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Residual Waste Inventories in the Plugged and Abandoned Pipelines at the Hanford Site

Steven L. Lambert
Meier Enterprises, Inc.
Richland, WA 99352
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Steven L. Lambert
Meier Enterprises, Inc.

Prepared for
CH2M HILL Hanford Group, Inc.

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Hanford Group, Inc.

Post Office Box 1500
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EXECUTIVE SUMMARY

The purpose of this study is to develop an estimate of the residual waste inventories in the waste transfer lines in the Hanford Site 200 East and 200 West Area waste management areas (WMA). The focus of this study is pipelines within WMAs that can be documented as being plugged and are therefore believed to contain residual waste. While other pipelines in WMAs may contain some residual waste inventory, it is believed this volume is small compared to the inventory estimated to be in plugged pipelines. This is based upon the assumption that, in general, lines taken out of service were flushed before being taken out of service or, if not flushed, were drained to a diversion box or other structure. In either case, minimal waste inventory is left in the pipelines.

The estimates of residual waste in the plugged WMA pipelines are needed to support the single-shell tank performance assessment. Data will continue to be reviewed concerning plugged pipelines, and if new information warrants, revisions may be made to the residual waste inventories in plugged pipelines in WMAs.

This study identifies 100 pipelines that have failed at the Hanford Site. Of these 100 failed pipelines, 10 waste transfer lines are identified within the fenceline of WMAs that are known to have failed because of plugging and are assumed to contain residual waste. These pipelines include SL101, SN261, V392, V410, V412, V453, V465, V514, and the waste cascade lines between tanks 241-BX-102 and 241-BX-103, and between tanks 241-C-110 and 241-C-111. Eight of those transfer lines were identified from published reference materials and memoranda (Kison 2002a[1]; Oberg 1966), while two others (the cascade lines for 241-BX-102 and 241-C-110) were identified from Hanford Site monthly reports and from waste transaction records (GE 1951a, GE 1952a, GE 1952b, GE 1953c; Agnew 1997b). The *Hanford Site Atlas* (Bechtel 1998) was used to determine the Hanford Site coordinates, and to estimate the potential length of each pipeline between the terminal diversion boxes and/or waste tanks. The maximum volume of residual waste and the proportional amount of waste in the tank farms (or in one of the defined WMAs where buried portions of the plugged pipelines exist) was then estimated. In this study, it is assumed that these lines were completely blocked between the primary and secondary diversion boxes. This assumption leads to an upper bounding set of residual waste inventory estimates for these pipelines. This conservative assumption provides a value of the residual inventory in plugged lines in the WMAs for the purpose of preparing the performance assessment. At this time, any residual waste in pipelines known to be plugged that are outside of the WMAs are not being considered in the inventories used in the single-shell tank performance assessment.

The pipeline routings and waste transaction records are combined with historical references to determine the time frame and waste types most likely involved in each pipeline pluggage incident. This leads to an improved understanding of which waste composition profiles should be used to represent the residual wastes in these pipelines. The Hanford Defense Waste model has been extensively used to determine the concentration of some chemicals and most radionuclides in the single-shell and double-shell tanks at the Hanford Site (Kupfer et al. 1999;

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[1] See Section 11.0 of main text for complete reference information.

Agnew 1997a; Place and Higley 2004). This model also provides waste composition profiles for most waste types, including those implicitly connected with the pipeline pluggage incidents. The appropriate waste composition profiles were used, together with the physical dimensions of the pipeline, to estimate the residual waste inventory in each line, including the proportional amount assigned to each tank farm. The Best Basis Inventory (as of February 10, 2005) was used to determine the residual waste composition in one line (SN216) that supported the saltwell pumping campaign for 241-U-107. Residual waste composition estimates for the plugged pipelines are summarized in Table 13 of this report, while Table 14 provides proportional waste inventory estimates for each of the tank farms where buried portions of the plugged pipelines are located. Table ES-1 lists the predicted waste volumes in each plugged pipeline, as well as the proportional volume in the buried pipelines in each tank farm.

Table ES-1. Summary of Predicted Waste Volumes in Plugged Pipelines at the Hanford Site.

Line	Total Length (ft)	Total Waste Volume (L)	Blockage Location	Farm	Proportional Waste Volume in Farm (L)	Blockage Location	Farm	Proportional Waste Volume in Farm (L)
SL101	1,444	861	241-S-152	S	20	241-U-D	U	112
SN216	1,444	1,988	241-S-152	S	45	241-U-D	U	258
V392	2,939	4,086	—	—	—	—	—	—
V410	3,666	5,096	—	—	—	—	—	—
V412	1,230	1,711	241-TY-153	TX	102	—	—	—
V453	441	614	241-U-151	U	184	—	—	—
V465	110	153	241-U-153	U	153	—	—	—
V514	1,793	2,492	—	—	—	—	—	—
Cascade line from 241-BX-102 to 241-BX-103	20	28	BX-102	BX	28	—	—	—
Cascade line from 241-C-110 to 241-C-111	20	28	C-110	C	28	—	—	—
Total	—	17,056	—	—	532	—	—	370

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LIST OF TERMS

Abbreviations and Acronyms

ARHCO	Atlantic Richfield Hanford Company
CWR	cladding waste REDOX
DOE	U.S. Department of Energy
HDW	Hanford Defined Waste (model)
MW2	bismuth phosphate metal waste produced from 1950 to 1956
R	REDOX high-level (waste) generated from 1952 to 1966
R1	REDOX high-level waste produced form 1952 to 1957
REDOX	reduction-oxidation
RL	Richland Operations Office
SST	single-shell tank
TWINS	Tank Waste Information Network System
WMA	waste management area

Units

%	percent
°F	degrees Fahrenheit
µg/mL	micrograms per milliliter
µg/g	micrograms per gram
µCi/mL	microcuries per milliliter
Ci	curies
ft	foot
g/g-mole	grams per gram-mole
g/mL	grams per milliliter
g-mole/L	gram-moles per liter
gal	gallon
in.	inch
kg	kilogram
L	liter
lb	pound
m	meter
mg/L	milligrams per liter
psig	pounds per square inch gauge
wt%	weight percent

1.0 BACKGROUND

The single-shell tank (SST) farm performance assessment must consider possible sources of contamination, including past releases from tanks and pipelines, potential leaks during waste retrieval, and residual wastes in tanks and in other facilities such as abandoned pipelines (Mann et al. 2004, *Integrated Disposal Facility Risk Assessment*).

Waste management areas (WMA) include miles of pipeline networks that have been used to transfer waste within a WMA, between WMAs, and to convey wastes between the 200 East Area and the 200 West Area. Historic waste operations occasionally resulted in a pipeline being plugged, and when attempts to unplug the pipeline failed, the line was taken out of service and the residual waste left in place. While the buried pipelines are expected to contain only a small fraction of the residual waste, these wastes and the pipelines that contain these wastes may influence other site closure activities, including the placement of barriers or the isolation and closure of ancillary systems and components. This study identifies pipelines that are known to have failed. The failed pipelines are further evaluated to determine which failed because of plugging and was removed from service, and of these plugged lines which ones exist within the boundaries of WMAs and should be included in the waste inventories used in the SST performance assessment.

This study provides estimates of the residual waste inventories in the plugged pipelines. Based on the historical records, only one plugged pipeline is known to have been mostly filled with waste, while two others appear to be only partially filled based on video camera surveys of the blocked lines (Elsen 1999, *Camera Inspection of SN216 and SL101*). For most other lines, the blockage locations are not known. Various methods were typically used to unplug the blocked lines, including using water pumps and fire hoses to force water under high pressure through the pipelines, high-pressure steam, and various chemical solutions. In some cases, these methods also diluted and washed out some of the excess waste, thus reducing the overall inventory in the blocked pipelines. In some cases, unplugging with high pressure may have compromised the integrity of the pipeline; while the blockage may have been removed, it was determined the line was unfit for further use and was taken out of service.

