pH

For the first core segment sample, density measurements were performed on the following: supernate, solids, composite core, wash composite, washed solids, and a 30 volume percent centrifuged washed solids solution. The density measurements of the second core segment samples were conducted on a composite of the solids blended from the two segments, a core composite (blended solids and liquids), washed solids (solid slurry remaining after washing the core composite), and three composite slurries composed of 60, 30, and 10 percent solids.

The percent solids data for the 1989 samples were tabulated as a volume percent and as a weight percent. These data were further divided as to the type of sample from which the data were derived. These samples are inclusive of the centrifuged solids, settled solids, dissolved solids, and total solids. The solid samples in both the first and second cores were quite dense with densities ranging from 1.62 g/mL to 1.8 g/mL.

To obtain the percent solids data, a sample of waste was placed into a tared crucible or vial, then the mass of the sample was determined. The sample was allowed to air-dry overnight to remove free liquid thus preventing splattering of the sample in the oven. After the free liquid was evaporated, the sample was transferred to a drying oven or furnace at 105 (± 5) °C where it was dried for 24 hours. The dried samples were removed from the oven and placed in a desiccator to cool to room temperature, after which the weight of the dried solids was determined. The weight percent total solids was the dried solids weight, divided by the initial sample weight.

The weight percent dissolved solids was determined for the supernate samples and the interstitial solution or centrifuged supernate from the slurry or sludge samples. The samples of the supernate and interstitial solution were dried using the same procedures as for the weight percent total solids measurement. For solutions, the weight percent dissolved solids was the dried material divided by the initial sample mass, multiplied by 100. For slurries or sludges, the weight percent dissolved solids was the weight percent dissolved solids in the supernate or interstitial solution multiplied by the weight percent supernate in the slurry or sludge.

The percent total oxides were measured using the dried solids from the weight percent total solids measurement. The dried solids were placed in a furnace at 1025 (±25) °C for 30 minutes, which converted the chemicals in the sample to their stable oxide form. Then the sample was allowed to cool to about 150 °C, transferred to a desiccator, and cooled to room temperature. Once cooled, the sample was weighed. The weight percent total oxide was the

final mass of the sample, divided by the initial sample mass prior to drying, multiplied by 100. During the weight percent total oxide measurement, volatile elements in the sample may have been lost.

Standard laboratory procedures were used to measure the pH of solutions and slurries. Before measuring, the pH electrode was calibrated using a two-standard method that took into account the temperatures of the standards and the samples.

The results of these measurements are tabulated in Table 4-4 and Table 4-5.

4.3.2 Settling Behavior

Settling rates and volume percent settled solids measurements were conducted in preweighed, volume-calibrated centrifuge tubes. The solids level in the centrifuged tubes were observed and recorded over time. It should be noted that settling behavior data should be used with caution. The settling rate is expected to be friction-dependent, and possibly slower in the laboratory than in waste tanks.

Settling rate data are shown in Figures 4-1 through 4-8 as the height of the solid-liquid interface, versus time. The height was calculated by multiplying the volume at the solid-liquid interface by the centimeter per milliliter ratio (cm/mL) determined initially for the centrifuge tube. The volume percent settled solids was determined by dividing the final settled solids volume by the total sample volume and multiplying by 100.

The settling rate sample was placed in the centrifuge tube, and the weight of the sample was determined. Volumes of the liquids, solids, and total sample were determined using the graduations on the centrifuge tube. Solids in the sample were allowed to settle for one hour, and the total sample volume and the volume at the liquid-solid interface were recorded. Solids were allowed to settle an additional hour, and volumes were recorded. Volumes were recorded at two-hour intervals. Volumes were measured until no change was observed among three successive measurements.

4.3.3 Particle Size

Particle size on the first core of the 1989 waste sample was determined using a HIAC/ROYCO* particle size analyzer. This particle analyzer measures the time required for a rapidly moving laser beam to traverse a glycerin solution of suspended particles. The solids were suspended in deionized water, then the slurry was thoroughly agitated. A portion of this sample was injected into the analyzer, and particle sizes between 5 and 225 micrometers were measured.

* Registered trademark of the HIAC/ROYCO Company.

Figure 4-1. Tank 241-AZ-101 First Core Settling Behavior for the First Wash Cycle.

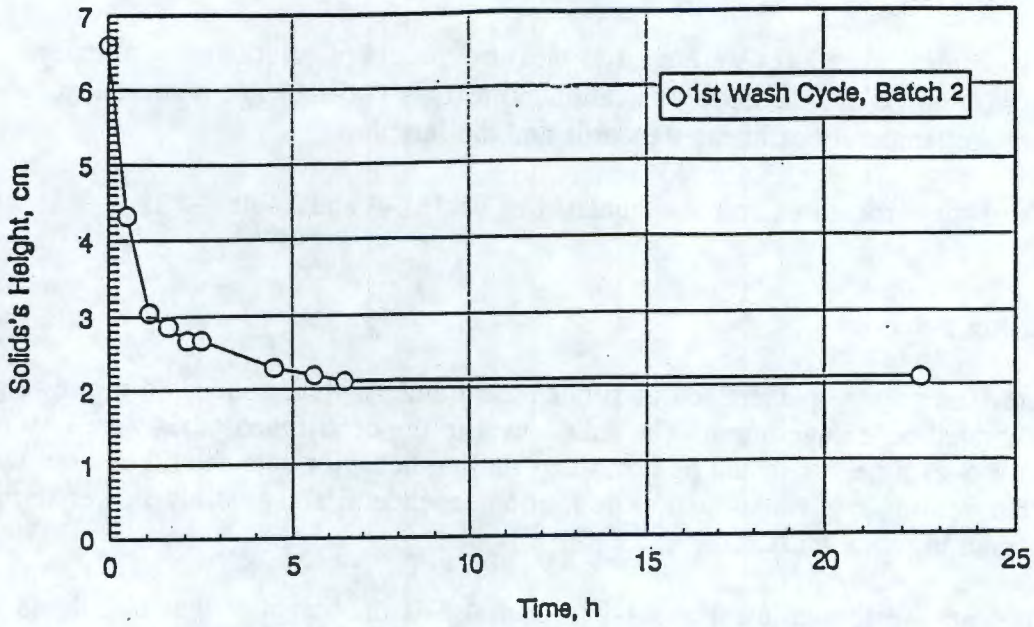


Figure 4-2. Tank 241-AZ-101 First Core Settling Behavior for the Second Wash Cycle.

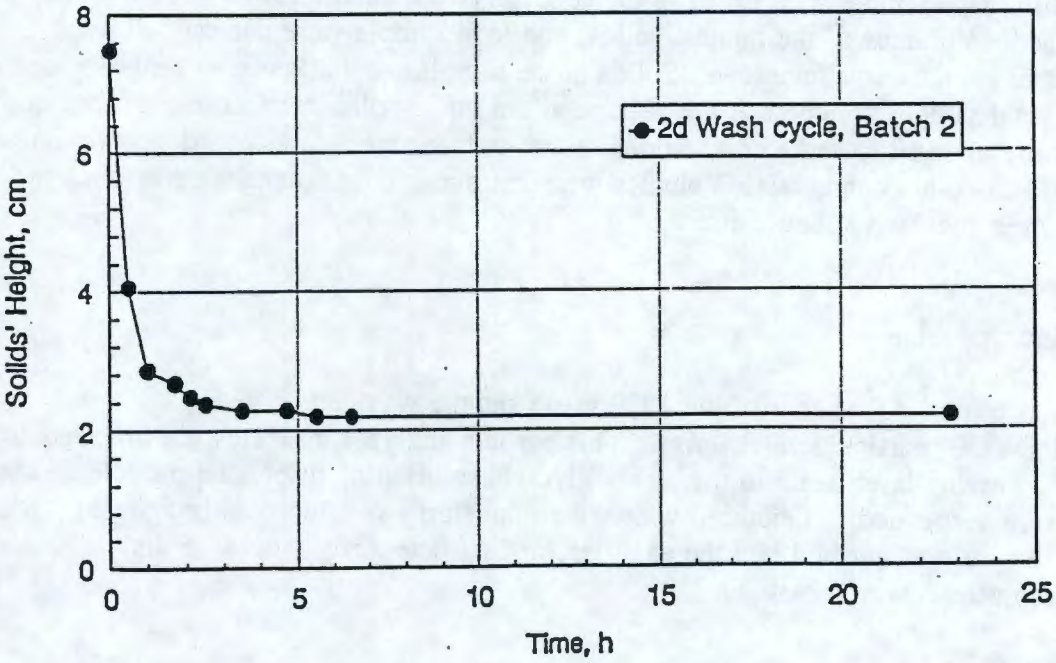


Figure 4-3. Tank 241-AZ-101 First Core Settling Behavior for the Washed Solids.

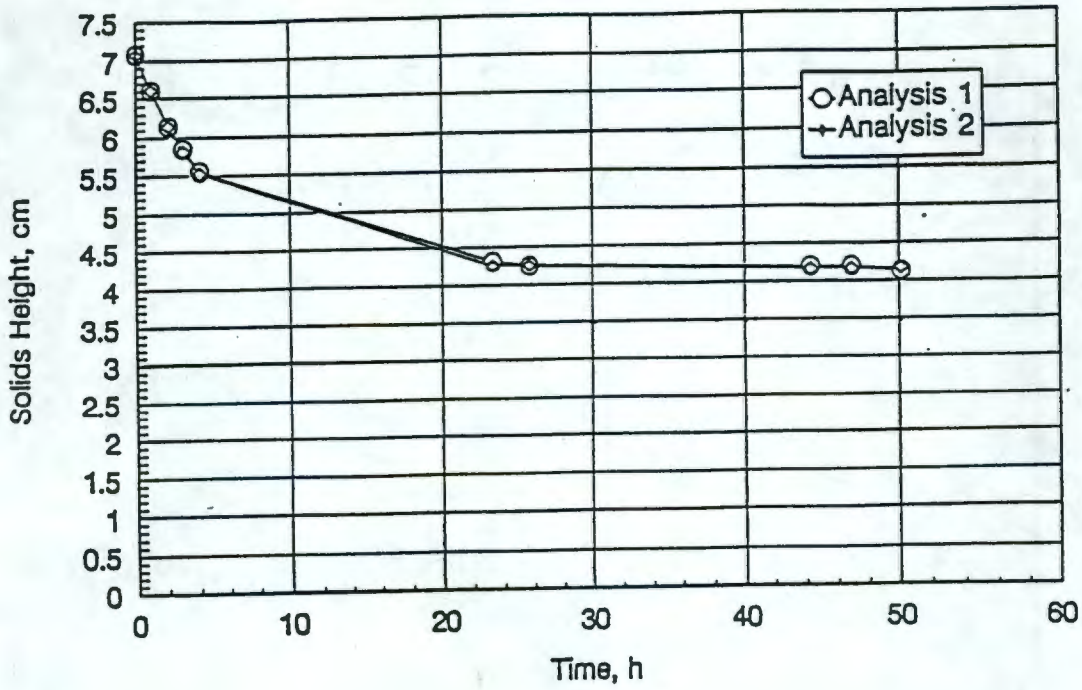


Figure 4-4. Tank 241-AZ-101 First Core Settling Behavior for the Composite Core.

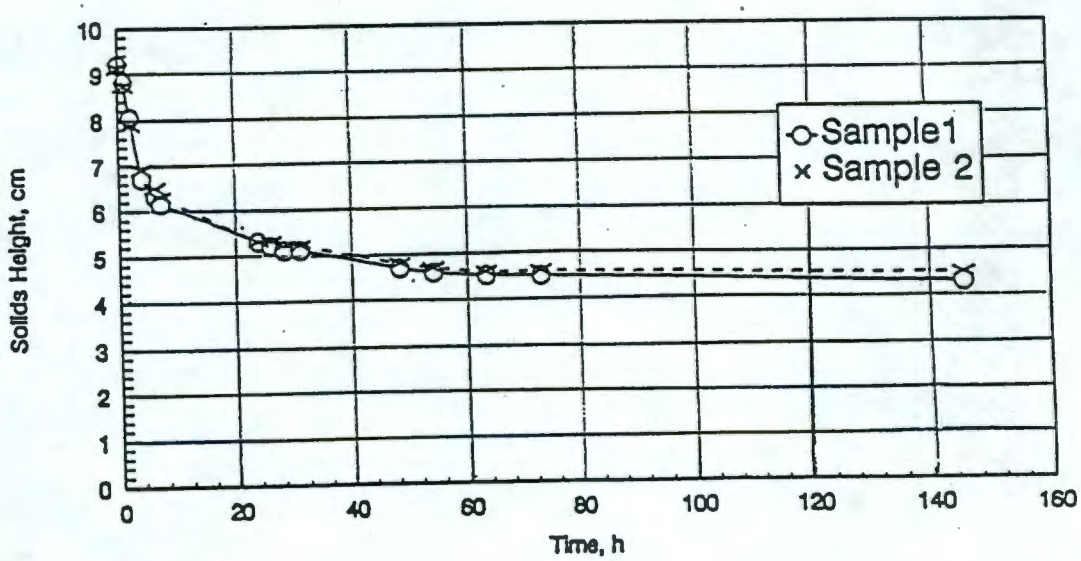


Figure 4-5. Tank 241-AZ-101 Second Core Settling Behavior of the 30 wt% Composite Solids/70 wt% Supernate Slurry.