This study assumes that the plugged lines were completely blocked between the primary and secondary diversion boxes, which results in an upper bounding set of residual waste inventory estimates for these pipelines. This conservative assumption provides a representative value of the residual inventory in plugged lines for the purpose of preparing the SST performance assessment. While this study focuses on plugged pipelines within the WMAs, it recognizes that some lines within the WMAs that are not plugged may contain some residual waste. Using the conservative assumptions of the volume of waste in the plugged pipelines, it is assumed that this additional residual waste inventory is within the bounding inventory developed in this study.

The historical records provide little insight as to when many of the waste transfer lines became permanently blocked. Many of these accounts refer to lines that were only temporarily plugged and were later cleared. In other cases, pipelines were apparently plugged when conveying certain wastes, including sodium phosphate-rich metal wastes, aluminum-rich reduction-oxidation (REDOX) wastes, or concentrated REDOX wastes from the self-boiling tanks or from various waste evaporator campaigns. All of these wastes are known to have been involved in past pipeline pluggage.

The Hanford Defined Waste (HDW) model was used to estimate the baseline composition for wastes implicitly involved in each pipeline pluggage. These waste compositions were extensively used to develop waste inventory estimates for some chemicals and most radionuclides in the SSTs and double-shell tanks at the Hanford Site (Kupfer et al. 1999, *Standard Inventories of Chemicals and Radionuclides in Hanford Site Waste Tanks*; Agnew 1997a, *Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 4*; Place and Higley 2004, *Best-Basis Inventory Template Compositions of Common Tank Waste Layers*). Some wastes, such as the REDOX high-level (R) waste and REDOX coating (CWR) wastes, were stored in one of the self-boiling waste tanks for several years before transfer through the pipeline systems that eventually plugged. These wastes were typically concentrated by a factor of 2 or 3 in the self-boiling storage tanks and were occasionally routed to one of the waste evaporators for additional evaporation (Roberts 1966, *Chemical Processing Department Waste Storage Experience from January 1955 to December 31, 1965*; Agnew 1997a). After the cesium-137 recovery campaign in B Plant, REDOX wastes were commonly processed through the 242-S and 242-T Evaporators; some wastes were partially neutralized and concentrated even further in the 242-S Evaporator (Agnew 1997a). These processes not only increased the concentration of soluble radionuclides but also led to an increased tendency for aluminum hydroxide deposits in some waste transfer lines. Other pipeline pluggage incidents seem to have been caused by the gradual buildup of bismuth phosphate metal waste or first-cycle waste deposits, by plug-forming conditions in saltwell liquid transfer lines (SN216), or by similar deposits in pipelines that transported partially neutralized and concentrated REDOX waste (SL101).

2.0 IDENTIFICATION OF FAILED PIPELINES

A number of surveys have been performed to identify the failed and blocked waste transfer lines at the Hanford Site. The Kison survey identifies the active and inactive waste transfer lines, diversion boxes, valve pits, and pump and heel pits for the Hanford Site (Kison 2002a; Kison 2002b, *Status of Facilities and Waste Transfer Lines with Single Shell Tank Farms*). Kison (2002a, 2002b) also include the waste transfer vaults and miscellaneous tanks and structures and list the primary and secondary diversion boxes for each transfer line.
A substantial number of these pipelines are no longer in service and have been cut and/or capped at the diversion boxes or re-routed in the field. Several pipelines have failed, including SL175, SL176, SN281, and SN282, while one was identified as blocked, SL101. Oberg compiled a similar list of failed, leaking, and plugged transfer lines in the 200 West Area, together with a list of the primary and secondary diversion boxes for each pipeline (Oberg 1966, "Failed Underground Transfer Lines – 200-W Area"). Five of these pipelines were apparently plugged, including V392, V410, V453, V465, and V514.

Other records list the status and pressure test results for direct-buried waste transfer lines from B Plant and pipelines that failed the hydraulic pressure tests in the 241-S tank farm and were subsequently capped:

- Fraser 1974c, "Status of Direct Buried Waste Transfer Lines from B Plant to the Tank Farms"
- Stout 1992, "Failed Hydrotest of Waste Transfer Lines in 241-S Tank Farm"
- Bauer 1993a, "Failed Hydrotest of Waste Transfer Lines in 241-S Tank Farm".

Other sources include useful information on pressure test requirements and pipeline installation dates for key pipelines:

- Diliberto 1982, *Basis for Developing Pressure Testing Specifications of All Direct Buried Transfer Lines and Cross-Site Lines; Fraser 1974a, Pressure Test and Schedule for Direct-Buried Waste Transfer Lines.*

Historical pipeline leakage estimates for failed pipelines are documented in the following:

- Fraser 1974b, "Radioactive Inventories in Leaks from Transfer Lines and Tanks"
- AEC 1973, *Hanford Radioactive Waste Management Plans.*

Additional sources include the tank farm event reports and occurrence reports, especially those related to major pipeline spills or pluggage events:

- Rockwell 1978b, *Release of Contamination While Preparing to Cut Process Line*
- Rockwell 1980a, *Line Failure-Slurry Line 176*
- Rockwell 1982a, *Failure of a Process Line / 244-TX*
- Rockwell 1984, *Transfer Line Leak Between B-Plant and the 244-AR Lift Station*
- Goetz 2003, *Historical Summary of Occurrences from the Tank Farms Final Safety Analysis Report.*

Detailed reports on the metallurgical examination of failed pipelines such as SL176, SN402, SN406, and V398, and leak location investigations include:

- Bendixsen 1983, *Analysis of Pipeline Failure, SL-176*
- Riddelle 1982, "SN-402 Failed Transfer Line Investigation"
- Certa 1983, *Metallurgical Analysis of Leak Failure of Waste Transfer Line V398*
- Knight 1985a, "Three-Inch SN-233 Line Leak Location"
- Elsen 1999, *Camera Inspection of SN216 and SL101*
- Schwenk 1984, *Analysis of Leakage Failure in Liquid Waste Transfer Lines SN 402 and 406.*

Finally, Hanford Site monthly reports and pipeline and waste tank leakage reports were screened to compile a list of historical pipeline pluggage incidents including:

- GE 1946 - 1962 Monthly Reports
- Maxfield 1979, *Handbook: 200 Areas Waste Sites*
- Westinghouse 1992b, *Tank 241-SX-108 Leak Assessment.*

Table 1 provides a comprehensive list of the failed and plugged waste transfer lines at the Hanford Site. The list also includes the failed pipelines identified on the 200 East Area Routing Board (drawing H-14-104175, *Waste Transfer Piping Diagram 200 East Area*) and on the 200 West Area Routing Board (H-14-104176, *Waste Transfer Piping Diagram 200 West Area*). The 200 East and 200 West Area Routing Boards are periodically updated to reflect current conditions in the tank farms. This data may not be complete for all pipelines, especially the historical pipelines that were installed in the tank farms from 1945 through the mid 1950s.

Table 1 includes a total of 100 waste transfer lines that are known to have failed, eight of which exist within the WMAs and are known to have become permanently blocked. Of the remaining lines, six were used as cross-site transfer lines; according to current records, two are still intact, one is not blocked but has unknown integrity, and three are known or suspected to be blocked. This leaves 86 waste transfer lines that apparently failed in service for reasons other than plugging. The residual waste inventory in the failed pipelines is probably negligible because these lines were typically flushed with raw water after each waste transfer (Agnew 1997a; Bauer 1993a). In those cases where the transfer lines are known to have collapsed, the hot waste drained by gravity to the downstream diversion box catch tanks (GE Monthly Reports 1946b, 1946c, 1946d, 1947a). These lines were typically flushed with raw water to reduce the radiation field in the surrounding area before the new jumpers were installed in the diversion boxes. In addition, during this review, two cascade lines were identified as being plugged: the line from 241-BX-102 to 241-BX-103 and the line from 241-C-110 to 241-C-111. This results in a total of 10 plugged lines, which are addressed in this report.

Table 1. Identified Pipeline Failures at the Hanford Site. (6 sheets)

Line No.	Status	Reference	First Block or Cap	Second Block or Cap
SL101	Plugged.	Kison 2002a	241-S-152-nozzle 1 (blocked)	Line SL-101 blocked close to 241-U-D, line connected to 241-U-D valve pit.
SL113	Failed pressure test on 5/25/1979.	Rockwell 1979	242-S Evaporator (nozzle 16)	241-S-C-L3
SL115	Failed pressure test on 6/10/1992.	Westinghouse 1992a	241-S-A-L10	241-S-C-L3
SL116	Failed hydro test on 5/14/1992.	Westinghouse 1993	241-S-D-R3, stub connected to drain	241-S-B-R10
SL119	Failed hydro test. Line was cut and plugged on 10/23/1992.	Westinghouse 1993 H-14-104175	241-S-103-03A	241-S-A-L7
SL126	Failed 2/21/1980 due to pinhole leaks. Waste drained.	Rockwell 1980b	241-S-D-R5	Capped near 241-S-107
SL133	Failed pressure test on 5/16/1988.	Westinghouse 1988 Mintz 1989	241-SX-104-04A pump pit	241-SX-B valve pit nozzle R-7
SL138	Failed 11/1/1980	H-14-104176	241-S-152-3	SL-138 stub from 241-S-152 cut and capped in field. SL138 stub from 242-S-19 connected to SL175 stub from 241-SY-A-L3.
SL139	Capped.	H-14-104176	241-S-152-4 capped	Stub from 241-S-152 cut and capped in field. SL139 stub from 242-S-18 connected to SL114, which is routed to 241-S-B-R3 and capped.
SL175	Failed.	Kison 2002a	241-S-152-8 capped	Line SL175 failed. Cut and capped close to 241-S-152. SL175 stub from 241-SY-A-L3 tied to line SL138 (3/1985) and routed to 242-S-19. Line 138 stub to 241-S-152-3 failed 11/1/1980 and was capped at 241-S-152 and in field close to 241-SY-B.
SL176	Failed on 11/11/1980 during transfer from 242-S Evaporator to 241-SY-103.	Kison 2002a	241-S-152-6 capped	Line SL176 failed on 10/30/1980 due to stress corrosion cracking. Leak located 18 ft 2" from COB SY-4. Line capped at 241-S-152 and cut and capped in field close to 241-SY-B. Short stub to 241-SY-B-R3 capped.
SL503	Failed on 10/26/1994.	Goetz 2003	204-AR	AY-102. Tripped leak detector in sluice pit on 241-AY-102.
SN200 [a]	Cut and capped.	Kison 2002a	241-BY-102-02A-U2, process blank	Connected to common header, cut/capped both ends in field, stub to 244-BX-C (process blank)
SN201	See note a	—	—	—

Table 1. Identified Pipeline Failures at the Hanford Site. (6 sheets)

Line No.	Status	Reference	First Block or Cap	Second Block or Cap
SN202	See note a	—	—	—
SN203	See note a	—	—	—
SN207 [b]	Cut and capped.	Kison 2002a		Connected to common header SN107, cut/capped north end, SN107 stub to 244-BX-D.
SN204 (200 West)	See note b	—	—	—
SN205	See note b	—	—	—
SN206	Cut and capped.	Kison 2002a	241-BY-111--11A-U2, process blank	Cut and capped close to 241-BY-111 on 10/19/1991.
SN215	Line failed pressure test on 6/12/1992.	Westinghouse 1994	241-S-C-L1	241-S-A-L14
SN216	Plugged. Attempts to unplug line failed 11/5 to 11/7/1999.	Kison 2002a	241-S-152-nozzle 9 capped at 241-S-152 diversion box	Line SN216 blocked 14 ft from 241-U-D-R1 valve pit. Line failed pressure test 9/22/1999. SN282 stub from 241-SY-B-R3 connected to SN216 and routed to 241-U-D-R1.
SN233	Failed 11/19/1984. Leaked to encasement.	Knight 1985b	241-ER-153	244-A lift station. Leak 20 ft from 244-A lift station.
SN235	Cut and capped.	Kison 2002a	241-A-102-02B-2	—
SN247	Failed pressure test on 5/3/2001. Leak assumed due to failed jumpers.	CH2M HILL 2001	241-AX-B valve pit R-11, capped	241-AN-101 01E, capped.
SN266	Capped.	Kison 2002a	244-U-C	—
SN281	Failed.	Kison 2002a	241-S-152-10 open	Line SN281 failed. Cut and capped close to 241-S-152. SN281 stub from 241-SY-A-2 also cut and capped at 241-SY-A.
SN282	Failed.	Kison 2002a	241-S-152-11 capped	Line SN282 failed. Cut and capped close to 241-S-152. Stub from 241-SY-B-R3 connected to SN216 from 241-U-D valve pit (capped), which later was blocked.
V004	Line failed 4/20/1972. 2,500 gal drained from encasement. Line abandoned.	ARHCO 1972	241-A-152-U2	241-A-151-L22
V005	Line failed.	H-14-104175	241-A-152-U4	241-A-151-L20
V007	Lines failed.	H-14-104175	241-A-152-U6	241-A-151 L-14, L-15 and L-16

Table 1. Identified Pipeline Failures at the Hanford Site. (6 sheets)

Line No.	Status	Reference	First Block or Cap	Second Block or Cap
V052	Cut and capped.	Kison 2002a	241-A-152-L9	—
V061	Capped.	Kison 2002a	241-A-152-L16	Connected to V052 stub from 241-A-152-L9.
V101	Cut and capped.	Kison 2002a	241-C-153	—
V112	Leaker.	H-14-104175	241-C-151 U-5	—
V121	Cut and capped.	Kison 2002a	241-C-152	—
V141	Cut and capped.	Kison 2002a	241-C-153-L6	Cut and capped in field close to 241-C-110.
V142	Cut and capped.	Kison 2002a	241-C-153-L7	Cut and capped in field close to 241-C-107.
V200	Failed pressure test on 7/14/1974, capped at B Plant.	H-14-104175	241-B-154	221-B, Section 10, process blank installed.
V219	Capped.	Kison 2002a	241-ER-151-L2	—
V233	Failed.	H-14-104175	241-B-151 L-4	241-B-101
V314	Capped.	Kison 2002a	242-B Evaporator	242-B-151
V329	Out of service, capped at B Plant.	Fraser 1974c	241-B-154	221-B, Section 9, process blank.
V330	Failed pressure test on 7/18/1974.	Fraser 1974c	241-B-154	221-B, Section 10, process blank.
V331	Failed pressure test on 7/6/1974.	Fraser 1974c	241-B-154	221-B, Section 15, process blank.
V333	Failed pressure test on 7/25/1974.	Fraser 1974c	241-B-154	221-B, Section 5, process blank.
V363	Plugged during Metals Recovery Program in 1950s. Also has integrity issues.	Sutey 1995	Undefined	Undefined
V364	Plugged during Metals Recovery Program in 1950s.	Sutey 1995	Undefined	Undefined
V366	Plugged during Metals Recovery Program in 1950s.	Sutey 1995	Undefined	Undefined
V383	Cut and capped.	Kison 2002a	241-TX-154-8 capped	Stub cut and capped between 241-TX-154 and 241-TX-155 and capped at 241-TX-155-5.