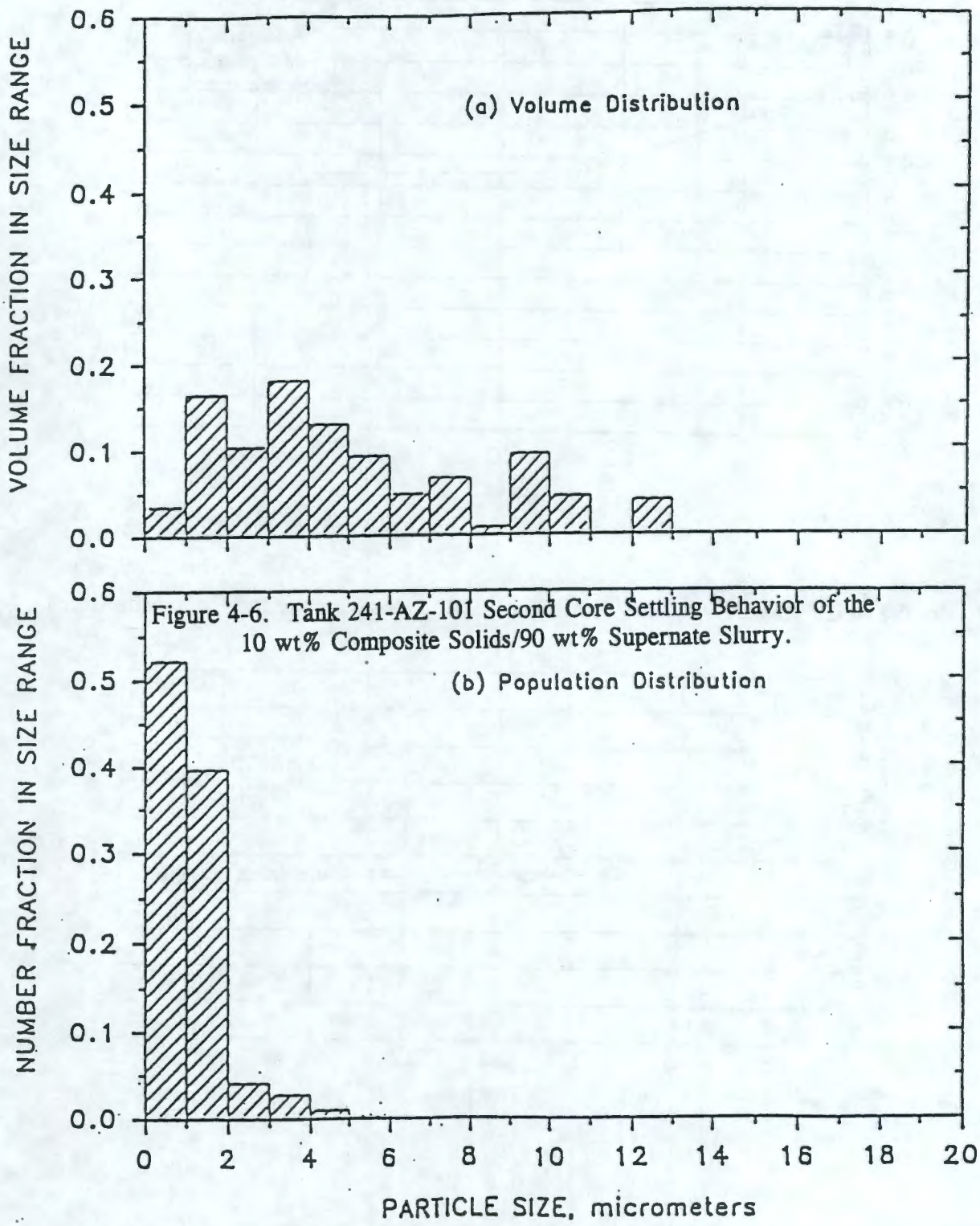


Figure 4-6. Tank 241-AZ-101 Second Core Settling Behavior of the 10 wt% Composite Solids/90 wt% Supernate Slurry.

Figure 4-7. Tank 241-AZ-101 Second Core Settling Behavior of the First Wash Slurry.

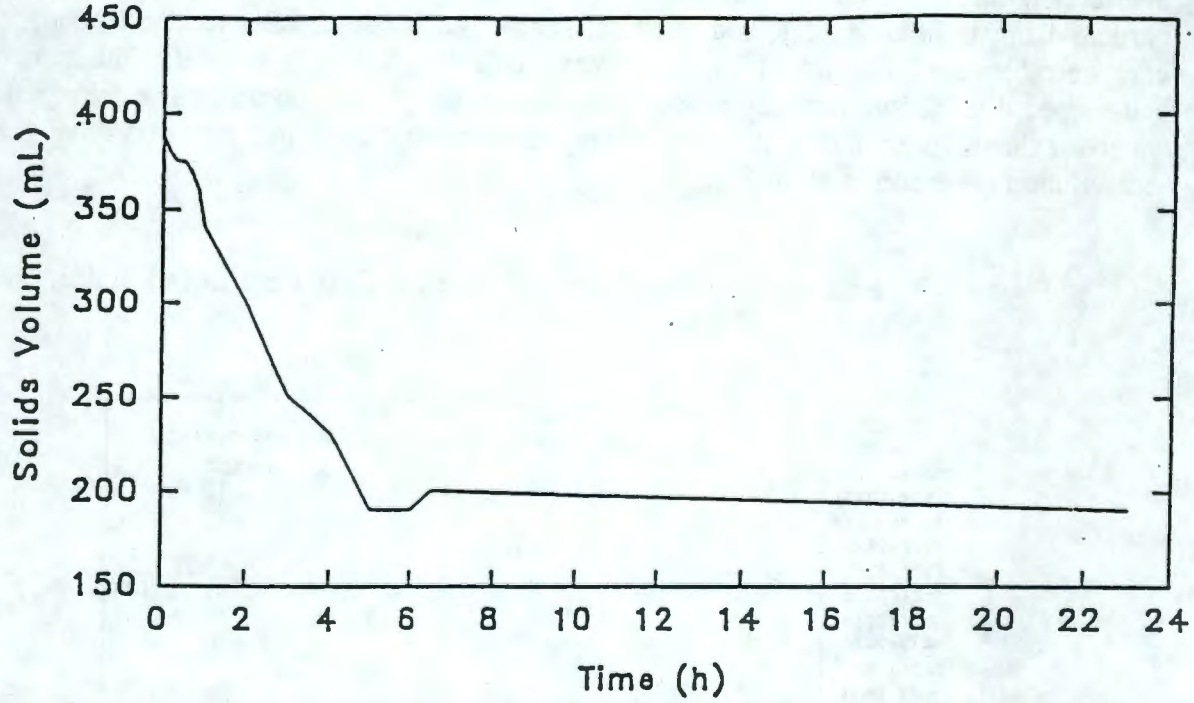
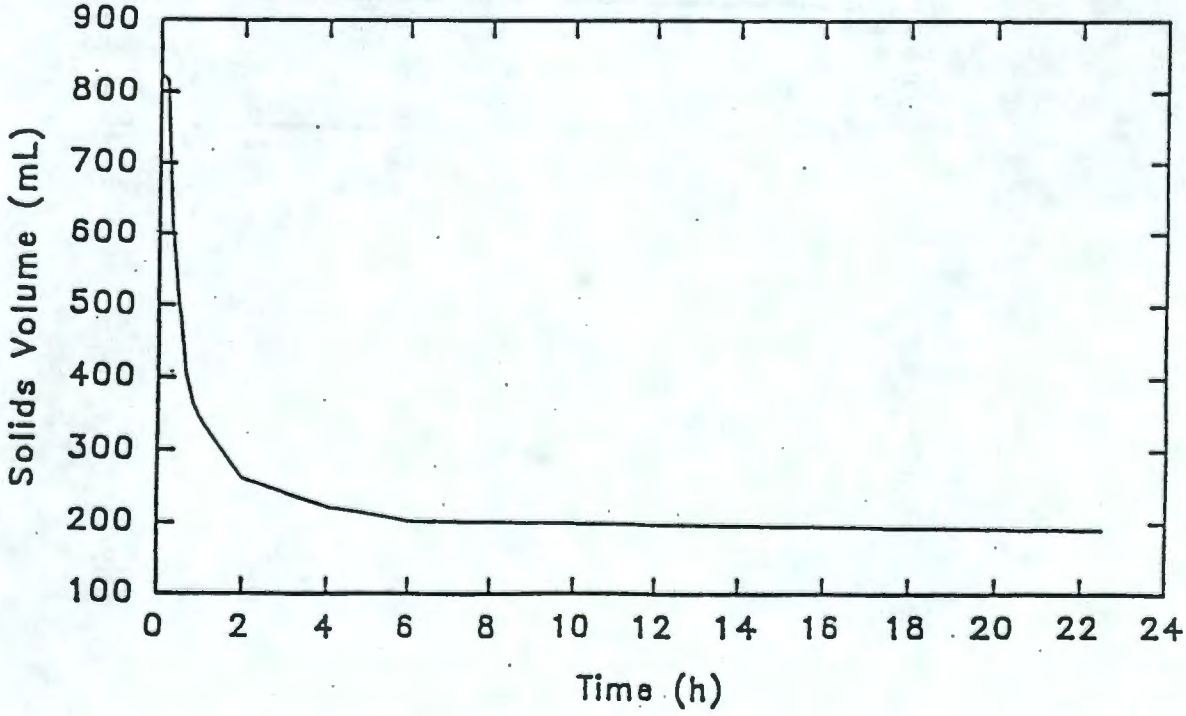
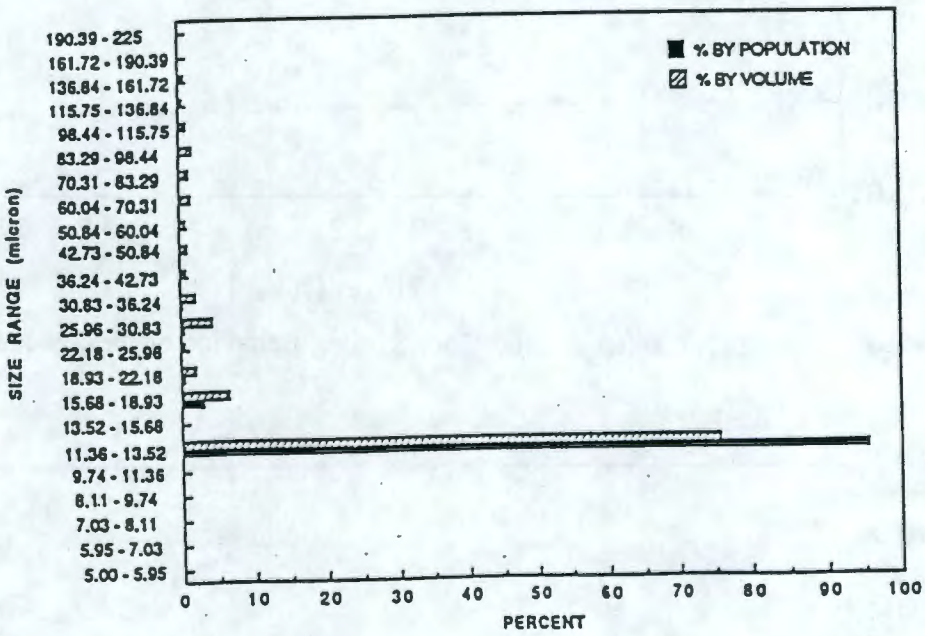


Figure 4-8. Tank 241-AZ-101 Second Core Settling Behavior of the Second Wash Slurry.



The particle size for the centrifuged solids from the first core is shown in Figure 4-9. The particle size distribution is based on both population and volume. The particle size distribution data based on population data are converted to volume by assuming a mean particle diameter in each range and spherical geometry. Most particles for the composite core were between 11.4 and 13.5 micrometers. This distribution is unusual. The more bell-shaped distribution normally expected did not occur. It may be that using deionized water for the dilutions shifted the chemical equilibrium, and some particles may have gone into solution (Peterson et al. 1989).

Figure 4-9. Particle Size Distribution for the First Core Centrifuged Solids.



For the second core sample from the 1989 waste sampling event, a Brinkman Model 2010 Particle Size Analyzer was used to determine the distribution of particle sizes in the solid samples. This instrument determines particle sizes between 0.5 and 150 micrometers by measuring the time required for the laser beam to traverse selected particles maintained in stirred suspension in a glycerin/water mixture. Two measurements on the same sample, about six weeks apart, yielded nearly identical results, thereby providing evidence that the glycerin/water mixture does not partially dissolve the sample thus reducing the particle sizes.

Figures 4-10 and 4-11 show the results of the particle size analyses that were performed on the samples of composite solids (a blend of the solids extruded from the two segments) and of washed solids. The mean particle diameters of the composite solids and the washed solids, based on the volume distribution, were 5.30 micrometers and 4.6 micrometers, respectively. Based upon the population distribution, the mean particle diameters were 1.2 micrometers and 1.1 micrometers, respectively, for composite solids and washed solids. The particle size measurement (six weeks after the first run) yielded mean particle sizes of 4.96 micrometers and 5.01 micrometers based upon volume and 1.21 micrometers and 1.21 micrometers based on population (Gray et al. 1993).

4.3.4 Rheology

Shear strength is a semi-quantitative, primarily qualitative, measure of the force required to move a material. A Haake RV 100 viscometer with a M500 measuring-drive head and a shear vane were used to measure the first and second core waste samples. Shear strength depends upon sample history. Shear strength is exhibited during transient "start-up" shear; it marks the transition from a solid to a viscous slurry. The value of the shear strength is determined using shear vane to generate a plot of torque versus time, at a constant rate.

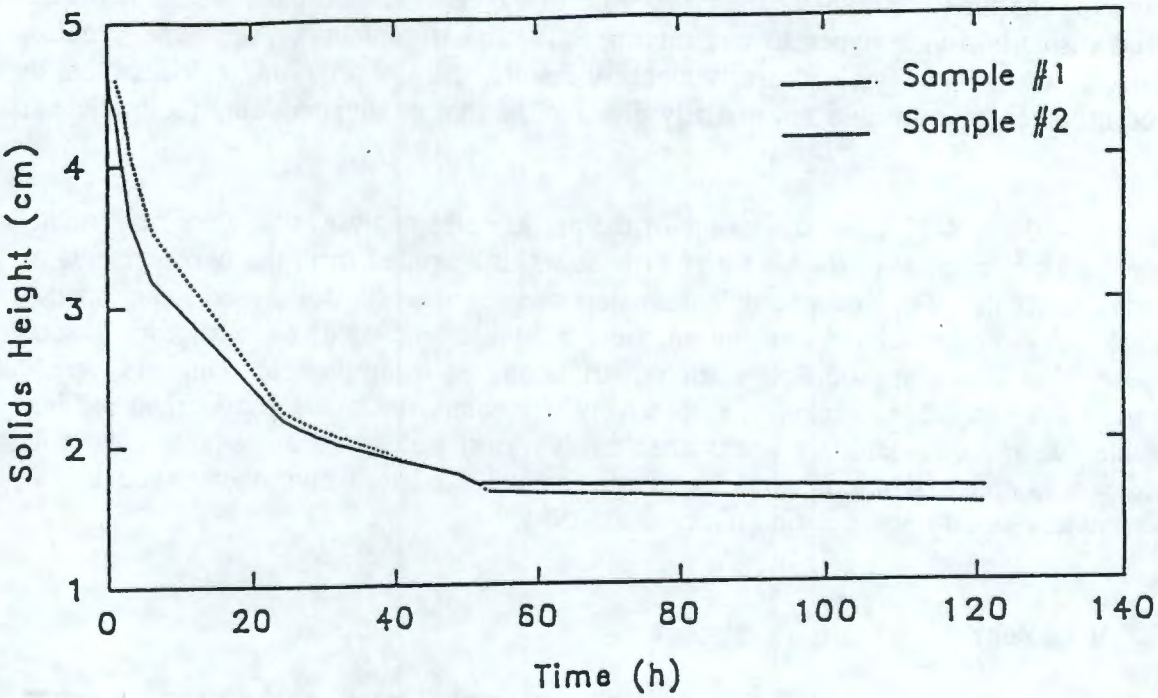
The shear strength for the first core sample was measured at the cell temperature of 28 °C with results of 2,100 and 2,600 dynes per square centimeter (cm^2), values which are consistent with the physical appearance of the solids. The solids were creamy in consistency and would not slide when the sample jar was rotated. The solids stuck to the shear vane and were not easily removed (Peterson et al. 1989).

The shear strength for the second core sample was measured at the cell temperature of 30 °C. The limited sample size only enabled measurement of the shear strength in the center of the waste sample, which, when measured, was determined to be approximately 15,000 dynes/cm^2 (Gray et al. 1993).

4.3.5 Penetration Resistance

The measurement of the penetration resistance of a sludge is used as a qualitative indicator of a sludge's cohesive or dilatant behavior. Knowledge of the cohesive or dilatant properties of a sludge is useful for interpreting shear strength data, applying pilot-scale sludge mobilization

Figure 4-10. Particle Size Distribution of the Second Core Composite Samples Based on (a) Volume and (b) Population (Source: Gray et al. 1993).



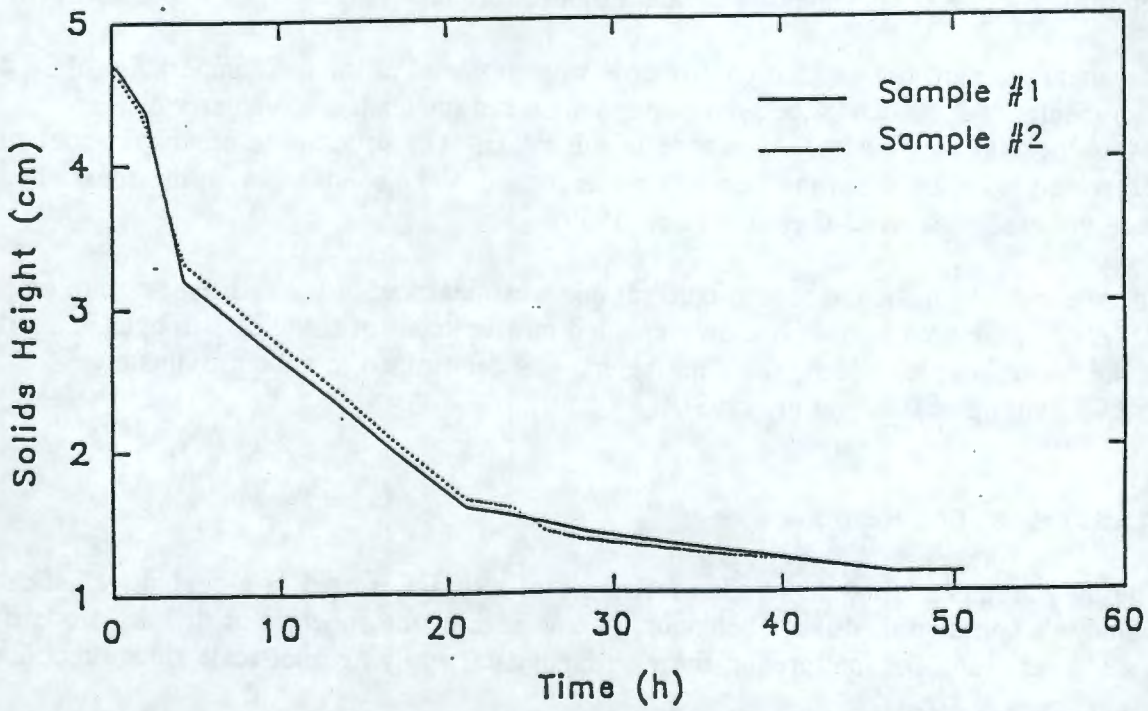
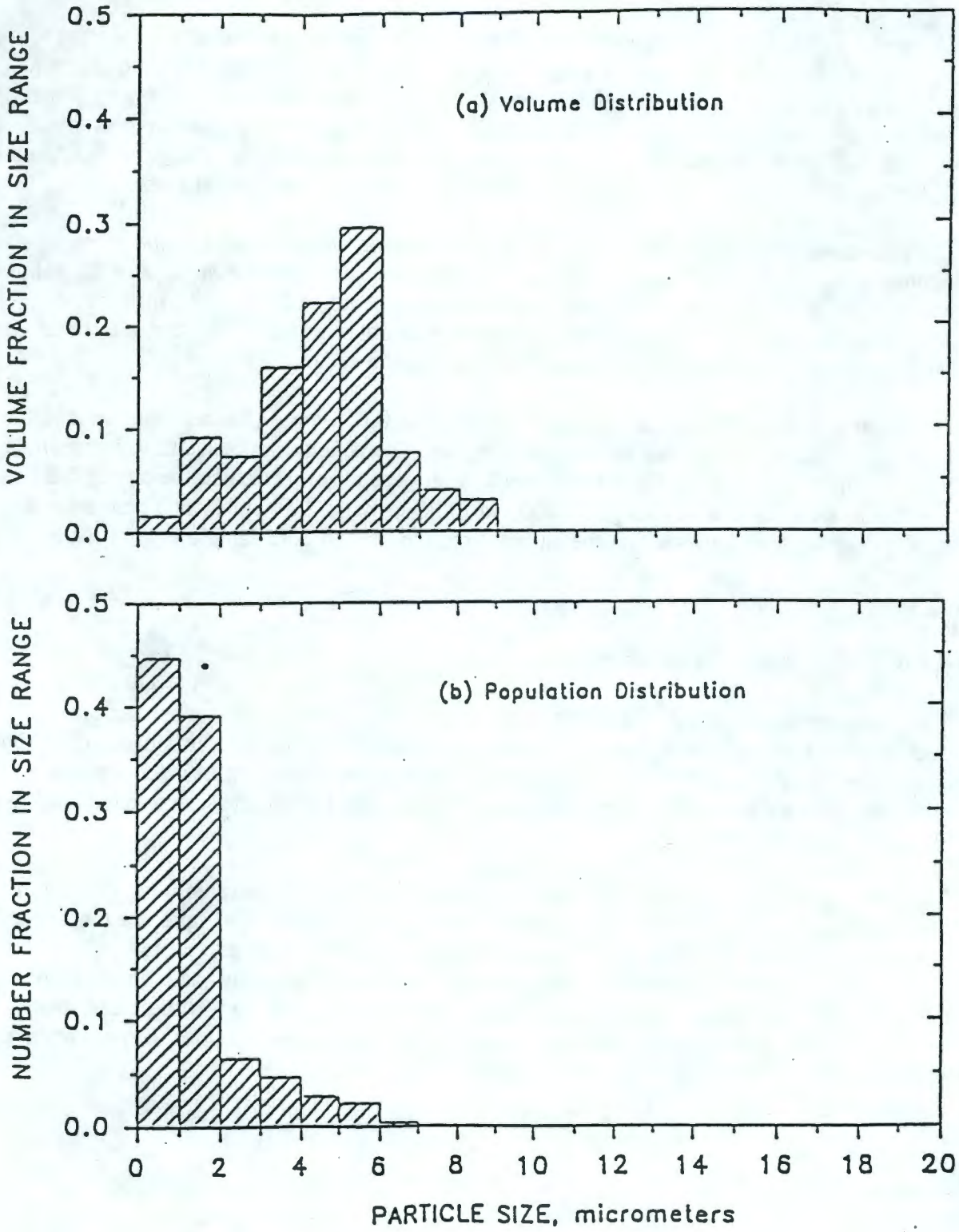


Figure 4-11. Particle Size Distribution of the Washed Solids Based on (a) Volume and (b) Population (Source: Gray et al. 1993).



equations, and determining full-scale mixer-pump performance for sludge retrieval. A dilatant sludge will tend to be eroded by the mixer pumps, whereas a cohesive sludge will be broken down into large chunks of sludge. Retrieval of a sludge by erosion action would require a smaller mixer pump than the retrieval of a sludge that breaks into large chunks.

The difference between the penetration resistance of a dilatant material and a cohesive material is quite large (a factor of 10), making the penetration resistance a good indicator of the sludge property. A low penetration resistance (0 to 10 pounds per square inch [lb/in.^{2}]) indicates the sludge is cohesive. A high penetration resistance (100 lb/in.^{2} or greater) suggests the sludge is dilatant, but it is necessary to know whether the sludge is composed of finely divided material or another type of material such as a solid crystal mass.

The penetration resistance for the first core waste sample was measured in the center of the sample using the one-inch diameter end of the penetrometer. The top surface of the solids was flat and smooth. The solids were penetrated to a depth of 2.54 cm (1 in.). A penetration resistance measurement of 0 lb/in^2 was obtained indicating that the solids exhibit cohesive properties rather than dilatant (Peterson et al. 1989).

The second core waste sample was analyzed with the 0.635-cm (0.25-in.) diameter and the 2.54-cm (1-in.) diameter ends of the penetrometer. The penetration resistance measurements were taken in the center of the waste sample, with penetration resistance results of 0.2 lb/in.^{2} and 0.8 lb/in.^{2}, respectively for the 0.635 cm (0.25 in.) and 2.54 cm (1 in.) penetrometer ends. These results indicate that the sludge from the second core sample is also cohesive, as in the first core sample (Gray et al. 1993).

4.3.6 Shear Stress Versus Shear Rate

Shear stress versus shear rate data are used to evaluate fluid viscosity. The data are generated as a rheogram or flow curve, which is a plot of shear stress as a function of shear rate. The rheograms for the first and second core samples from tank 241-AZ-101 were obtained using a Haake RV 100 viscometer equipped with an M5 measuring-drive head and the MV1 sensor system.

The measurement of viscosity with this instrument requires that the sample be placed in the gap between two coaxial cylinders. Approximately 40 milliliters of sample are thoroughly agitated and transferred into the cylinders. When the system is set into motion, a viscosity-related torque, caused by the sample's resistance to shearing, acts on the inner cylinder. This torque deflects a measuring device which is correlated to the shear stress value. A slurry with a yield stress will "clamp" the rotor to the cup until the applied torque exceeds the yield stress (Peterson et al. 1989).

For non-Newtonian fluids, viscosity changes with shear rate. Therefore, data representing shear stress versus shear rate are fit to a rheological model to describe the fluid behavior. The rheological model parameters for the non-Newtonian fluids are input into a computer program that calculates the critical velocity, critical Reynolds number, friction factor, and pressure drop for pipeline design (Peterson et al. 1989).

The shear stress versus shear rate was measured on the first core centrifuged supernate, the washed solids, and a 30 volume percent centrifuged solids concentration of the washed solids. No rheological measurements were performed on the composite cores or any dilutions thereof. The rheological characterization of the composite core is important to the retrieval operation. Questions concerning the representativeness of the solids in this core sample arose because the samples were obtained by a suction method. A decision was made to postpone the extensive rheological characterization of the composite core to the second core sample from tank 241-AZ-101 (Peterson et al. 1989).

The rheology of the centrifuged supernate was characterized at 65 °C and 95 °C; two measurements were obtained at each temperature. The viscosity versus the shear rate curve is shown in Figure 4-12. At shear rates greater than 40 sec^{-1} (which is equivalent to a flow rate of 30 gallons per minute (gal/min) or 1.3 feet per second (ft/s) in a 3-in.-diameter pipe), the fluid exhibits Newtonian behavior. The average viscosity at 65 °C was 3 centipoise (cP), and the average viscosity at 95 °C was 2 cP.

The rheological characterization of the washed solids was performed at the cell temperature of 29 °C and at a concentration of 15 volume percent centrifuged solids. Again, two rheograms were generated. The washed solids exhibited a small yield stress; therefore, the data from the rheograms were "fit" to a yield-pseudoplastic model. The rheological models for the washed solids were:

$$r = 483 + 0.0118(\gamma)^{.8290}$$
$$r = 483 + 0.0076(\gamma)^{.8803}$$

where

r = shear stress, Pa
γ = shear rate, s^{-1}

Figure 4-13 shows the viscosity versus shear rate of the washed solids. This relationship was obtained using the rheological models.

Figure 4-12. Viscosity of the Tank 241-AZ-101 Centrifuged Supernate (Peterson et al. 1989).

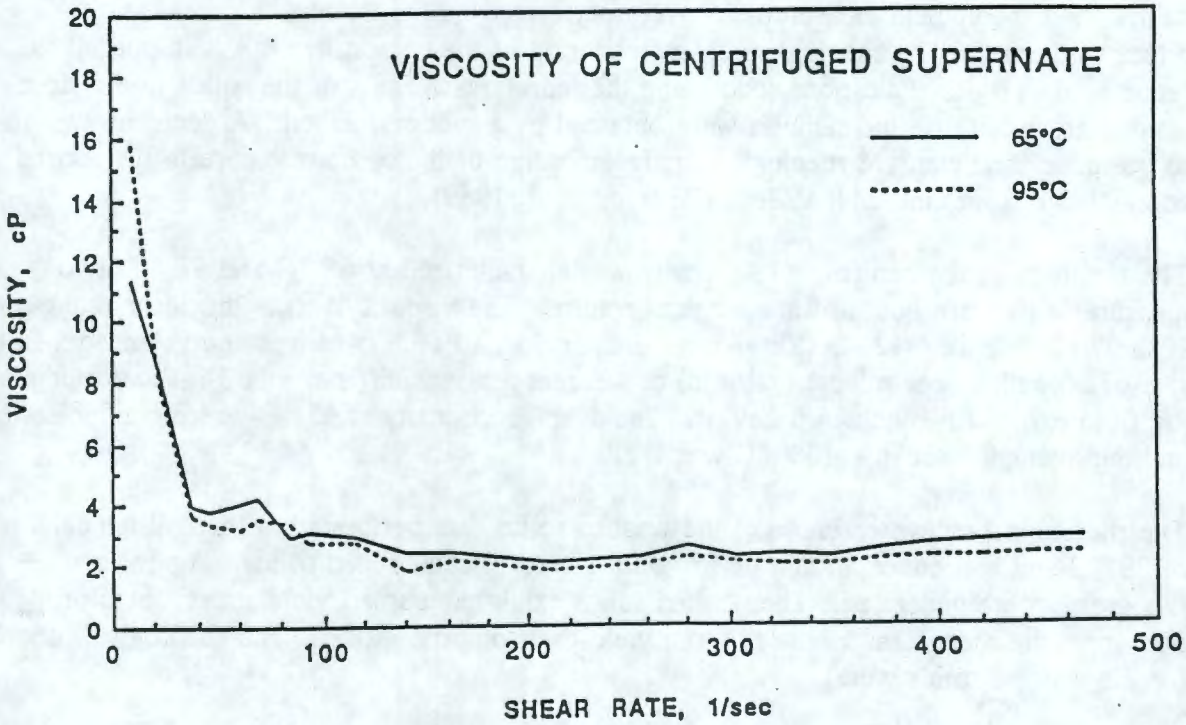
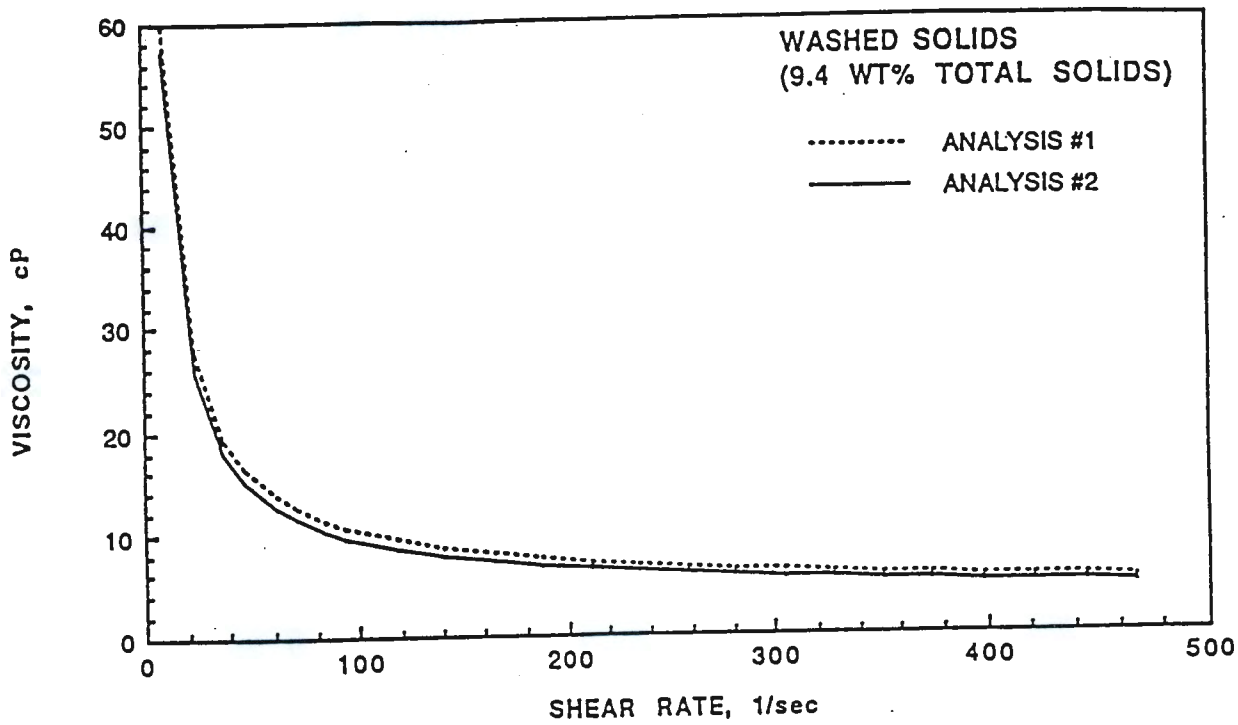