Table 1. Identified Pipeline Failures at the Hanford Site. (6 sheets)

Line No.	Status	Reference	First Block or Cap	Second Block or Cap
V384	Cut and capped.	Kison 2002a	241-TX-154-7 capped	Stub cut and capped between 241-TX-154 and 241-TX-155 and capped at 241-TX-155-6.
V385	Cut and capped.	Kison 2002a	241-TX-154-6 capped	Stub cut and capped between 241-TX-154 and 241-TX-155 and capped at 241-TX-155-7.
V386	Cut and capped.	Kison 2002a	241-TX-155-8	Cut and capped at 241-TX-155.
V388	Cut and capped.	Kison 2002a	241-TX-154-L4 open	Capped at 241-TX-152-U3.
V392	Plugged.	Oberg 1966	241-TX-154-L2	241-TX-155-U18
V398	Failed pressure test on 5/15/1982.	Rockwell 1982b	241-TX-155-L5	Capped close to 241-U-151.
V402	Stainless steel line failed on 1/5/1982 because of chloride induced pitting.	Rockwell 1982b	241-TX-155-L9 open	Line cut and capped at 241-TX-155, cut and capped at 241-TY-103-12. Stub from 241-TX-155 to 241-TY-153 cut and capped in field.
V406	Stainless steel line failed because of chloride induced pitting. Line cut.	Kison 2002a	241-TX-155-L13 open	Line cut and capped at 241-TX-155, cut and capped at 241-TY-103-9. Stub from 241-TX-155 to 241-TY-153 cut and capped in field.
V408	Cut and capped.	Kison 2002a	241-TX-155-L15 open	Cut and capped at 241-TX-155, cut and capped at 241-TY-103-6. Stub from 241-TX-155 to 241-TY-153 cut and capped in field.
V410	Plugged. Line cut and capped.	Oberg 1966	241-TX-155-L17 open	Cut and capped at 241-TX-155 12/23/1988. Stub to 241-U-151-U2.
V412	Plugged.	Kison 2002a	241-TX-155-L19 capped	Cut and capped at 241-TX-155. Stub to 241-TY-153 cut and capped at 241-TY-153-3.
V416	Leaks.	Oberg 1966	241-U-152-U1	241-TX-153-U10
V426	Failed 7/1979.	Kison 2002a	241-U-152-L-4 capped	Line V426 failed 7/1979. Stub to 241-U-153-U6 capped.
V453	Plugged. Hole drilled in line on 1/20/1978 and waste sprayed out.	Oberg 1966	241-U-151-L4	Tank 241-U-101
V465	Plugged. [d]	Oberg 1966	241-U-153-L3	Tank 241-U-110
V514	Plugged. Line cut.	Oberg 1966	240-S-151-L6. Line cut and capped at 240-S-151 diversion box 3/27/1987.	241-S-151-U12.
V517	Cut and capped.	Kison 2002a	241-S-151-16-U16	Line cut at 240-S-151-5-L5 diversion box 3/27/1987. Stub connected to 3603 from 202S lab.
V601	Leaks.	Oberg 1966	241-T-152-L10	241-TX-153-U9

Table 1. Identified Pipeline Failures at the Hanford Site. (6 sheets)

Line No.	Status	Reference	First Block or Cap	Second Block or Cap
V608	Leaks.	Oberg 1966	241-TX-153-L2	Tank 241-TX-101
V624	Leaks.	Oberg 1966	242-T Evaporator condensate	#18 lower nozzle 241-TX-153
V654	Leaks.	Oberg 1966	241-T-151-U4	Section 9, 221-T nozzle 101
V657	Leaks.	Oberg 1966	241-T-151-L1	241-T-153-U1
V667	Leaks.	Oberg 1966	241-T-152-U4	Section 5, 221-T nozzle 11
V669	Leaks.	Oberg 1966	241-T-152-U6	Section 15, 221-T nozzle11
V671	Leaks.	Oberg 1966	241-T-152-U9	Building 224-T
V740	Leaks.	Oberg 1966	Steam jet on 241-TX-302C catch tank	#10 upper nozzle 241-TX-154
103	Abandoned and capped.	Kison 2002a	241-SX-103-03A	Line from SX-103 saltwell screen abandoned and capped.
V456	Capped.	Kison 2002a	241-SX-152	—
812	Failed 3/1971.	Maxfield 1979	244-AR	812 line connected to V108 to 241-C-151 U1 (process blank).
3603	Cut and capped.	Kison 2002a	240-S-151-U7	Line cut at 240-S-151 diversion box 3/27/1987. 3603 stub routed around 240-S-151 box and connected to V517stub to 241-S-151-16.
4004	Cut and capped in field.	Kison 2002a	241-AX-151-G cell	Line from 241-AX-151 cut and capped in field between 241-AX-151 and 241-A-A flush pit. Line 4004 stub from PUREX has process blank, while 4029 bypass from PUREX no longer used as of 6/17/1991, line 4004 from PUREX re-routed to L-12 nozzle (with process blank) in flush pit 241-A-A.
4006	Cut and capped in field.	Kison 2002a	241-AX-151-E cell	Cut and capped in field between 241-AX-151 and 241-AX-152. Stub from nozzle T-9A in 244-AR vault tied to line 4018 from 241-AX-152 diversion box.
4014	Cut and capped in field.	Kison 2002a	241-AX-151 washdown	Cut and capped in field near 241-AX-151.
4015/814	Cut and capped in field.	Kison 2002a	241-AX-151 washdown	Cut and capped in field near 241-AX-151. Stub line 814 from 244-AR vault bypasses cut and connected to line 4002/4028, which is routed to PUREX.
4017	Cut and capped in field.	Kison 2002a	241-AX-151 washdown	Cut and capped in field between 241-AX-151 and 241-AX-152. Stub from 241-AX-152 nozzle B tied to line 4003 from PUREX (process blank).

Table 1. Identified Pipeline Failures at the Hanford Site. (6 sheets)

Line No.	Status	Reference	First Block or Cap	Second Block or Cap
4018	Cut and capped in field.	Kison 2002a	241-AX-151 washdown	Cut and capped in field between 241-AX-151 and 241-AX-152. Stub from 241-AX-152 tied to line 4006 stub from 244-AR vault.
4019	Capped in field.	Kison 2002a	241-AX-151-F cell	Truncated and capped at 241-AX-151.
4020	Cut and capped in field.	Kison 2002a	241-AX-151-G cell	Cut and capped in field close to 241-AX-152. Stub at 241-AX-151 not plugged, other end not located on routing board.
4024	Capped.	Kison 2002a	241-AX-152-B	Truncated and capped at 241-AX-152-B.
4510/A107	Cut and capped in field.	Kison 2002a	241-AX-152-7	Cut and capped in field close to 241-AZ-152 (near 241-AZ-102). Stub not found on routing board.
4851/4857	Failed 4/28/1975.	Oberg 1966	L-4 241-UX-154-L4	U-3 241-TX-155-U3
6012	Cut and capped.	Kison 2002a	241-TR-153-U13 capped	Cut in field. Remaining line routed from 244-TX-H (capped) to 241-T-104 saltwell screen also capped.
6012	Cut and capped.	Kison 2002a	241-TXR-151-U10 capped	Cut in field. Section from 241-TXR-151 capped. Stub rerouted from 244-TX-H (capped) to T-104 saltwell screen also capped.
7624	Cut and capped.	Kison 2002a	241-TXR-151-U14 capped 241-TR-153-U14 capped	Cut in field. Sections from 241-TXR-151 and from 241-TR-153 capped. Stub rerouted from 244-TX-I (capped) to T-109 and T-111 saltwell screens also capped.
9653/141	Cut and capped in field close to 241-BX-104.	Kison 2002a	221-B capped	241-BX-104 cut and capped.

Reference information is provided in Section 11.0 of this document.

[a] SN200 was a transfer line from 241-BY-102. It also served as a collector line for SN201, SN202, and SN203. SN200 is cut and capped below the junction point of these other pipelines. In 1997, SN200 plugged and an attempt was made to unplug the line. There is no documentation that the plug was dislodged or that attempts to free the plug resulted in the pipeline rupturing. Some documentation indicates that SN201, SN202, and SN203 failed and were cut and capped. Other documents do not support this assessment and indicate that only SN200 failed and was cut and capped. SN201, SN202, and SN203 are accounted for in the total number of failed lines as part of SN200.

[b] SN207 was a transfer line that also served as a collector line for SN204, and SN205. SN207 is cut and capped below the junction point of these other pipelines. In 1997, the line was cut and capped. Some documentation indicates that SN204, and SN205 failed and were cut and capped. Other documents do not support this assessment and indicate that only SN207 failed and was cut and capped. SN204 and SN205 are accounted for in the total number of failed lines as part of SN207.