Figure 4-13. Viscosity of the Tank 241-AZ-101 Washed Solids (Peterson et al. 1989).



The rheological parameters, together with the density of the dilutions or derivative slurries, were input into the Hank's computer model (Hanks 1978) to obtain the critical Reynolds Number, flowrate, and velocity for transporting the slurries in 3.0 in. and 2.0 in. diameter pipes. For a 3.0 in.-diameter pipe, the critical Reynolds Number ranged from 6,100 to 7,200, and the critical velocity and flowrate ranged from 136 liters per minute (L/min) (0.475 ft/s) to 125 L/min (0.442 ft/s). For a 2.0 in.-diameter pipe, the critical velocity and flowrate ranged from 68 L/min (0.533 ft/s) to 64.4 L/min (0.494 ft/s). The critical velocities, flowrates, and Reynolds Numbers calculated for the washed solids will not be difficult to achieve in full-scale transport (Peterson et al. 1989).

The rheological properties (shear stress versus shear rate) of the second core waste sample were more extensive. The 30 weight percent solids slurry exhibited yield pseudoplastic behavior (i.e., the slurry had a significant yield stress). The data from the rheograms were fit to a nonlinear yield power law model.

$$\acute{o} = \alpha + \beta\gamma^n$$

where

$\acute{o}$	=	shear stress
γ	=	shear rate
α	=	yield stress (not a fit parameter)

The rheological properties for the 10 weight percent solids slurry exhibited pseudoplastic behavior. The behavior of this slurry differs from that of the 30 weight percent in that no yield stress was observed for the 10 weight percent solids slurry. Therefore, setting $\alpha = 0$, the rheological data for this slurry were also fit into the above equation. Results from the fit for the separate runs are tabulated in Table 4-6.

Figures 4-14 and 4-15 present the apparent viscosity versus velocity in a 2.0-in. internal diameter and 3.0-in. internal diameter pipe, respectively. As with the first core rheological parameters, the properties, along with the density of the slurries, were input into the Hank's computer model to obtain the critical Reynolds Number and the critical velocity for transporting the slurries in a 2.0-in.- and a 3.0-in.-diameter pipe. The critical velocities and the Reynolds Numbers calculated for this waste slurry are achievable for full-scale transport. For the 3.0-in.- and the 2.0-in.-diameter pipes, the critical velocities for the 30 weight percent solids slurry correspond to critical flowrates of approximately 874 and 458 L/min, respectively. For the 10 weight percent solids slurry, the critical velocities in a 3.0- and 2.0-in. internal diameter pipe correspond to critical flowrates of approximately 372 and 201 L/min, respectively (Gray et al. 1993).

Table 4-6. Results from Fit to Rheological Models for the First Core.

Slurry	α	β	n	R^2
30 wt% Solids	1.26	0.050	0.7872	0.98
	1.29	0.030	0.8664	0.98
10 wt% Solids	0	0.080	0.5953	0.98
	0	0.024	0.6856	1.00
	0	0.059	0.6472	0.99

Critical Reynolds Numbers and Velocities

Slurry	Pipe ID in.	Critical Velocity (m/s)	Critical Reynolds number
30 wt% Solids	3.0	0.822	4,300
		0.792	4,800
	2.0	0.945	3,700
		0.91	3,900
10 wt% Solids	3.0	0.427	2,300
		0.213	2,300
		0.396	2,300
	2.0	0.518	2,300
		0.274	2,300
		0.457	2,300

Notes:

α = yield stress
β = Beta
R^2 = Percent of the variability of the data that can be explained by the model.
m/s = meters/second

Figure 4-14. Viscosity Versus Velocity for the Second Core from Tank 241-AZ-101. (2 in. pipe)

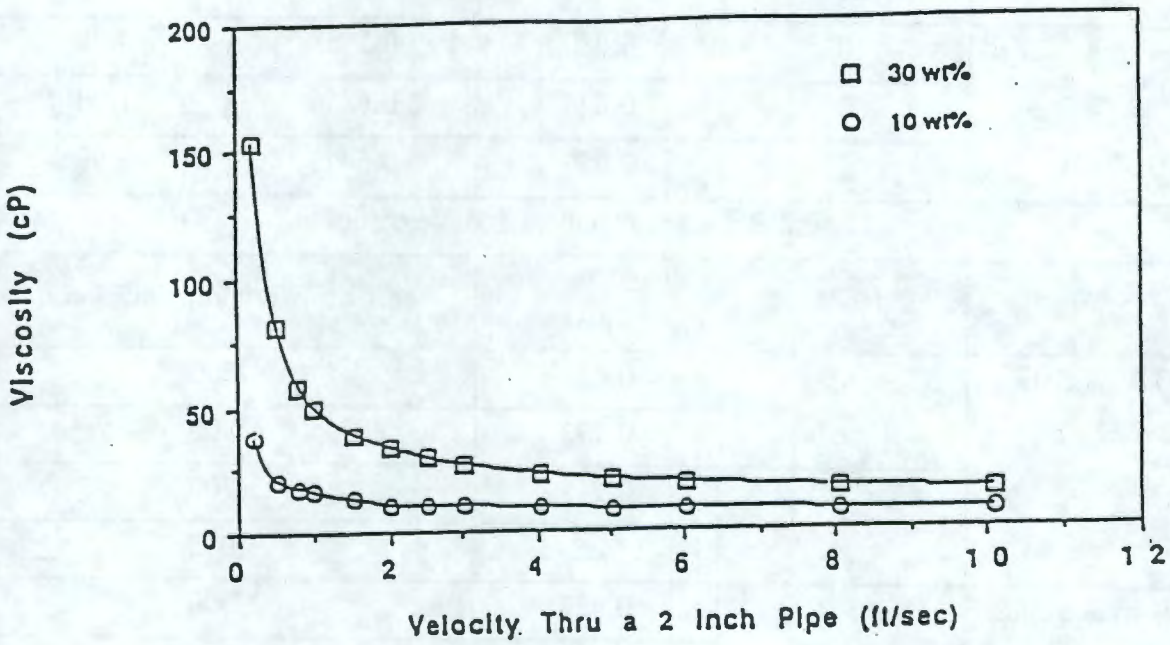
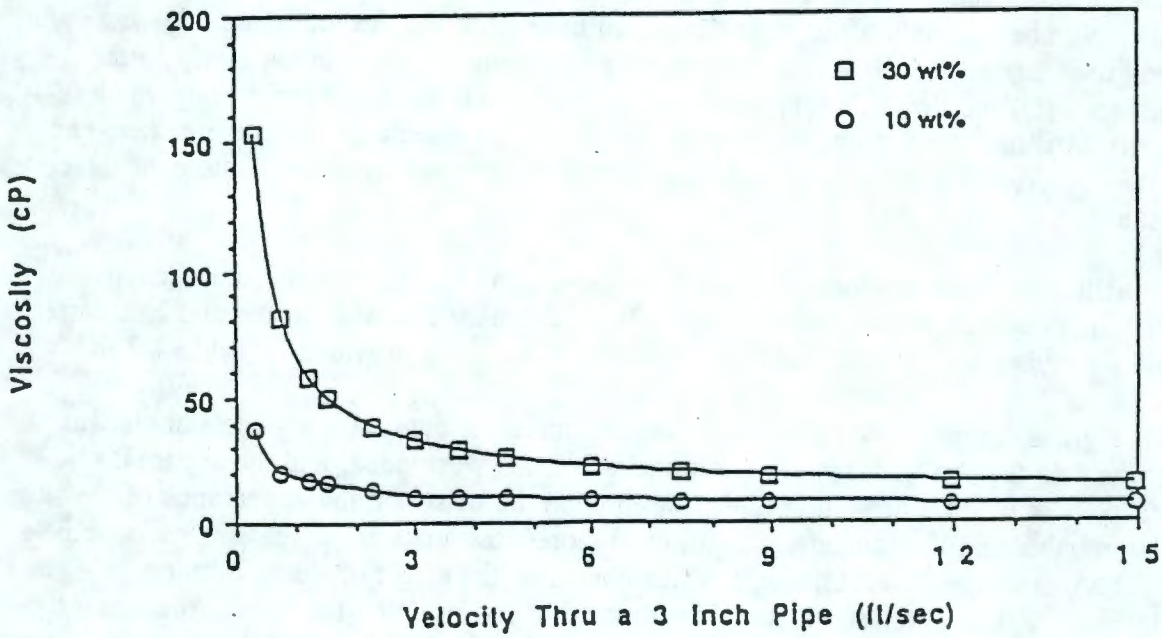


Figure 4-15. Viscosity Versus Velocity for the Second Core from Tank 241-AZ-101. (3 in pipe)



4.3.7 Miller Number

A third core sample containing one segment was taken from tank 241-AZ-101 for the sole purpose of a Miller Number measurement. The Miller Number is a measure of the abrasiveness of a slurry. It describes the relative degree of abrasiveness based upon the mass-loss of a standard 27 percent chrome steel wear block when run in a particular slurry for a period of time. Because of the unique nature of radioactive waste slurries, a modified Miller Number procedure has been developed to account for the following: 1) waste slurries being too viscous at a 50 weight percent solids concentration to flow properly in the instrument; 2) the limited amount of waste and supernate available for testing which is usually less than the amount required; 3) solids being appreciably soluble in water; and 4) the potential evaporation of significant quantities of water from the waste over the course of the test.

The Miller Number measurement was performed using standard sand, nonradioactive stimulants and waste from tank 241-AZ-101 core three. The wear losses and calculated Miller Number for standard sand and the waste sample are provided in Table 4-7.

A 112-gram sample of waste material was measured for eight hours. The sample was observed to thicken noticeably. Additional supernate was added, and the apparent abrasiveness of the slurry increased. Based upon the behavior and appearance of the slurry, it is probable that the thinner slurry allowed more fresh material to reach the wear block, thereby increasing the abrasiveness which overcame the effect of slurry dilution (McGrail 1991). The test was terminated one day and resumed the next. Additional supernate was added to compensate for drying overnight. With the addition of supernate the apparent abrasiveness increased, but no noticeable wear occurred on either lap overall.

Table 4-7. Wear Losses and Miller Number for Standard Sand and the Third Core Sample from Tank 241-AZ-101[1].

Time (hours)	Standard Sand (milligrams)	Third Core Sample (milligrams)
0	0	0
4	37.4	2.3
8	58.2	2.9
12	77.5	4.4
16	95.9	7.0
Miller Number	143	8.4

Note:

[1]McGrail, B. P., 1991, *Results of the Analysis of the Large Chunk of Material and the Measurement of the Miller Number for DST 101-AZ Core #3 Waste*, Incoming Correspondence No. 9101055 to L. M. Sasaki, dated February 11, Westinghouse Hanford Company, Richland, Washington.

The Miller Number measured for the radioactive waste from the third core ranged between 8.2 and 8.6, with a mean of 8.4.

4.3.8 Thermodynamic Analyses

Differential scanning calorimetry analyses were performed on the 1995 waste compatibility grab samples. No exothermic reactions were noted (Rollison 1995). Thermogravimetric analysis was used to determine the percentage of water in the 1995 grab samples, and the results are reported in Table 4-3 and Appendix B. No differential scanning calorimetric or thermogravimetric analysis were conducted on the 1989 core samples.

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5.0 INTERPRETATION OF CHARACTERIZATION RESULTS

5.1 ASSESSMENT OF SAMPLING AND ANALYTICAL RESULTS

This section evaluates 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 limitations in its use.

5.1.1 Field Observations

An error in the recorded height of the riser, which was used to obtain the first 1989 core sample (#15F), led sampling personnel to lower the sampler to the tank bottom for the first segment, rather than taking it from the top of the waste. Furthermore, the first sampler contained supernate when the sampling point was well into the settled solids region of the waste. The second segment was obtained by withdrawing the piston and allowing differential pressure to push the waste into the sampler. As a result, any stratification of waste was obliterated by the resulting flow, and the disturbance probably made any rheological measurement suspect.

No difficulties were noted in other sampling events.

5.1.2 Quality Control Assessment of Analytical Data

An attempt is always made to quantify the different sources of error possible during the chemical analysis of a sample. When these errors are summarized, they give a strong indication of data reliability. If one or more error estimates are outside acceptable limits, the accuracy of the concentration estimate is questioned. Possible sources of error include analytical method error, matrix interferences, sample contamination, and poor instrument calibration. Error estimates are determined from analyzing standards, spike recoveries, blank contamination, and sample duplicate variation.

Quality control information was not provided with the sludge core samples from 1989. Therefore, the accuracy and precision of those analytical results are not known. The data packages for the 1995 grab samples provided some quality control information which is discussed in the following paragraphs (Rollison 1995).