[c] Line V452 becomes V421 which ties into 241-U-152-U8. According to H-14-104176, this is an active line.

[d] According to H-14-104176, this line is not plugged.

PUREX = plutonium-uranium extraction.

3.0 CROSS-COUNTRY WASTE TRANSFER LINES

Six, concrete-encased, stainless steel waste transfer lines were installed in 1952 between the 241-ER-151 diversion box in the 200 East Area and the 241-UX-154 diversion box near U Plant in the 200 West Area. An air-relief station, 241-EW-151, was located at the high point between the 200 East and 200 West Areas to vent the cross-country lines. These lines were initially used to transport dissolved metal waste from the 200 East Area vaults to U Plant for uranium recovery and to return the uranium recovery waste to the 200 East Area for disposal. Later, these lines were used to transfer REDOX supernates to B Plant for cesium recovery operations and to return depleted wastes to the 200 West Area for waste evaporation. Occasionally, these lines were also used for other cross-site transfers, but were eventually replaced by a new set of cross-site transfer lines in the 1990s.

Historically, information in the Hanford Site Records and Information Management Information Locator System (RILS) and Records Management Information System (RMIS) concerning the status of the cross-country waste transfer lines could not be found extending back beyond the mid 1970s, and documentation of the status of the cross-country transfer lines is inconsistent at best. A summary of the system and its operational history is presented in *Preoperational Environmental Survey Report: 200 Areas Cross-Site Transfer Line Replacement (W-058)* (Johnson 1996). The earliest record found that addresses plugging of the cross-country lines was "Validation of Cross Country Transfer Temperature Losses" (Atherton 1975). This report notes that temperature loss as the waste is conveyed through the cross-country transfer lines causes "salting out," which "would probably plug the transfer line." The solution to this problem was to provide dilution with water at the origin and then diminish the dilution rate as the line warmed up during the transfer, thus reducing the heat loss rate in the waste.

Four of the six original cross-country waste transfer lines were commonly assumed to have failed and were beyond repair (Cejka 1990, *Engineering Study, Replacement of the Cross-Site Transfer System, Project W-058*). Other references state that four of the six lines were unusable due to past plugging or leaking (Riesenweber 1995, *Replacement Cross-Site Transfer System Systems Engineering Summary Report*).

The surface contamination around the 241-EW-151 vent station and along the cross-country transfer line right-of-way was apparently caused by the overflow of the 241-EW-151 catch tank, with the waste being channeled to the concrete encasement and from there to the soil:

- ARHCO 1975, *Possible Leakage of Encased Pipeline*
- ARHCO 1976a, *Plugged Cross Country Transfer Line*
- ARHCO 1976b, *Swab Riser Increase in Excess of Allowed Variant*
- ARHCO 1976c, *Swab Riser Increase in Excess of Allowed Variant*
- McKinney et al. 1988, "Surface Contamination Investigation Letter Report Cross-Country Waste Transfer Line"
- Mollusky 1988, "Cross-Site Transfer Line Surface Contamination"
- Maxfield 1979, *Handbook: 200 Areas Waste Sites*

- CH2M HILL 1998, *Contaminated Tumbleweeds Discovered at "Old" Cross-Site Transfer Line.*

The cross-country lines did plug, and the blocked lines were generally cleared:

- ARHCO 1976a
- Rockwell 1978a, *Plugged Cross-Country Transfer Line*
- Hummer at al. 1978, *Investigation of Plugged Cross-Country Transfer Line V360*
- Rockwell 1980c, *Plugged Cross Country Transfer Line*
- Garfield 1976, "Dilute Waste Transfer in Line 362"
- Saueressig 1989, "Cross-Site Transfer Line Pressure Test".

On February 15, 1976, the Energy Research and Development Administration directed Atlantic Richfield Hanford Company (ARHCO) to pressure test all east-west cross-country transfer lines, with exception of the two in use, to verify their integrity (Elgert 1976, "Cross Country Transfer Lines"). In replying to this request, ARHCO stated that it was difficult to justify such an extensive effort considering the status of the six lines. Two of the lines were being used and had passed all pressure tests, while a third line was available as a spare in the event that one or both of the active lines failed. ARHCO asked for a delay in pressure testing the three remaining lines (Malody 1976, "241-EW Transfer System"). In Garfield (1976), a summary of the factors involved in reusing the recently unplugged cross-country line V-362 is addressed. Line V-362 was plugged and then unplugged over a two-day period by injecting 14,000 gal of water into the line from a fire hydrant. Attached to this memorandum is a hand-written exchange that reads, "Isn't there another cross-country line that is plugged? Why don't we try and unplug it with the 600 # hit?" The response to this comment is:

> "There is a rumor that at least one and possibly 2 of the remaining cross-country lines are plugged and that the other one leaks. Efforts to confirm or identify which lines have thus far been futile. ERDA wrote a letter saying these lines should be tested by 6/1/76 and TFM replied that they would be included in a plan that would be issued 5/15. If flow can not be established before or by testing at 200 lbs, the higher pressure would be tried."

In April 1976, "Investigation of the Plugged Cross-Country Transfer Line 362," (Appendix 1 of Hummer et al. 1978) was issued. This report presented the findings of a test to demonstrate that transfer waste solution could be safely transferred without the use of dilution waste. During this test after addition of all dilution water was suspended, cross-country line V-362 plugged. An investigation was conducted to establish the facts concerning the occurrence and to make recommendations to correct problems associated with this particular transfer. The report analyzes the problems and establishes corrective measures. The pluggage problems with one and possibly two lines, and integrity questions of at least one of the cross-county lines, are documented in these early 1976 records.

In *Operational Safety Analysis Report Cross-Country Waste Transfer System* (Entrop 1977), all six lines were considered to be potentially available as of August 1977. While the occurrence and event reports cover the temporary pluggage incidents for lines V360 and V362, no such reports were issued for the remaining cross-country transfer lines (V361, V363, V364, V366).

In "Cross-Site Transfer" (Carothers 1978a), a sample of cross-site transfer material is described as non-flowable at room temperature but at 45°C liquefies and then again solidifies at 10 to 15°C. The internal memorandum states:

> "Based upon these preliminary observations, my recommendation for attempting to unplug the cross-site transfer line if current pressurized methods prove to be unsatisfactory is to increase the temperature of the plug to reliquify it."

As stated in "Recommendation for Restarting Cross-Site Transfer" (Carothers 1978b), the viscosity of the transfer material was one factor that contributed to the line pluggage during August. The recommendation was to dilute the transfer material by 60%; however, preliminary evaluation indicated that additional salts may be formed during concentration. A hand-written note reads, "We don't want more salt in East – drop it in West." It is not clear whether the dilution solution was implemented based on this problem.

Hummer et al. (1978) appears to address the line plug referenced in the Carothers (1978a, 1978b) memoranda, and the report notes that immediate efforts to unplug the line from the 154-UX diversion box were successful. However, the report goes on to describe the failings of procedures and the failure to follow recommendation of the investigation of the plugging of cross-country line V-362 in April 1976. It can be concluded that in August and September of 1978, line pluggage was now a documented problem in lines V-360 and V-362 and attempts were being made to resolve this problem, but a permanent solution had not been developed.

High-pressure valves were installed on transfer lines V360, V361, and V362 in 1980, but line V360 was the only one still in service as of mid 1983 (Carlson 1987, "Cross-Site Transfer Line-Pressure Testing;").

Plugging of the cross-country waste transfer lines was an issue in the mid 1970s to late 1970s and appears to be somewhat problematic. It is also clear that the means to avoid plugging, the detection of plugging, and how to unplug a line was evolving. For the period between 1978 and 1987, there is no documentation as to the status of the five lines that were not in service beginning in 1983. Lines V-360 and V-362 had plugging problems, and the balance of the lines had not been in service. Indications are that one line may have had integrity problems and not plugging problems.

The U.S. Department of Energy (DOE), Richland Operations Office (RL) conducted an audit of the cross-country facilities in 1988 and found that the corporate history was extremely limited. Only two of six lines were being used when the audit was performed. The four unused lines are either plugged or of questionable integrity. Documentation concerning what happened to these four lines was nearly completely lacking (Gerton 1988, "Department of Energy, Richland Operations Office, Audit of the Cross-Country Transfer Facilities, August 25, 1988, Thru October 6, 1988").

As stated in "Cross-Country Transfer Audit Observation 88-EC-1" (Kimura 1989a), in February 1989, as part of the development of the response to the RL audit concerning pressure testing, it is noted that transfer line V-360 is currently used for transfers and that:

> "A pressure test of other backup lines is scheduled to be performed after the next transfer. Lines V-361 and V-362 are likely backup lines to be tested. There is no evidence of any line failures along the cross-country route, however, documentation exists which indicates three lines were plugged."

Kimura (1989a) indicates that in early 1989, three of the six lines were considered serviceable. Unfortunately, Kimura (1989a) does not reference the documentation of the other three lines. It is also curious that while RL raises the question of line integrity, Kimura (1989a) does not. It is not clear at this point if it is to be inferred that integrity and pluggage are being used interchangeably to describe the conditions of the lines. Westinghouse Hanford Company compiled a cross-country transfer system history (Kimura 1989b, *Cross-Country Transfer System Historical Information*). In reviewing many of the documents references, they provided limited insight into the issue of line plugging or line integrity.

In Saucressig (1989), concerning the pressure testing of line V-360, there is an attached note from R.T. Kimura that presents a preliminary history of the cross-site lines indicating that in September 1977, lines V-360, V-361, and V-362 passed a pressure test but the other lines did not pass. It is further noted that in March 1978, the pluggage of lines V-363, V-364, and V-366 is documented but again no reference or a basis for this conclusion is provided. In October 1989, Westinghouse provided "Quarterly Response Report to Audit of Cross-Country Transfer Facilities Conducted August 25, 1988, through October 6, 1988" (Daugherty 1989) to the RL audit, which presented Kimura (1989a) as the documented history for the cross-country transfer line.

In May 1990, Westinghouse Hanford Company issued "Engineering Study for Replacement of the Cross-Site Transfer System" (Wodrich 1990). As part of this report, the existing east/west pipeline was summarized as follows: "Project 6-362 III, circa 1950, installed six 3-in., schedule 10 stainless-steel pipelines. Four of the pipelines have failed and are considered beyond repair."

The environmental assessment prepared for the new cross-site transfer system (Bauer 1993b) states that, as part of taking the existing line out of service, "The existing system would be drained, isolated and capped." This would imply that there was some perception that any remaining waste in the system could be removed.

"Cross-Site Transfer Lines" (Sutey 1995) presents information on the present status and operating history of the six lines. This document indicates that:

- Line V-360 was pressure tested and used in 1989 and was scheduled for pressure testing and use in 1993.
- Line V-361 was used in the early 1980s, no indication of failure or plugging.
- Line V-362 was apparently plugged in 1960s but may have been operational in 1976.
- Line V-363 was plugged in the 1960s and its integrity may have been compromised during attempted unplugging with high-pressure.
- Line V-364 was plugged in the 1960s.
- Line V-366 was plugged in either the 1950s or 1960s.

The original cross-site transfer lines were replaced because these lines were nearing the end of their useful lives and did not comply with DOE and other federal and state regulations (Brantley 1993, *Title I Design Report: Replacement of the Cross-Site Transfer System Project W-058*).

Documentation of the status and condition of the six cross-country waste transfer lines from the late 1970s up until they were taken out of service is inconsistent. This inconsistency results in there being some ambiguity in attempting to determine if there is any waste still remaining in the lines. Based on the available information, the following conclusions appear to be reasonable concerning the status of these lines:

- Plugging of the cross-country waste transfer lines was recognized as a problem since the mid to late 1970s and probably was an issue prior to that time considering the operational history of the six lines.
- In 1989, three of the six lines passed their pressure testing and were considered serviceable. The remaining three did not pass the pressure testing but it is unclear what caused the failure of the lines to pass the test (line pluggage or line integrity). The procedure for pressure testing applied 200 lb of pressure into the lines. Documentation exists which indicates that pressures may have been applied as high as 600 lb if pluggage was a concern. This higher pressure had the risk of compromising the integrity of the thin-walled line thus rendering it unusable.
- Wodrich (1990) notes that four of the lines have failed and are beyond repair. Again it is unclear as to the basis for this conclusion and whether failure means the integrity of the pipes were compromised, they were plugged, or both.
- Sutey (1995) presents the most specific information on the present status and operating history of the six lines in that it actually calls out the status of each line. From the information sheet it can be concluded that at least two lines (V-364 and V-366) are probably plugged. Line V-363 had plugging problems, and at best was plugged and in attempting to unplug, it probably lost its integrity. Lines V-360 and V-361 probably are not plugged and have stable integrity. Line V-362 passed a pressure test in 1977 and was considered usable in 1989 but does not appear to have been used after that point. Wodrich (1990) documents that four lines had failed and were beyond repair, which would have included line V-362. This line may not have been plugged but considered not a viable pipeline for other reasons.
- Line V-360 was pressure tested and used in 1989 and was scheduled for pressure testing and use in 1993. This line is probably not plugged.
- Line V-361 was used in the early 1980s, and there is no indication of failure or plugging. This line is probably not plugged.
- Line V-362 was apparently plugged in 1960s but was deemed operational in 1989. This line has integrity problems and is considered unusable for other reasons than being plugged.
- Line V-363 was plugged in the 1960s and its integrity may have been compromised during attempted unplugging with high pressure. This line is probably plugged and has integrity problems that rendered it unusable.

- Line V-364 was plugged in the 1950s or 1960s.
- Line V-366 was plugged in either the 1950s or 1960s.

Based upon available history concerning the blockage of these lines, it is unlikely that the blockage exists within the boundary of any tank farm. These lines were Schedule 10, Type 347 stainless steel, 3-in. single-wall pipe. Because of their length and the fact that the majority of the cross-country transfer lines are between the 200 East and 200 West Areas and not within the WMAs, lines V363, V364, and V366 are removed from further consideration in this report.

4.0 PLUGGED WASTE TRANSFER LINES

Table 2 identifies the 10 plugged pipelines that were identified in Section 2.0 and that are addressed in this report, while Table 3 provides estimates of the projected length of each pipeline, based on the Hanford Site coordinates (Bechtel 1999, *Hanford Site Atlas*). The predicted volume of residual waste in the 10 pipelines is listed in Table 4. These estimates are based on the diameter of each pipeline and estimated distance between the terminal diversion boxes or downstream receiver tanks. Table 5 identifies the fractional length of each pipeline within the fenced perimeter of the tank farms. For most pipelines, only a small portion actually extends into the tank farms, while other lines such as V363, V364, V366, V392, V410, and V514 are totally outside the fenced boundaries of all tank farms.

Table 6 lists the relevant Hanford Site drawings and other key references that were used to determine the length of each plugged pipeline.

Table 2. List of 10 Plugged Pipelines at the Hanford Site within Waste Management Areas.