Standards are used to estimate the accuracy of the analytical method and are evaluated prior to and concurrent with sample analysis. Standards contain the analytes of interest at known concentrations. Standard solutions may or may not be independent of the standard used for calibration. The criterion for standard recovery is 100 ($\pm$ 10 percent). If a standard is above or below the criterion, the analytical results may be biased high or low. For the three supernatant samples, two standards were run for differential scanning calorimetry, percent water by thermogravimetric analysis, and all of the anions except fluoride. No standards

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were run for the inductively coupled plasma metals (aluminum, iron, and sodium) or ^{238}Pu, and one standard was run for the remainder of the analytes. The only standard that failed the criteria was for ^{241}Am (86.3 percent recovery), which indicated the data for this analyte may be biased slightly low.

Matrix spikes are used to estimate the bias of the analytical method caused by matrix interferences. Spike samples are prepared by splitting a sample into two aliquots and adding a known amount of a particular analyte to one aliquot to calculate a percent recovery. The quality control criterion for matrix spikes is 100 (± 20) percent recovery. If a spike is above or below the criterion, then the analytical results may be biased high or low. Spikes were conducted only on iron (3 spikes) and the anions (1 spike each). The only spike to fall outside the criterion was for nitrate (120.3). Thus, the analytical results for nitrate may be biased slightly high. The possible influence of matrix interferences on the results for the remaining analytes cannot be assessed or estimated because no matrix spikes were conducted on them.

Method blanks, which document the contamination resulting from the analytical process, are prepared by filling sample containers with deionized, distilled water. They are carried through the complete sample preparation and analytical procedure, and all reagents used in the sample processing are added in the same volumes. One blank was conducted on all anions and radionuclides (except ^{137}Cs), and no blanks were reported for the remaining analytes. The only analyte for which a blank was detected was $^{89/90}Sr$, whose blank value was only 2 percent of the analytical result. This indicates that contamination was not a problem for the analytes on which blanks were conducted.

Random analytical error is estimated from analytical results (variation between duplicate samples, and sample heterogeneity) and indicates laboratory precision and the homogeneity of the samples. To estimate this error, a relative percent difference (RPD) is calculated for each duplicate pair. The RPD is a measure of variability and is defined as the absolute value of one duplicate minus the other, divided by the mean. The tank characterization plan for tank 241-AZ-102 set the duplicate precision acceptance criterion at no RPD being larger than 20 percent (Schreiber 1995). The analytes, in which all values were detected, had three duplicate pairs each. No violations of the criterion were noted, indicating that laboratory precision was excellent.

5.1.3 Data Consistency Checks

The ability to assess the overall consistency or trends of data between segments and between cores is limited for tank 241-AZ-101 sampling and analysis events because of the limited number of cores taken. Some assessment is made based upon the analyses of discrete segments at different depths (see Section 5.4). A comparison of sludge results from the 1989 sampling event indicates data consistency. Additional checks can be made on individual analytes when the same aliquot of sample is analyzed by two comparable methods. Some comparisons are provided in the following sections.

5.1.3.1. Comparison of Inductively Coupled Plasma Phosphorus and Inductively Coupled Phosphate Analyses. Phosphorus was measured by inductively coupled plasma on the 1989 sludge. Phosphate was measured by ion chromatography on a water-digested sludge sample. Using the calculated analyte concentrations in Table 4-2 a comparison of the total phosphate from the inductively coupled plasma analyses (7,820 μg/g) and the results of the ion chromatography analyses (610 μg/g) implies that much of the phosphate is insoluble, which is logical considering the large amount of iron present in the waste. This is addressed further in the next section and in Section 5.4.

5.1.3.2. Comparison of Total Alpha and Total Beta with the Sum of Individual Isotopes. This evaluation is used to ascertain the performance of the radiochemical separation methods or to indicate the presence of other isotopes in significant quantities. With regard to the centrifuged solids from the core composite from core 2, a comparison was made between the sums of the gross beta and gross alpha activities with the sum of the individual beta and alpha emitters. The activities of the individual beta emitters were summed according to the following equation:

$$\text{Total Beta} = (2 * {}^{90}\text{Sr}) + ({}^{137}\text{Cs})$$

(The factor of 2 in the total beta equation accounts for the ^{90}Y daughter product.)

The activities of the individual alpha emitters were summed according to the following equation:

$$\text{Total Alpha} = {}^{241}\text{Am} + {}^{239}\text{Pu} + {}^{240}\text{Pu} + {}^{233/234}\text{Cm}$$

Comparisons are given in Tables 5-1 and 5-2. The tables are based upon results in Gray et al. (1993). The comparisons are limited to data from analyses of the second core because that data set included a list of alpha and beta emitters and the results for total alpha and total beta.

5.1.3.3. Mass and Charge Balance. The principle objective in performing a mass and charge balance is to determine if the measurements are self-consistent. In calculating the balances, only the sludge phase analytes which were detected at a concentration of 2,000 μg/g or greater were considered (see Table 4-2).

With the exception of sodium and potassium, all cations listed in Table 5-3 were assumed to be in their most common hydroxide or oxide forms, and the concentrations of the assumed species were calculated stoichiometrically. There may be some argument about whether certain species are hydroxides or oxides, but the difference in molecular weight has a minimal effect on the overall mass balance. Although smaller concentrations of other forms of the species are probably present in the waste, they are not included in order to keep the mass-charge balance calculations simple and consistent.

Table 5-1. Comparison of Gross Beta Activities with the Total of the Individual Activities[1].

Analyte	Half-Life (years)	Centrifuged Solids (microcuries per gram)
^{90}Sr	28.6	57,200
^{137}Cs	30.17	1,470
Total beta sum (a)	---	116,000
Gross beta result (b)	---	147,000
Relative percent difference[2]	---	23.6 percent

Note:

[1]Gray, W.J., M.E. Peterson, R.D. Scheele, and J.M. Tingey, 1993, *Characterization of the Second Core Sample of Neutralized Current Acid Waste from Double-Shell Tank 101-AZ*, Pacific Northwest Laboratory, Richland, Washington.

[2]Relative Percent Difference is the absolute difference of a and b, divided by their average.

Table 5-2. Comparison of Gross Alpha Activities with the Total of the Individual Activities.

Analyte	Half-Life (years)	Centrifuged Solids (microcuries per gram)
^{241}Am	458	191
^{239}Pu	24,400	4.51
^{240}Pu	6,570	1.27
$^{243/244}Cm$	29.1/18.1	1.31
Sum of alpha emitters(a)	---	198
Total alpha (b)	---	213
Relative percent difference[1]	---	7.30

Note:

[1]Relative percent difference is defined as the absolute difference of a and b, divided by their average.

Since precipitates are neutral species, all positive charge was attributed to sodium and potassium cations. The anionic analytes listed in Table 5-4 were assumed to be present as sodium salts and were expected to balance the positive charge. The acetate and carbonate data were derived from the total organic and total inorganic carbon analyses, respectively. The insoluble phosphate concentration was calculated by subtracting the soluble phosphate (the result of the IC analysis) from the total phosphate (the result of the ICP analysis). The insoluble phosphate was assumed to be in the form of $FePO_4$ because iron was found in a relatively large concentration. The remainder of the iron was assumed to be in combination with oxide and hydroxide as FeO(OH). The concentrations of the assumed species in Table 5-3, the anionic species in Table 5-4, and the percent water were ultimately used to calculate the mass balance, shown in Table 5-5.

The mass balance was calculated from the formula below. The factor 0.0001 is the conversion factor from μg/g to weight percent.

Mass balance = % Water + 0.0001 x {Total Analyte Concentration}
= % Water + 0.0001 x $\{Al(OH)_3 + Ca(OH)_2 + CdO + FeO(OH) + FePO_4 + La(OH)_3 + MnO(OH) + Nd_2O_3 + K^+ + Ni(OH)_2 + SiO_3^{2-} + Na^+ + U_2O_3 + ZrO_2 + C_2H_3O_2^- + CO_3^{2-} + F^- + NO_3^- + NO_2^- + SO_4^-\}$

The total analyte concentrations calculated from the above equation was 540,980 μg/g. The mean weight percent water was determined to be 41.1 percent since the percentage of solids in the sludge was 58.9 percent. The percent of solids used is from the solids analysis for the first 1989 core (see Table 4-4). The mass balance resulting from adding the percent water to the total analyte concentration is 0.95.

The charge balance is the ratio of cations (microequivalents) to total anions (microequivalents) with respect to the species listed below, which were assumed to be water soluble.

Total cations (microequivalents) = $Na^+/23.0 + K^+/39.1$

The total cation charge, 3,587 μmol/g, is calculated in Table 5-3.

Total anions (microequivalents) = $C_2H_3O_2^-/59.0 + CO_3^{2-}/30.0 + F^-/19 + NO_3^-/62.0 + NO_2^-/46.0 + SiO_3^{2-}/38.0 + SO_4^{2-}/48.0$

The total anion charge, 3,731 μmol/g, is calculated in Table 5-4.

The ratio of microequivalents of total cations to microequivalents of total anions was 0.96; a perfect charge balance would yield a ratio equivalent to 1.00.

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Table 5-3. Sludge Cation Mass and Charge Data.

Analyte	Concentration (μg/g)	Assumed Species	Concentration of Assumed Species (μg/g)	Charge (μmol/g)
Aluminum	24,200	$Al(OH)_3$	70,000	0
Cadmium	4,920	CdO	5,620	0
Calcium	2,130	$Ca(OH)_2$	3,940	0
Iron	87,200	FeO(OH)	132,000	0
		$FePO_4$	10,690	0
Lanthanum	3,320	$La(OH)_3$	4,540	0
Manganese	2,650	MnO(OH)	4,240	0
Neodymium	2,380	Nd_2O_3	2,780	0
Nickel	3,940	$Ni(OH)_2$	6,220	0
Potassium	5,700	K^+	5,700	147
Sodium	79,000	Na^+	79,000	3,440
Uranium	4,910	U_2O_3	5,410	0
Zirconium	30,900	ZrO_2	41,600	0
Totals			371,740	3,587

Notes:

μg/g = micrograms per gram
μmol/g = micromole per gram

Table 5-4. Sludge Anion Mass and Charge Data.

Analyte	Concentration (μg/g)	Charge (μmol/g)
Acetate (total organic carbon)	22,500	382
Carbonate (total inorganic carbon)	26,200	874
Fluoride	2,160	114
Nitrate	45,800	733
Nitrite	43,200	940
Silicate	13,980	367
Sulfate	15,400	321
Totals	169,240	3,731

Notes:

μg/g = micrograms per gram
μmol/g = micromole per gram

Table 5-5. Mass Balance Totals.

	Concentrations (μg/g)
Total from Table 5-3	371,740
Total from Table 5-4	169,240
Water	411,000
Grand Total	951,980

Notes:

μg/g = micrograms per gram
μmol/g = micromole per gram

The charge and mass balance results (0.96 and 0.95 recovery respectively) demonstrate agreement among analyses when the uncertainty in the assumptions and numerous measurements used to arrive at the values is considered. The material and charge balances are acceptable and indicate no large errors or ommissions in the data.

5.2 DATA COMPARISON

As discussed in Section 3.0, this report is based upon three sampling events, two of which were used to project the estimated inventories for tank 241-AZ-101. Also of interest is a comparison of different sampling events which indicate the precision of the analyses. Based upon the quality of information available, the only comparison that could be made is between the 1987 and 1995 supernatant results. Common analytes from both sampling events are listed in Table 5-6. The 1995 values used are the means given in Appendix B.

It is assumed that comparable preparation and analytical methods were used. It is also assumed that the supernatant was relatively unchanged between 1987 and 1995 given the transfer history of the tank during that period (see Section 2.0).

Using an arbitrary criterion of a 50 percent difference between the two data sets for a given analyte, only chloride and total organic carbon do not fall within this constraint.

5.3 TANK WASTE INVENTORY PROFILE

Two constraints were encountered in attempting to describe the horizontal and vertical disposition of waste in tank 241-AZ-101. The riser from which the 1987 sludge and supernate samples were taken were not identified; therefore, it is not known whether they were the same risers from which the 1989 sludge sample or the 1995 supernatant sample

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Table 5-6. Comparison of Supernate Constituents[1,2].

Analyte	1987 Supernatant Sample	1995 Supernatant Sample
Metals	moles per liter	moles per liter
Al	0.44	0.34
Na	4.42	4.14
Anions	moles per liter	moles per liter
Cl^-	0.019	0.0049
F^-	0.097	0.083
OH^-	0.90	0.67
NO_3^-	1.39	1.06
NO_2^-	0.79	1.20
PO_4^{-3}	0.017	0.014
SO_4^{-2}	0.16	0.160
Carbon	moles carbon per liter	moles carbon per liter
Total inorganic carbon	0.25	0.48
Total organic carbon	0.43	0.086
Radionuclides	microcuries per milliliter	microcuries per milliliter
^{137}Cs	2,270	1590
$^{89/90}Sr$	1.66	1.20

Notes:

[1]WHC, 1987, *Chemical Analysis of Tank 101-AZ and 102-AZ Samples Taken in October 1987*, (internal memo no. 12221-PCL88-091 from D. L. Herting, dated March 11), Westinghouse Hanford Company, Richland, Washington.

[2]Rollison, M. D., 1995, *Results for 241-AZ-101 Grab Samples*, (internal memo no. 8E480-95-023, dated April 11), Westinghouse Hanford Company, Richland, Washington.

were taken. This precludes any effort to compare or incorporate the 1987 information with the 1989 and 1995 information for horizontal or vertical analysis. Because supernate samples are available only for the 1995 results and these were all taken from the same riser, no horizontal variability analysis can be conducted for the supernatant layer.

Of the four grab samples collected in 1995, three were supernatant samples and the fourth was supposed to be sludge. These samples were taken from the same riser (24A) near the top, the middle, and the bottom of the supernatant layer. No visual description of the samples was given. Differences between supernatant samples are sufficiently small that they should not be considered - for a given analyte the difference between one and another

did not exceed 20 percent, and the criterion for duplicate precision is also 20 percent. Based upon these results, the contents of the supernatant layer appear to be homogeneous.

The first two sludge cores from the 1989 sample were examined more closely in order to determine if any patterns were present in the waste disposition. The first core was taken from riser 15F and the second core was taken from riser 24D. This allows a comparison of the analytical results between the two risers for horizontal variability. Table 5-7 lists and compares the concentrations of several major analytes. Although the results are not consistent in terms of the concentrations being higher in all cases for one riser and lower for the other, it does seem to point out major differences between the two locations and the possible horizontal heterogeneity of the tank contents within the sludge layer. Referring to Table 3-2, the visual description of the samples from the two cores also indicates some differences between them.

Table 5-7. Comparison of Horizontal Variation in the Sludge Layer Between Core 1 and Core 2 from the 1989 Sampling Event.