Line No.	Status	Reference	First Block or Cap	Second Block or Cap
SL101	Failed 4/81. Cut and capped in field. Plugged.	Kison 2002a H-14-104176	241-S-152-nozzle 1 (blocked)	Line SL-101 blocked close to 241-U-D, line connected to 241-U-D valve pit
SN216	Plugged. Attempts to unplug line failed 11/5 to 11/7/1999.	Diliberto 1982 Kison 2002a H-14-104176	241-S-152-nozzle 9 capped at 241-S-152 diversion box	Line SN216 blocked 14 ft from 241-U-D-R1 valve pit. Line failed pressure test 9/22/99. SN282 stub from 241-SY-B-R3 connected to SN216 and routed to 241-U-D-R1.
V392	Plugged.	Oberg 1966	#2 lower nozzle 241-TX-154	#18 upper nozzle 241-TX-155.
V410	Plugged. Line cut and capped.	Oberg 1966 H-14-104176	241-TX-155-L17 open	Cut and capped at 241-TX-155 12/23/88, stub to 241-U-151-U2.
V412	Plugged.	Kison 2002a	241-TX-155-L19 capped	Cut and capped at 241-TX-155, stub to 241-TY-153 cut and capped at 241-TY-153-3.
V453	Plugged. Hole drilled in line on 1/20/1978 and waste sprayed out.	Oberg 1966	#4 lower nozzle 241-U-151	Tank 241-U-101
V465	Plugged.	Oberg 1966	#3 lower nozzle 241-U-153	Tank 241-U-110
V514	Plugged. Line cut.	Oberg 1966 H-14-104176	240-S-151-L6. Line cut and capped at 240-S-151 diversion box 3/27/1987.	241-S-151-U12
Cascade line from 241-BX-102 to 241-BX-103	Plugged 1/1951.	GE 1951a Agnew 1997b	241-BX-102	Tank 241-BX-103
Cascade line from 241-C-110 to 241-C-111	Plugged 12/1952.	GE 1952a GE 1952b Agnew 1997b	241-C-110	Tank 241-C-111

Reference information is provided in Section 11.0 of this document.

Table 3. Predicted Length of Plugged Pipelines.

Line No.	First Blockage	North (m)	East (m)	Second Blockage	North (m)	East (m)	Distance (ft)
SL101	241-S-152	134,590	566,820	241-U-D	135,030	566,830	1,444
SN216	241-S-152	134,590	566,820	241-U-D	135,030	566,830	1,444
V392	241-TX-154	136,850	567,590	241-TX-155	136,100	567,100	2,939
V410	241-TX-155	136,100	567,100	241-U-151	134,995	566,935	3,666
V412	241-TX-155	136,100	567,100	241-TY-153	136,355	566,825	1,230
V453	241-U-151	134,995	566,935	241-U-101	135,095	566,845	441
V465	241-U-153	135,015	566,875	241-U-110	135,000	566,845	110
V514	240-S-151	134,030	567,370	241-S-151	134,325	566,910	1,793
Cascade line from 241-BX-102 to 241-BX-103	241-BX-102	137,357	57,360	241-BX-103	137,363	57,360	23
Cascade line from 241-C-110 to 241-C-111	241-C-110	136,580	575,105	241-C-111	136,585	575,110	20

Table 4. Estimated Volume of Residual Waste in Plugged Pipelines.

Line No.	Tank Farm (241-)	Elevation Difference	Pipeline Diameter (in.)	Maximum Length of Plugged Section (ft)	Maximum Waste Volume (L)
SL101	S and U	7 ft 6 in., sloped down to 241-S-152	2	1,444	861
SN216	S and U	7 ft 6 in., sloped down to 241-S-152	3	1,444	1,988
V392	TX	26 ft sloped down to 241-TX-155	3	2,939	4,086
V410	TX and U	17.37 ft, sloped down to 241-U-151, plugged at 241-U-151	3	3,666	5,096
V412	TX and TY	20.38 ft sloped down to 241-TY-153	3	1,230	1,711
V453	U	32.5 ft, sloped down to bottom of 241-U-101	3	441	614
V465	U	25 ft, sloped down to bottom of 241-U-110	3	110	153
V514	S	9.74 ft, sloped down to 241-S-151	3	1,793	2,492
Cascade line from 241-BX-102 to 241-BX-103	BX	Sloped down from 241 BX-102 to 241-BX-103	3	20	28
Cascade line from 214-C-110 to 241-C-111	C	Sloped down from 241-C-110 to 241-C-111	3	20	28
Total	—	—	—	—	17,057

Table 5. Predicted Length of Each Plugged Pipeline Within Fenced Perimeter of Tank Farms.

Line No.	Blockage Location	North (m)	East (m)	Tank Farm (241-)	Tank Farm Fence Location	North (m)	East (m)	Distance to Fence (ft)
SL101	241-S-152	134,590	566,820	S	S	134,600	566,820	33
SL101	241-U-D	135,030	566,830	U	U	134,973	566,830	187
SN216	241-S-152	134,590	566,820	S	S	134,600	566,820	33
SN216	241-U-D	135,030	566,830	U	U	134,973	566,830	187
V392	241-TX-154	136,850	567,590	Outside TX	NA	NA	NA	NA
V392	241-TX-155	136,100	567,100	Outside TX	NA	NA	NA	NA
V410	241-TX-155	136,100	567,100	Outside U	NA	NA	NA	NA
V410	241-U-151	134,995	566,935	Outside U	NA	NA	NA	NA
V412	241-TX-155	136,100	567,100	Outside TX	NA	NA	NA	NA
V412	241-TY-153	136,355	566,825	TX	TX	136,335	566,835	73
V453	241-U-151	134,995	566,935	Outside U	NA	NA	NA	NA
V453	241-U-101	135,095	566,845	U	U	135,075	566,880	132
V465	241-U-153	135,015	566,875	U	U	135,000	566,845	110
V465	241-U-110	135,000	566,845	U	U	NA	NA	NA
V514	240-S-151	134,030	567,370	Outside S	NA	NA	NA	NA
V514	241-S-151	134,325	566,910	Outside S	NA	NA	NA	NA
Cascade line from 241-BX-102 to 241-BX-103	241-BX-102	137,357	57,360	BX	BX	137,364	57,360	23
Cascade line from 241-BX-102 to 241-BX-103	241-BX-103	137,363	57,360	BX	BX	NA	NA	NA
Cascade line from 241-C-110 to 241-C-111	241-C-110	136,580	575,105	C	C	136,585	575,110	23
Cascade line from 241-C-110 to 241-C-111	241-C-111	136,585	575,110	C	C	NA	NA	NA

NA = not applicable.

Table 6. Hanford Site Drawings and References Used for Each Plugged Pipeline.

Line No.	Tank Farm (241-)	References
SL101	S and U	Kison 2002a; Bechtel 1999; H-2-2338 sheet 62; H-2-37318; H-2-37317; H-2-37344; Elsen 1999; H-13-000275
SN216	S and U	Diliberto 1982; Kison 2002a; Bechtel 1999; H-2-2338 sheet 62; H-2-37318; H-2-37317; H-2-37344; H-13-000275; H-14-104176; H-2-37346; H-2-73142; Elsen 1999
V392	TX	Oberg 1966; Bechtel 1999; H-2-71660; H-2-840; H-2-2338, sheets 6 and 7
V410	TX and U	Kison 2002a; H-14-104176; H-2-843; H-2-44511; H-2-39551; H-2-844; H-2-2338, sheets 7 and 8; Bechtel 1999, 2002a
V412	TX and TY	Kison 2002a; H-14-104176; H-2-44511; H-2-2236; Bechtel 1998, 2002b
V453	U	Oberg 1966; Rockwell 1978b; Bechtel 1999; H-2-2338 sheet 8
V465	U	Oberg 1966; Bechtel 1999; H-2-2338 sheet 10
V514	S	Oberg 1966; Kison 2002a; Bechtel 1999; H-14-104176; H-2-71664; H-2-2338 sheet 25; H-2-71663
Cascade line from 241-BX-102 to 241-BX-103	BX	GE 1951a; Agnew 1997b; Bechtel 1999
Cascade line from 241-C-110 to 241-C-111	C	GE 1952a, 1952b; Agnew 1997b; Bechtel 1999

Reference information is provided in Section 11.0 of this document.

5.0 HISTORICAL WASTE PIPELINE FAILURES

Most pipelines are currently identified by a unique numbering system on the 200 East and 200 West Area Routing Boards (H-14-104175; H-14-104176). Unique pipeline identification numbers were apparently developed in the early to mid 1950s and were commonly used by the mid 1960s. When Hanford Site operations first started, the monthly operating reports typically referred to the pipeline routings in terms waste type (or section of the separation plant where the wastes were produced) or the source tank and destination of the waste. Sometimes, the diversion boxes were also called out in identifying which transfer line had been used. These reports were reviewed to identify all of the pipeline failures from 1945 to about 1972. Several additional pipeline failures were also identified in "Chronological Record of Significant Events in Chemical Separations Operations" (McCullugh and Cartmell 1968), Maxfield (1979), and in the historical event and occurrence reports (Goetz 2003; Mintz 1989, "1987-1988 Tank Farms Annual Trending Report, Tank Farm Events Root Cause"). Table 7 summarizes the historical pipeline failures at the Hanford Site, based on these records. Table 8 lists the pipelines that failed due to pluggage at the Hanford Site, based on the reference reports.