Analyte	Core 1 (Table A-1)	Core 2 (Table A-2)
Metals	Microgram per gram (μg/g)	Microgram per gram (μg/g)
Al	32,500	15,900
Fe	65,400	109,000
K	8,900	2,500
Na	78,200	79,800
Zr	14,100	47,700
Ions	Microgram per gram (μg/g)	Microgram per gram (μg/g)
NO_2^-	29,000	57,400
NO_3^-	43,500	48,100
SO_4^{-4}	10,600	20,300
Radionuclides	Microcuries per gram (μCi/g)	Microcuries per gram (μCi/g)
^{137}Cs	1,660	1,690
^{144}Ce	2,110	6,520
^{90}Sr	18,760	58,400

A further analysis of the waste disposition was conducted by dividing each of the two segments recovered from the second sludge core (riser 24D) into two subsegments. Chemical analysis was undertaken on the subsegments to determine if any vertical trends were apparent. Table 5-8 lists the subsegments, tank depth increases from left to right. Samples L1 and L2 were obtained from the upper segment and samples L3 and L4 from the second segment. The numerical order of sampling was reversed between the two samplers.

Sample L1 came from the upper sludge layer, sample L3 came from near the bottom, and samples L2 and L4 came from near the middle. Vertical variability within the sludge layer was then examined for trends in the data as a function of tank depth. Of the major analytes listed, aluminum, sodium, nitrite, nitrate, and sulfate generally increased in concentration as a function of depth; the opposite was generally true for iron, zirconium, and ^{137}Cs. Potassium and ^{144}Ce did not show as clear a trend. Given these results, it is difficult to conclude anything about the vertical disposition of waste within the sludge layer other than to say that the contents appear heterogeneous. Visual differences were also noted in Table 3-2.

Table 5-8. Vertical Segment Analysis of Sludge from Core 2 for the 1989 Sampling Event[1].

Analyte	Segment 1		Segment 2	
	L1	L2	L4	L3
Metals	μg/g	μg/g	μg/g	μg/g
Al	13,600	13,400	20,800	53,700
Fe	127,000	132,000	112,000	46,800
K	2,500	3,200	5,900	2,800
Na	74,300	71,300	82,100	138,000
Zr	51,700	54,400	45,700	4,160
Ions	μg/g	μg/g	μg/g	μg/g
NO_2^-	36,700	35,900	42,100	58,400
NO_3^-	32,900	30,000	37,200	41,400
SO_4^{4-}	9,100	11,000	6,300	16,500
Radionuclides	μCi/g	μCi/g	μCi/g	μCi/g
^{137}Cs	1,930	1,930	899	996
^{144}Ce	160	9,840	6,640	6,680

Notes:

μg/g = micrograms per gram
μCi/g = microcuries per gram

[1]Gray, W.J., M.E. Peterson, R.D. Scheele, and J.M. Tingey, 1993, *Characterization of the Second Core Sample of Neutralized Current Acid Waste from Double-Shell Tank 101-AZ*, Pacific Northwest Laboratory, Richland, Washington.

5.4 COMPARISON OF ANALYTICAL AND TRANSFER HISTORY INFORMATION

A comparison of the transfer history of tank 241-AZ-101 with analytical data shows some correlation in terms of overall characteristics. For example, americium, which was a

constituent of neutralized current acid waste, appears in a relatively insoluble form in tank sludge. The ^{241}Am, which appears in high concentrations in the 1989 sludge samples, is a component of the waste stream from the PUREX plant where it was separated from other transuranics in the solvent extraction process. Strontium, a component of aging waste which forms relatively insoluble compounds, is present in high concentrations in the sludge sampled in 1989. Cesium, a highly soluble component of aging waste, is present in the 1989 sludge samples. Cesium and strontium also appear in significant, if lower, concentrations in the 1995 grab samples.

Total organic carbon was analyzed in the layer samples from 1989, and the result corroborates the tank process history which implies a high complex concentrate waste presence in the lower regions of the sludge. The total carbon analytical results of the 1989 layer samples, however, are not reliable or consistent (Gray et al. 1993).

Large quantities of iron in the form of ferrous sulfamate were used in the PUREX second solvent extraction step to reduce the valence of plutonium to the +3 state. The iron, which is assumed to exist in hydroxide and phosphate forms, shows up in all the sludge analyses in relatively high concentrations. In addition, the higher iron concentration in the upper sludge layer reflects the addition of aging waste from PUREX later in the tank's operating life.

Other waste constituents such as nickel and zirconium, which are components of aging waste from PUREX, are present in higher concentrations in upper layers of the sludge.

5.5 EVALUATION OF PROGRAM REQUIREMENTS

Although data quality objectives (DQOs) were not developed when the sludge sampling and analysis of this tank were performed, criteria identification in present DQOs are used in the following evaluations. The waste compatibility DQO was issued prior to the March 1995 supernate sampling and is considered here. It should be noted, however, that the tank characterization plan for the 1995 grab sampling event (Schreiber 1995) specified that the samples were to be obtained from one riser instead of two as required by the *Tank Safety Screening Data Quality Objective* (Babad and Redus 1994).

5.5.1 Safety Evaluation

The data criteria identified in the *Tank Safety Screening Data Quality Objective* (Babad and Redus 1994) is used to assess the safety of waste in tank 241-AZ-101. Although supernate was not sampled for safety screening, the data required for a safety screening evaluation are provided in the *Data Quality Objectives for the Waste Compatibility Program* (Carothers 1994). The safety screening data quality objective identifies the following factors for consideration: energetics, moisture, total alpha, and gas composition.

The waste fuel energy value is usually determined by differential scanning calorimetry (DSC). Differential Scanning Calorimetry analyses were performed on the 1995 grab samples; no exotherms were observed. These analyses were not performed on the 1989 sludge samples from tank 241-AZ-101. Total organic carbon and cyanide are additional criteria for energetics evaluation. The total organic carbon concentration of the 1989 sludge samples ranged from 2.1 percent (wet weight) based upon analysis of the first core sample to 0.14 percent (wet weight) based on analysis of the second core sample. If a moisture content of 41.1 percent is assumed (see Section 5.1.3.3) then the dry weight basis TOC concentration would be 3.7 percent and 0.24 percent respectively. While the TOC value for the first core is close to the 5 percent TOC (dry weight) limit established by the organic safety program (Babad et al. 1994), the moisture content greatly exceeds 17 percent. Cyanide analysis was not performed on the sludge. However, based upon the process history of the tank, there is no basis for cyanide being present in the tank.

Large amounts of moisture reduce the potential for propagating exothermic reactions in the wastes. Because the waste in tank 241-AZ-101 is 96 percent liquid by volume, the moisture content of the sludge is expected to be high. Although no specific weight percent water determination was made for the sludge, the weight percent total solids of the 1989 core composite from the first core sample was 58.9 percent and 55 percent from the second (Gray et al. 1993). This resulted in corresponding weight percent water values of 41.1 percent and 45 percent, respectively. These values satisfy the 17 percent criterion established by the *Tank Safety Screening Data Quality Objective* (Babad and Redus 1994).

Another factor in assessing the safety of tank waste is the heat generation and temperature of the waste. In tanks, heat is generated primarily from radioactive decay. The primary contributors for tank 241-AZ-101 are ^{241}Am, ^{144}Ce, ^{137}Cs, ^{106}Ru, and ^{90}Sr. As shown in Table 5-9, the estimated heat generated from isotopes in the sludge in the tank is 152,000 Btu/hr (44,500 watts), which is approximately 4 percent of the maximum heat limit for tank 241-AZ-101 of 4,000,000 Btu/hr (Bergmann 1989). From December 1993 through December 1994, the maximum waste temperatures ranged from 74.4 °C (166 °F) to 84.4 °C (184 °F).

The heat load from the ^{137}Cs in the supernate is 89,600 Btu/hr (26,200 watts). Adding this to the sludge heat load gives a total of 241,600 Btu/hr, 6.04 percent of the maximum heat load.

The potential for criticality is assessed from total alpha analysis or plutonium analysis. Criticality specifications for double-shell storage tanks are defined in Vail (1994). The safety screening criteria for criticality is 1 g/L. This is equivalent to 36.4 or 37.1 μCi/g of $^{239/240}$Pu in the waste using the sludge core densities of 1.7 g/mL for the first core sample or 1.67 g/mL for the second core sample, respectively. The 1989 first core sample results show a ^{239}Pu concentration of 2.65 μCi/g and a ^{240}Pu concentration of 0.758 μCi/g (see Table A-1). The second core sample results (see Table A-3) show a ^{239}Pu concentration of 4.51 μCi/g and ^{240}Pu concentration of 1.27 μCi/g. The concentration of $^{239/240}$Pu in the 1995 supernate sample was less than 3.53E-05 μCi/g. The total waste inventory of $^{239/240}$Pu, based

Table 5-9. Tank 241-AZ-101 Sludge Projected Heat Load.

Radionuclides	Curies (Ci) (from Table 4-2)	Watts
^{241}Am	66,600	2,190
^{144}Ce	3,750	30
^{60}Co	2,080	32
^{134}Cs	821	8.4
^{137}Cs	319,000	1,500
^{154}Eu	22,300	201
^{240}Pu	222	6.80
^{106}Ru	6,800	65.6
^{125}Sb	19,700	66.0
^{90}Sr	6,020,000	40,400
Total watts		44,500

upon these analytical values, is still significantly lower than the safety screening criterion for criticality of 1 g/L. The criticality specifications also require the pH of waste to be greater than 8.0 when the plutonium inventory exceeds 10 kg, and the depth of the supernate liquid exceeds 30 cm. The supernate depth in tank 241-AZ-101 exceeds 30 cm and the Pu inventory is approximately 18 kg. The pH of the supernate is 13.6, which satisfies the criticality prevention specification.

The flammability of the gas in the tank head space is another safety screening consideration. Analysis of tank head space is outside the scope of this report.

The analysis of tank 241-AZ-101 does not fully meet the safety screening requirements. However, historical and analytical information do not show that the waste composition exceeds the safety criteria for water content, heat, or criticality. Even though the fuel content of the waste has not been measured, the values for DSC, TOC, and historical uses of the tank suggest that excessive fuel is not present.

5.5.2 Operational Evaluation

The 1995 supernate sampling and analysis were performed to evaluate the compatibility of waste for transfer to another tank. Sampling and analysis requirements for assessing waste compatibility have been addressed in the *Waste Compatibility Data Quality Objectives* (Carothers 1994). This objective is based on safety and operational considerations. Operational considerations include pumpability, waste segregation, heat generation, tank waste type, and high phosphate waste. The 1995 supernate results are compared to the key compatibility criteria in Table 5-10 (results from Table 4-2). The assessment shows

Table 5-10. Compatibility Assessment for Tank 241-AZ-101 Supernate.

Parameter	Criteria	1995 Results
$^{239/240}Pu$	< 0.05 g/gal (0.8 μCi/g)[1]	< 3.53E-05 μCi/g
Specific Gravity	< 1.41	1.19
Energetics	exotherm/endotherm < 1	No exotherm observed
Corrosivity[2]	0.01 M < $[OH^-]$ < 8.0 M $[NO_3^-]$ < 1.0 M 0.011 M < $[NO_2^-]$ < 5.5	$[OH^-]$ = 0.67 M $[NO_3^-]$ = 1.06 M $[NO_2^-]$ = 1.20 M
Transuranics	< 100 nCi/g	< 25.4 nCi/g
Total organic carbon	< 10 g/L	1.03 g/L

Notes:

μCi/g = microcuries per gram
nCi/g = nanocuries per gram

[1]Based upon ^{239}Pu specific activity and an assumed supernate density of 1 g/mL.

[2]Corrosivity decision rules were not developed for the aging waste tanks in the *Data Quality Objectives for the Waste Compatibility Program* (Carothers 1994) waste compatibility DQO because aging wastes are no longer generated with the permanent shutdown of the PUREX Plant (Carothers 1994). Instead, the wastes stored in Tank 241-AZ-101 must comply with the corrosion specifications listed in Operating Specifications for Aging Waste Operations in 241-AY and 241-AZ (Bergmann 1989).

that the nitrate concentration does not meet the primary criteria. In this situation the waste compatibility data quality objective requires that the following two conditions be met:

For 1.0 M < NO_3^- $\leq$ 3.0 M

1. $0.1\ (NO_3^-) \leq OH^- < 10$ M

2. $OH^- + NO_2^- \geq 0.4\ (NO_3^-)$

These two conditions are met for tank 241-AZ-101.

The low phosphate concentration (131 μg/mL) observed in the 1995 grab samples indicates that the potential for insoluble phosphates forming is low, and the waste is pumpable.

5.5.3 Environmental Evaluation

Tank 241-AZ-101 waste was not characterized to designate the waste or to evaluate environmental compliance issues. It was characterized to meet regulatory requirements ensuring that waste is stored and managed safely. No specific organic (volatile or semi-volatile) analyses have been performed on the tank; therefore, no environmental assessment of these compounds can be made.

5.5.4 Process Development Evaluation

The metal and anion analyses of the sludge samples taken in 1989 are important for evaluating the formation of the disposal waste form (glass) and identifying potential components that may affect the treatment and disposal process. Because the waste sludges may be blended, washed, and treated before disposal, there are no specific criteria for the parameters measured. The 1989 physical measurements will be important in evaluating retrieval and pretreatment process equipment needs.

The solubility information obtained from the analyses of the solids and washed solids of the 1989 first core sample that may be relevant to process development is shown in Table 5-11 (Peterson et al. 1989).

Table 5-11. Solid and Washed Solid Concentrations from the 1989 First Core Sample.

Analyte	Solids	Washed Solids
Metals	Micrograms per gram (μg/g)	Micrograms per gram (μg/g)
Ba	549	194
Cr	2,860	418
Ni	3,520	< 117
U	6.78	1,270
Radionuclides	Microcuries per gram (μCi/g)	Microcuries per gram (μCi/g)
^{137}Cs	1,700	240
^{90}Sr	24,000	6,100

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6.0 CONCLUSIONS AND RECOMMENDATIONS

The sludge in tank 241-AZ-101 was sampled and analyzed in 1987 and 1989; the supernate was sampled and analyzed in March 1995. The analysis of tank 241-AZ-101 does not fully meet the safety screening requirements. However, historical and analytical information indicate that the waste composition satisfies the safety criteria for water content, heat, and criticality. Although the fuel content of the sludge has not been measured by differential scanning calorimetry (DSC), the total organic carbon (TOC) and historical tank uses indicate that excessive fuel is not present. When the sludge is sampled again, the analyses should include an evaluation of the fuel content by DSC to confirm the fuel estimates based on historical information and TOC analysis. Tank 241-AZ-101 meets the criteria specified in the waste compatabilty DQO (Carothers 1994).

As expected the sludge contains large quantities of aluminum, iron, manganese, sodium, and zirconium as expected from PUREX chemical processing wastes. Concentrations of nitrate, nitrite, and sulfate are high also, as expected. The major radioactive constituents in the waste are ^{90}Sr, ^{137}Cs, and ^{241}Am. The heat generated by these isotopes is well below the 4,000,000 Btu/hr limit set for aging waste storage tanks.

The supernate $^{239/240}Pu$ and ^{241}Am levels are below the transuranic classification limit of 100 nCi/g. However, the sludge significantly exceeds the transuranic classification limit.

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APPENDIX A

ANALYTICAL RESULTS FROM 1989 CORE SAMPLING EVENT OF DOUBLE-SHELL TANK 241-AZ-101

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Table A-1 summarizes the chemical and radiological characteristics of the sludge layer in tank 241-AZ-101 based upon analytical results of the first core sample taken in 1989 (Peterson et al. 1989). "Analyte" column contains the name of the analyte. The second and fourth columns are the centrifuged solid and centrifuged liquid concentrations in units of μmol/g, as they were reported in Peterson et al. (1989). The third and fifth columns are the same concentrations in μg/g.

"Calculated Analyte Concentration" lists the concentration of each analyte with respect to the entire mass of the sludge. This is calculated as follows:

$$\left(\frac{\text{Projected Sludge Inventory (kg)}}{\text{Total Mass of Tank Sludge 2.21E+08 g}}\right)\left(\frac{1.00\text{E+09 } \mu\text{g}}{1 \text{ kg}}\right)$$

where the total mass of the tank sludge, 2.21E+08 g, is obtained by multiplying the sludge volume (Hanlon 1995), 130,000 L, by the core composite density, 1.7 g/mL.

The last column lists the total projected inventory of tank 241-AZ-101. The first step in determining the inventory is combining the molarities of the centrifuged solid and centrifuged liquid according to the equation given below. The centrifuged solids concentration in μmol/g is converted to a molarity (mol/L) using the centrifuged solids density (1.8 g/mL). This result is multiplied by the volume percent centrifuged solids (74 percent) to obtain the partial solids concentration in the sludge. The partial supernate concentration is determined similarly using the centrifuged supernate density of 1.2 g/mL and the volume percent centrifuged supernate of 26 percent. The partial solids and supernate concentrations are then summed to give the total molar concentration.

$$\text{Total Molar Concentration} = \text{Centrifuged Solids } (\underline{M}) + \text{Centrifuged Supernate } (\underline{M})$$

$$= \text{solids } (\mu\text{mol/g}) * \begin{matrix}\text{centrifuged}\\ \text{solids}\\ \text{density}\end{matrix} \div 1000 * \begin{matrix}\text{volume \%}\\ \text{centrifuged}\\ \text{solids}\end{matrix} + [(1 - \begin{matrix}\text{volume \%}\\ \text{solids}\end{matrix}) * \begin{matrix}\text{centrifuge}\\ \text{supernate}\end{matrix}$$

After obtaining the total molar concentration, the result is converted into kilograms using the analyte's atomic weight and the total volume of sludge in the tank, 130,000 L. This conversion is performed as shown below to yield the projected sludge inventory.

$$\begin{matrix}\text{total molar}\\ \text{concentration}\end{matrix} * \begin{matrix}\text{analyte's}\\ \text{atomic weight}\end{matrix} \div 1000 * \begin{matrix}\text{total sludge amount}\\ \text{(130,000L)}\end{matrix} = \begin{matrix}\text{Projected Sludge}\\ \text{Inventory (kg)}\end{matrix}$$

When the analytical results are less than the instrument's detection limit, the individual inventory values are determined based upon the limit. The projected inventory is then reported as less than the sum of the individual inventory results. In the case of one detect and one nondetect, individual inventory results are calculated as before but the projected inventory is reported as a detect.

Table A-2 summarizes the chemical and radiological characteristics of the sludge layer in tank 241-AZ-101 based upon analytical results of the second core sample taken in 1989 (Gray et al. 1993). The numerical values used in the derivation of the projected inventory are:

total mass of tank sludge	=	2.17E+08 g
sludge volume	=	130,000 L
core composite density	=	1.67 g/mL
centrifuged solids density	=	1.84 g/mL
percent centrifuged solids	=	71 percent
centrifuged supernate density	=	1.22 g/mL
percent centrifuged supernate	=	29 percent

Table A-3 shows the division of the U and Pu data into their respective isotopes by weight percentage, according to Gray et al. (1993).

Table A-1. Core Analytical Summary for the Sludge in Tank AZ. (3 sheets)

Analyte	Centrifuged Solid	Centrifuged Solid	Centrifuged Liquid	Centrifuged Liquid	Calculated Analyte Concentration	Projected Inventory
Metal	μmol/g	μg/g	μmol/g	μg/g	μg/g	kg
Al	1,460	39,400	332	8,960	32,500	7,180
As	< 10	< 749	< 1	< 74.9	< 600	< 132
B	22	238	2	21.6	190	41.9
Ba	4	549	0.01	1.37	429	94.9
Ca	48	1,924	0.09	3.61	1,500	333
Cd	< 1	< 112	< 0.02	< 2.25	< 88.2	< 19.5
Ce	8	1,120	< 0.01	< 1.40	874	193
Cr	55	2,860	13	676	2,360	523
Dy	< 0.9	< 146	< 0.01	< 1.63	< 115	< 25.3
Fe	1,500	83,800	0.2	11.2	65,400	14,500
K	270	10,600	88	3,440	8,900	1,970
La	14	1,940	< 0.03	< 4.17	1,520	337
Li	< 20	< 139	0.1	0.694	109	24.1
Mg	26	632	0.09	2.19	494	109
Mn	86	4,720	0.02	1.10	3,690	8,170
Mo	2	192	0.8	76.8	165	36.3
Na	3,420	78,700	3,760	86,500	78,200	17,200
Nd	12	1,730	< 0.07	< 10.1	1,350	299
Ni	60	3,520	< 0.2	< 11.7	2,750	609
P	< 100	< 3,100	18.5	57.3	2,540	560
Se	< 40	< 3,160	3	237	2,510	556
Si	274	7,700	5	140	6,020	1,330
Sr	4	350	0.01	0.876	274	60.6
Te	< 30	< 3,830	< 0.4	< 51.0	< 3,000	< 663
Th	8	1,860	0.03	6.96	1,450	321
Ti	28.5	1,370	0.03	1.44	1,065	235
U	0.0285	6.78	0.025	5.95	6.45	1.43
Zn	10	654	0.3	19.6	514	114
Zr	199	18,200	0.03	2.74	14,100	3,140

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Table A-1. Core Analytical Summary for the Sludge in Tank AZ. (3 sheets)

Analyte	Centrifuged Solid	Centrifuged Solid	Centrifuged Liquid	Centrifuged Liquid	Calculated Analyte Concentration	Projected Inventory
Ion	μmol/g	μg/g	μmol/g	μg/g	μg/g	kg
F^-	58	1,100	68	1,290	1,100	246
Cl^-	< 0.3	< 10.6	< 0.02	< 0.709	< 8.43	< 1.86
Cr(VI)	8.02	417	9.8	510	424	93.9
NO_2^-	560	25,800	1,000	46,000	29,000	6,420
NO_3^-	640	39,700	1,040	64,500	43,500	9,610
PO_4^{3-}	6.5	618	17	1,620	795	175
SO_4^{2-}	110	10,600	130	12,500	10,600	2,350
Carbon	μmol/g	μg C/g	μmol/g	μg C/g	μg C/g	kg C
TOC	1,800[1]	21,600	52	624	17,000	3,760
TIC	380[1]	4,560	280	3,360	4,210	931
Radionuclide	μCi/g		μCi/g		μCi/g	Ci
^{241}Am	590		0.011		461	102,000
^{14}C	0.0019		0.0012		0.00172	0.380
^{144}Ce [2]	2,700		< 17		2,110	467,000
^{242}Cm	0.13		0.000034		0.10	22.5
$^{243/244}Cm$	0.67		0.00012		0.52	116
^{60}Co [2]	12		< 0.75		9.54	2,110
^{134}Cs [2]	27		30		26.9	5,950
^{137}Cs [2]	1,700		1,700		1,660	366,000
^{154}Eu [2]	82		< 5.5		65.1	14,400
^{3}H	0.015		0.032		0.018	3.96
^{129}I	< 0.00065		< 0.0006		< 0.00062	< 0.138
^{237}Np	0.023		< 0.000059		0.018	3.97
^{238}Pu	0.69		0.000066		0.539	119
^{239}Pu	3.4		0.00034		2.65	587
^{240}Pu	0.97		0.000094		0.758	168
^{241}Pu	37		0.0036		28.9	6,490
^{106}Ru*	1,400		< 27		1,100	243,000
^{125}Sb*	160		< 21		129	28,500
^{79}Se	< 0.0045		0.00021		0.004	0.786

Table A-1. Core Analytical Summary for the Sludge in Tank AZ. (3 sheets)

Analyte	Centrifuged Solid	Centrifuged Solid	Centrifuged Liquid	Centrifuged Liquid	Calculated Analyte Concentration	Projected Inventory
Radionuclide	μCi/g		μCi/g		μCi/g	Ci
^{90}Sr	24,000		4.8		18,760	4,148,000
^{99}Tc	0.81		0.32		0.695	154

Notes:

C = Carbon
Ci = curies
kg = kilogram
μCi/g = microcuries per gram
μgC/g = micrograms of carbon per gram
μg/g = micrograms per gram
μmol/g = micromoles per gram

[1]Based on wet weight

[2]Determined by gamma energy analysis

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Table A-2. Core 2 Analytical Summary for the Sludge in Tank 241-AZ-101 (3 sheets).

Analyte	Centrifuged Solid	Centrifuged Solid	Centrifuged Liquid	Centrifuged Liquid	Calculated Analyte Concentration	Projected Inventory
Metal	μmol/g	μg/g	μmol/g	μg/g	μg/g	kg
Ag	4.26	460	0.019	205	360	78.2
Al	733	19,800	81.6	2,200	15,900	3,460
As	< 7.0	< 524	0.077	5.77	411	89.3
B	< 40	< 432	0.484	5.23	339	73.6
Ba	7.89	1,080	0.015	2.06	848	184
Be	2.17	19.6	0.010	0.0901	15.3	3.32
Ca	88.1	3,530	0.196	7.86	2,760	600
Cd	111	12,500	0.032	3.60	9,760	2,120
Ce	11.5	1,610	< 0.007	< 0.981	1,260	274
Co	< 22	< 1,300	< 0.029	< 1.71	< 1,010	< 220
Cr	16.3	848	8.29	431	754	163
Cu	7.65	486	0.004	0.254	380	82.6
Dy	< 0.28	< 45.5	< 0.001	< 0.163	< 35.6	< 7.74
Fe	2,500	140,000	0.351	19.6	109,000	23,700
K	67.6	2,640	52.1	2,040	2,500	542
La	47.1	6,540	0.023	3.19	5,120	1,110
Li	< 3.7	< 25.7	< 0.005	< 0.0347	< 20.1	< 4.36
Mg	30.5	741	0.078	1.90	580	126
Mn	37.5	2,060	0.008	0.440	1,610	350
Mo	< 0.61	< 58.5	0.443	42.5	54.8	11.9
Na	3,890	89,500	2,020	46,500	79,800	17,400
Nd	30.1	4,340	0.008	1.15	3,400	737
Ni	112	6,570	0.043	2.52	5,140	1,100
P	103	3,190	10.3	319	2,560	556
Pb	2.88	597	0.019	3.94	468	101

Table A-2. Core 2 Analytical Summary for the Sludge in Tank 241-AZ-101 (3 sheets).

Analyte	Centrifuged Solid	Centrifuged Solid	Centrifuged Liquid	Centrifuged Liquid	Calculated Analyte Concentration	Projected Inventory
Pu	101 μg/g		0.0154 μg/g		79.0	17.2
Re	< 0.35	< 65.2	0.002	0.372	51.1	11.0
Rh	4.75	489	0.020	2.06	383	83.1
Ru	9.86	997	0.009	0.910	780	169
Sb	< 25	< 3,050	< 0.033	< 4.02	< 2,380	< 517
Se	< 11	< 869	< 0.015	< 1.18	< 680	< 148
Si	194	5,450	3.03	85.1	4,280	929
Sr	8.73	765	0.002	0.175	598	130
Te	3.96	505	0.017	2.17	396	85.9
Th	4.00	928	< 0.002	< 0.464	726	158
Ti	2.37	114	< 0.001	< 0.0479	88.8	19.3
Tl	< 37	< 7,560	< 0.049	< 10.0	< 5,920	< 1,280
U	12.3 mg/g	12,300	0.918 mg/g	918	9,820	2,140
Metal	μmol/g	μg/g	μmol/g	μg/g	μg/g	kg
V	< 0.57	< 29.0	0.014	0.713	22.9	4.97
Zn	3.88	254	0.010	0.654	199	43.1
Zr	668	60,900	0.094	8.57	47,700	10,300
Ion	μmol/g	μg/g	μmol/g	μg/g	μg/g	kg
F^-	208	3,950	30.6	581	3,210	698
Cl^-	6.74	239	7.19	255	241	52.3
NO_2^-	954	43,900	2,370	109,000	57,400	12,400
NO_3^-	619	38,400	1,380	85,600	48,100	10,500
PO_4^{3-}	4.97	472	2.8	266	426	92.4
SO_4^{2-}	227	21,800	160	15,400	20,300	4,410
Carbon	μmol/g	μg C/g	μmol/g	μg C/g	μg C/g	kg C
TOC	142	1,700	8.5	102	1,350	294
TIC	463	5,560	765	9,180	6,290	1,360

Table A-2. Core 2 Analytical Summary for the Sludge in Tank 241-AZ-101 (3 sheets).

Analyte	Centrifuged Solid	Centrifuged Solid	Centrifuged Liquid	Centrifuged Liquid	Calculated Analyte Concentration	Projected Inventory
Radionuclide	μCi/g		μCi/g		μCi/g	Ci
^{241}Am	191		0.0130		149	32,400
^{14}C	0.00157		0.00130		0.00196	0.326
^{144}Ce	6,390		< 4.1		6,520	1,086,000
$^{243/244}Cm$	1.31		< 0.00068		1.34	223
^{60}Co	41.0		< 2.0		12.0	7,060
^{137}Cs	1,470		2,540		1690	366,000
^{154}Eu	254		< 5.5		261	43,400
^{129}I	0.0676		< 0.00000063		0.069	11.5
^{237}Np	0.0982		< 0.00000069		0.100	16.7
^{106}Ru	3,680		< 55		3,770	628,000
^{125}Sb	901		< 39		930	155,000
^{79}Se	< 0.0001		0.00215		0.000695	0.116
^{90}Sr	57,200		3.47		58,400	9,750,000
^{99}Tc	< 4.6		0.271		4.77	794

Notes:

C = Carbon
Ci = curies
kg = kilogram
μCi/g = microcuries per gram
μgC/g = micrograms of carbon per gram
μg/g = micrograms per gram
μmol/g = micromoles per gram

Table A-3. Core 2 Distribution of U and Pu Isotopes.

Isotope	Wt %[1]	μg/g	μCi/g	Ci
U Isotopes[2]				
^{234}U	0.009	0.884	0.00552	1.20
^{235}U	0.866	85.0	0.000184	0.040
^{236}U	0.073	7.17	0.000464	0.100
^{238}U	99.1	9,730	0.00327	0.710
Pu Isotopes[3]				
^{238}Pu	0.053	0.0419	0.717	156
^{239}Pu	92.0	72.7	4.51	975
^{240}Pu	7.09	5.60	1.27	276
^{241}Pu	0.76	0.600	61.8	13,400
^{242}Pu	0.056	0.0442	0.000173	0.038

Notes:

Ci = curies
μCi/g = microcuries per gram
μg/g = micrograms per gram

[1]Based on the weight percentage breakdowns given in Gray et al. (1993).

[2]Based on an overall sludge U concentration of 9,820 μg/g.

[3]Based on an overall sludge Pu concentration of 79.0 μg/g.

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APPENDIX B

ANALYTICAL RESULTS FROM 1995 GRAB SAMPLING EVENT OF DOUBLE-SHELL TANK 241-AZ-101

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Appendix B summarizes the chemical and radiological characteristics of the 1995 grab samples taken from tank 241-AZ-101 (Rollison 1995) in terms of the specific concentrations of metals, ions (anions and cations), radionuclides, physical properties, and total carbon.

The data table for each analyte lists the laboratory sample identification number, an analytical data result for each sample, an evaluated data result, a relative standard deviation of the mean, and a projected tank inventory. These data are listed in standard notation for values greater than .001 and less than 100,000. Values outside these limits are listed in scientific notation.

Standard abbreviations are used to describe analytical methods.

Metals	ICP - Inductively Coupled Plasma (generic for all metals unless otherwise indicated)
Anions	IC - Ion Chromatography
	Pot. Titrat. - Potentiometric Titration
Radionuclides	GEA - Gamma Energy Analysis
	Extr. - Extraction
	IonEx - Ion Exchange
	HighLev. - High-Level Alpha and Beta Analysis
Physical properties	TGA - Thermogravimetric Analysis
	Grav. Gravimetric
Total carbon	Coul. - Coulmetry

"Analyte" contains 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 analytes that were digested by more than one method. Digestion methods used are abbreviated as follows: a - acid digestion, w - water leach, and f - potassium hydroxide fusion, followed by acid digestion. Analytes may also be measured directly on an undigested sample and are abbreviated as d-direct.

The analyte and method are given as follows: "method.analyte," or, (where applicable) "method.digestion.analyte." For example, the specific concentration of Na was determined by the inductively coupled plasma method which was preceded by acid digestion. It is listed as "ICP.a.Na."

"Sample Number" lists the laboratory sample from which the analyte was measured. This identification number differs from the number assigned to the samples at the tank farm. Sampling rationale, locations, and a description of the sampling event are given in Section 3.0. The 1995 grab samples were obtained from tank 241-AZ-101 through riser 24A. The grab sample breakdown is as follows:

R-0

Grab Sample Number	Laboratory Sample Number
AZ-101-1	S95T000278
	S95T000305
AZ-101-2	S95T000279
	S95T000306
AZ-101-3	S95T000280
	S95T000307

The samples are listed in order of increasing tank depth.

"Result" is the specific concentration of the analyte determined at different sampling points. No quality control data such as matrix spikes, serial dilutions, or duplicate analyses are listed. This information may be obtained from the tank 241-AZ-101 grab sample data package (Rollison 1995). Numbers that are preceded by a less than symbol (<) indicate the analyte was noted but was below the analytical instrument's calibrated detection limit for the sample.

The stated "Mean" is a simple average of the above results.

"Relative Standard Deviation" (RSD), is a measure of variability defined as the square root of the variance of the mean divided by the mean. The variance of the mean was computed using analysis of variance with Restricted Maximum Likelihood estimates from the statistical software package, S-Plus*. Relative standard deviation is expressed as a percentage.

"Projected inventory" is the product of the concentration of the analyte and the volume of the supernate in the tank at the time of sampling: supernate volume = 3.50E+06 liters (925,000 gal).

Projected Inventory Formula:

(Supernate Volume)(Result)(Conversions) = Projected Inventory

Example:

$$Kg = (3.50E+06L)(\text{Result } \mu g/mL)(1{,}000mL/L)(kg/1.00E+09\mu g)$$

* Registered trademark of Statistical Sciences, Inc.

Table B-1. Tank 241-AZ-101 Analytical Data.

Analyte	Sample number	Result	Mean	RSD (mean)	Projected inventory
Metal					
Drainable liquid		µg/mL	µg/mL	%	kilogram
Aluminum					
ICP.a.Al	S95T000278 Duplicate	9,230 9,320	9,320	0.83	32,600
	S95T000279 Duplicate	9,180 9,260			
	S95T000280 Duplicate	9,540 9,410			
Iron					
ICP.a.Fe	S95T000278 Duplicate	< 10.1 < 10	< 10	N/A	< 35.0
	S95T000279 Duplicate	< 10.1 < 10			
	S95T000280 Duplicate	< 10.1 < 10			
Sodium					
ICP.a.Na	S95T000278 Duplicate	94,800 94,800	95,200	1.16	3.33E+05
	S95T000279 Duplicate	93,300 93,800			
	S95T000280 Duplicate	97.800 96,800			

R-0

Table B-1. Tank 241-AZ-101 Analytical Data.

Analyte	Sample number	Result	Mean	RSD (mean)	Projected inventory
Anion					
Drainable liquid		µg/mL	µg/mL	%	kg
Chloride					
IC.Cl^-	S95T000305 Duplicate	199 175	174	---	609
	S95T000306 Duplicate	< 158 173			
	S95T000307 Duplicate	< 158 183			
Flouride					
IC.F^-	S95T000305 Duplicate	1,640 1,600	1,580	1.59	5,530
	S95T000306 Duplicate	1,660 1,520			
	S95T000307 Duplicate	1,570 1,510			
Hydroxide					
Pot.Titrat.OH^-	S95T000278 Duplicate	11,100 11,200	11,400	2.06	39,900
	S95T000279 Duplicate	11,200 11,300			
	S95T000280 Duplicate	11,300 12,500			
Nitrate					
IC.NO_3^-	S95T000305 Duplicate	65,000 65,200	66,000	1.70	231,000
	S95T000306 Duplicate	67,200 69,300			
	S95T000307 Duplicate	64,800 64,600			

Table B-1. Tank 241-AZ-101 Analytical Data.

Analyte	Sample number	Result	Mean	RSD (mean)	Projected inventory
Anion					
Drainable liquid		µg/mL	µg/mL	%	kg
Nitrite					
$IC.NO_2^-$	S95T000305	56,800	56,800	2.03	199,000
	Duplicate	56,200			
	S95T000306	58,500			
	Duplicate	59,500			
	S95T000307	55,200			
	Duplicate	54,900			
Phosphate					
$IC.PO_4^{3-}$	S95T000305	1,230	1,310	3.38	4,590
	Duplicate	1,210			
	S95T000306	1,320			
	Duplicate	1,350			
	S95T000307	1,250			
	Duplicate	1,480			
Sulfate					
$IC.SO_4^{2-}$	S95T000305	15,200	15,400	1.85	53,900
	Duplicate	15,200			
	S95T000306	15,800			
	Duplicate	16,200			
	S95T000307	15,200			
	Duplicate	15,000			

Table B-1. Tank 241-AZ-101 Analytical Data.

Analyte	Sample number	Result	Mean	RSD (mean)	Projected inventory
Radionuclide					
Drainable liquid		µCi/mL	µCi/mL	%	Ci
Americium-241					
Extr. ^{241}Am	S95T000305 Duplicate	< 0.0216 < 0.0221	< 0.0301	---	< 105
	S95T000306 Duplicate	< 0.0217 < 0.0214			
	S95T000307 Duplicate	< 0.0451 < 0.0487			
Cesium-137					
GEA. ^{137}Cs	S95T000305 Duplicate	1,580 1,590	1,590	0.51	5.57E+06
	S95T000306 Duplicate	1,620 1,560			
	S95T000307 Duplicate	1,590 1,580			
Plutonium-238					
IonEx. ^{238}Pu	S95T000305 Duplicate	< 2.91E-05 < 2.96E-05	< 4.20E-05	---	< 0.147
	S95T000306 Duplicate	< 2.89E-05 < 4.19E-05			
	S95T000307 Duplicate	< 6.00E-05 < 6.22E-05			
Plutonium-239/240					
IonEx. $^{239/240}$Pu	S95T000305 Duplicate	< 2.91E-05 < 2.96E-05	< 4.20E-05	---	< 0.147
	S95T000306 Duplicate	< 2.89E-05 < 4.19E-05			
	S95T000307 Duplicate	< 6.00E-05 < 6.22E-05			

Table B-1. Tank 241-AZ-101 Analytical Data.

Analyte	Sample number	Result	Mean	RSD (mean)	Projected inventory
Radionuclide					
Drainable liquid		µCi/mL	µCi/mL	%	Ci
Strontium-89/90					
HighLev. $^{89/90}$Sr	S95T000305	1.21	1.20	1.47	4,200
	Duplicate	1.25			
	S95T000306	1.16			
	Duplicate	1.19			
	S95T000307	1.19			
	Duplicate	1.17			
Physical property					
Drainable liquid		%	%	%	
Gravimetric Percent Water					
Grav. %H_2O	S95T000278	73.8	73.8	0.10	
	Duplicate	73.5			
	S95T000279D	73.9			
	uplicate	73.8			
	S95T000280	73.9			
	Duplicate	73.9			
Thermogravimetric Analysis Percent Water					
TGA. %H_2O	S95T000278	71.36	73.02	1.13	
	Duplicate	71.38			
	S95T000279	74.02			
	Duplicate	73.86			
	S95T000280	74.17			
	Duplicate	73.31			

Table B-1. Tank 241-AZ-101 Analytical Data.

Analyte	Sample number	Result	Mean	RSD (mean)	Projected inventory
Physical property					
Drainable liquid		%	%	%	
Specific Gravity					
SpG	S95T000278	1.19	1.19	0.70	
	Duplicate	1.20			
	S95T000279	1.18			
	Duplicate	1.16			
	S95T000280	1.20			
	Duplicate	1.19			
pH					
pH	S95T000278	13.55	13.56	0.06	
	Duplicate	13.59			
	S95T000279	13.54			
	Duplicate	13.56			
	S95T000280	13.55			
	Duplicate	13.58			
Carbon					
Drainable liquid		µg/mL	µg/mL	%	kg
Total Organic Carbon					
Coul.TOC	S95T000305	906	1,030	4.69	3,600
	Duplicate	969			
	S95T000306	1,060			
	Duplicate	1,090			
	S95T000307	1,090			
	Duplicate	1,090			

Table B-1. Tank 241-AZ-101 Analytical Data.

Analyte	Sample number	Result	Mean	RSD (mean)	Projected inventory
Carbon					
Drainable liquid		µg/mL	µg/mL	%	kg
Total Inorganic Carbon					
Coul.TIC	S95T000305	5,940	5,780	1.85	20,200
	Duplicate	6,040			
	S95T000306	5,640			
	Duplicate	5,680			
	S95T000307	5,660			
	Duplicate	5,700			

Notes:

Ci	=	Curies
kg	=	kilograms
µCi/mL	=	microcuries per milliliter
µg/mL	=	micrograms per milliliter

[1]Rollison, M. D., 1995, *Results for 241-AZ-101 Grab Samples*, (internal memo no. 8E480-95-023, dated April 11), Westinghouse Hanford Company, Richland, Washington.

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APPENDIX C

ANALYTICAL RESULTS FROM 1987 SAMPLING EVENT OF DOUBLE-SHELL TANK 241-AZ-101

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Results from analyses of samples obtained from the 1987 sampling event of tank 241-AZ-101 are taken from the Double Shell Tank Waste Characterization Database and *Chemical Analysis of Tank 101-AZ and 102-AZ Samples Taken in October 1987* (WHC 1987). The sample numbers, their characteristics, and analytical results are listed below:

Sample number:	T-3493
Date of sample:	October 1987
Date of analysis:	03/11/88
Waste type:	NCAW
Appearance:	Clear, bright yellow liquids with a trace of brown solids. The brown solids were combined with trace of brown solids in sludge sample T-3494.

Volume % centrifuged (filtered) solids:	0.150
Volume % centrifuged (filtered) supernate:	99.850

Sample number:	T-3494
Date of sample:	October 1987
Date of analysis:	03/11/88
Waste type:	NCAW
Appearance:	Clear, bright yellow liquids with a trace of brown solids. Solids analysis for 101-AZ was accomplished by combining solids from T-3493 and T-3494 together (total volume was only 0.06 ml)

Volume % centrifuged (filtered) solids:	0.150
Volume % centrifuged (filtered) supernate:	99.850

The supernate from the two samples were also combined for analysis.

Table C-1. Previous Sampling Results for Tank 241-AZ-101.

Analyte	Tank Characterization Results		
	T-3493/3494	T-3493 & T-3494	
	Supernate	Solids	Acid wash
Metals	mole/L	mole/L	mole/L
Aluminum (Al)	0.44	0.25	0.0015
Calcium (Ca)	---	0.25	0.0015
Chromium (Cr)	0.013	0.01	0.00003
Iron (Fe)	---	0.62	0.0037
Magnesium (Mg)	---	0.20	0.0012
Nickel (Ni)	---	0.08	0.0005
Sodium (Na)	4.42	1.18	0.0071
Uranium (U)	<0.05 g/L	18.33	0.11
Zirconium (Zr)	---	0.37	0.0022
Ions	mole/L	mole/L	mole/L
Carbonate (CO_3^{2-})	0.25	---	---
Chloride (Cl^-)	0.019	0.00	<0.005
Fluoride (F^-)	0.097	12.50	0.075
Hydroxide (OH^-)	0.90	---	---
Nitrate (NO_3^-)	1.39	---	---
Nitrite (NO_2^-)	0.79	---	---
Phosphate (PO_4^{3-})	0.017	0.07	0.0004
Sulfate (SO_4^{2-})	0.16	0.00	<0.014
Radionuclides	μCi/L	μCi/L	μCi/L
$^{89/90}Sr$	1660	2.2E+07	1.29E+05
^{99}Tc	402	5.3E+03	32
^{137}Cs	2.27E+06	2.5E+05	1.47E+03
^{241}Am	<10	8.7E+04	520
Total β	2.79E+06	---	---
Total α	<200	1.1E+05	630
Carbon	g/L	g/L	g/L
Total organic carbon	0.43	103.33	0.62

Notes:

g/L = grams per liter
Mole/L = mole per liter
μCi/L = microcuries per liter

REFERENCES

WHC, 1987, *Chemical Analysis of Tank 101-AZ and 102-AZ Samples Taken in October 1987*, (internal memo no. 1221-PCL88-091 from D. L. Herting, dated March 11), Westinghouse Hanford Company, Richland, Washington.

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B. C. Simpson	R2-12	X	
G. L. Smith	H4-62		X
G. L. Troyer	T6-50	X	
D. A. Turner	S7-15	X	
D. J. Washenfelder	H5-27	X	
M. S. Waters	S6-30	X	
W. I. Winters (3)	T6-50	X	

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EDMC	H6-08	X
TCRC (2)	R2-12	X
W.J. Powell	H5-27	X

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EDMC	H6-08	X
TCRC (2)	R2-12	X