Table 7. Historical Pipeline Failures at the Hanford Site. (3 sheets)

Source	Date	Pipeline Plugs and Failures
Maxfield 1979	1945	Broken process transfer line from T Plant section R-19 (UN-216-W-6).
Apple 1946	3/29/1946	A tie line between the 241-T-152 and 241-U-152 diversion boxes plugged with coating waste and/or first-cycle waste.
GE 1946a	4/8/1946	Metal waste line plugged with $UO_2CO_3 2NaCO_3$. Line flushed and cleared with 10% sodium bicarbonate solution.
Maxfield 1979	4/29/1905	Metal waste leak in line R-3 from B Plant (UN-216-E-8).
GE 1946e	4/5/1946	First-cycle (and coating) waste line from T Plant plugged. Long length of tie line from T Plant to the U diversion box plugged. Plugging due to crystallization of sodium phosphate ($Na_2HPO_4 12H_2O$).
GE 1946c	5/9/1946	Plugged first-cycle waste line from T Plant cleared with high-pressure water. Line also flushed with sodium bicarbonate solution.
GE 1946d Bell 1946	6/17/1946	Metal waste line 9-1 from 221-B to 241-B-154 diversion box failed on 6/17/1946.
GE 1946b	9/23/1946	Ground contamination found 80 ft from location of 6/17/1946 metal waste line failure.
GE 1947a	6/23/1947	Metal waste line 10-1 from 221-B to 241-B-154 diversion box partially plugged in 11/1946 and failed pressure test in 2/1947.
GE 1947a	6/23/1947	Metal waste line from tank 9-1 in 221-T Evaporator failed.
GE 1947c	8/1/1947	Five stainless steel transfer lines from the 241-BX-154 to the 241-BX-155 diversion box failed due to electrolytic corrosion. Lines replaced.
GE 1947b	10/1/1947	Seven underground lines from 241-U to 241-U farm tanks failed hydrostatic tests due to galvanic corrosion. Corrosion also noted in stainless steel lines close to 241-BX-153 diversion box. Because of serious corrosion concerns, 2,600 ft of stainless steel pipe installed under Project C-112 was rejected.
GE 1950	11/15/1950	Encased metal waste line from 221-B to 241-BX-154 diversion box failed. First failure of encased line.
GE 1951a	2/1/1951	Cascade line from 241-BX-102 to 241-BX-103 plugged. Approximately 91,600 gal of metal waste overflowed from 241-BX-102.

Table 7. Historical Pipeline Failures at the Hanford Site. (3 sheets)

Source	Date	Pipeline Plugs and Failures
GE 1951b	9/15/1951	First-cycle waste line from 221-B to 241-BX-154 diversion box failed on 9/15/1951.
GE 1952b	11/1/1952	Plugged cascade line between 241-C-110 and 241-C-111. TBP waste re-routed to 241-T-107.
GE 1952a	12/1/1952	Cross-site line temporarily plugged 1,500 ft west of ER-151 diversion box.
GE 1952a	12/1/1952	Cascade line between 241-C-110 and 241-C-111 plugged. Waste being transferred by overland line.
GE 1953a	1/2/1953	Line from ER-151 to BX-109 and another line from ER-151 to 241-C were frozen. Lines unplugged.
GE 1953a	3/18/1953	Three days lost at T Plant due to plugged cascade line between 241-TX-105 and 241-TX-106.
GE 1953b	5/27/1953	Underground header connecting first-cycle bottoms 241-B-104 to 241-B-106 feed tank at waste evaporator failed.
GE 1953c	09/01/1953	Plugged cascade line between 241-C-110 and 241-C-111. Overland transfer line used.
GE 1953c	09/01/1953	Plug forced TBP waste from 241-T-101 to be pumped overland to 241-C-103.
GE 1953c	09/01/1953	Pumping necessary because of plugged cascade line between 241-C-101 and 241-C-102.
GE 1954b	01/20/1954	Partially plugged transfer line from REDOX tank D-8 to 241-U-110 because of gelatinous deposits. This was a new cross-country transfer line. Spare line was activated.
GE 1954a	02/01/1954	Plugged line prevented transfer of evaporator bottoms from 241-TX-117 to 241-T-108 until 2/26/1954 when evaporator operations resumed.
GE 1954c Maxfield 1979	12/20/1954	First-cycle waste line from 241-T-105 to 241-T-118 via the 241-T-152 and 241-T-153 diversion boxes failed, resulting in cave-in and run-off of solution (UN-216-W-5).
GE 1955b	12/20/1954	First-cycle waste line from 241-T failed, resulting in cave-in and run-off of solution.
GE 1955a	1/30/1956	Partially plugged line between REDOX tank D-8 and 241-S tank farm.
GE 1956c	1/30/1956	Failure of underground process line near 241-TX-154 diversion box.
GE 1956b	01/01/1956	All attempts to unplug metal waste line from the 241-TX-154 diversion box and 241-U-101 were unsuccessful.
GE 1956a	11/01/1956	Two waste lines plugged from REDOX tank D-8 to 241-SX diversion box. To date, attempts to unplug lines with high-pressure water, steam, and a 4% caustic solution have failed.
GE 1957b	12/01/1956	Five attempts made to unplug line from 241-S-151 to 241-SX diversion boxes with high-pressure steam, high-pressure water, and a 4% hot caustic solution under pressure. Preparations underway to use a reamer to bore through the waste plug.
GE 1957a	01/01/1957	Coating waste line to 241-C-104 plugged, necessitating transfer of coating waste to 241-C-111.
GE 1958a	01/10/1957	Emergency re-routing of waste because of plugged line. Jumpers changed in A-151 diversion box to re-route solution.
GE 1958b	02/07/1958	Attempts to remove plug unsuccessful. Waste re-routed to 241-SX-113. Jumper was removed and taken to 241-U for unplugging.

Table 7. Historical Pipeline Failures at the Hanford Site. (3 sheets)

Source	Date	Pipeline Plugs and Failures
GE 1962	10/01/1958	Of the two lines available for pumping non-boiling waste from 241-SX-111 to 241-TX, one was plugged and the other leaks. Waste was pumped to 241-U-102 and 241-U-103 instead.
McCullugh and Cartmell 1968	12/05/1962	Coating waste line from PUREX to 241-C-102 plugged. Line unplugged on 12/20/1962.
Neilson 1992	3/22/1965	Failure of coating waste line in a diversion box that drains to the 244-CR vault.
Neilson 1992	6/1/1965	REDOX coating waste line plugged. Plug was found in line between 241-S-151 diversion box and 241-S-107. Plug cleared on 7/7/1965.
Isochem 1966	9/3/1965	An attempt will be made to unplug the original REDOX tank D-8 routing that plugged in 1956.
Isochem 1966	08/01/1966	On two occasions, line between 241-TX-116 and 241-TX-117 was restricted if not plugged.
Maxfield 1979	7/1/1966	Failure of encased waste line from 202-A to the 241-A tank farm. Distorted sections of pipeline replaced.
Maxfield 1979	1/1/1968	Leakage in line from tank 9-2 in B Plant to 241-B-110 cave-in at 241-B-152 diversion box (UN-216-E-4).
Maxfield 1979	10/1/1969	Leak in transfer line from PUREX to 241-C-102. Approximately 36,000 gal leaked close to the 241-CR-151 diversion box (UN-216-E-9).
Maxfield 1979	12/1/1969	Leakage in transfer line V122 from 241-C-105 to B Plant. Approximately 2,600 gal leaked close to the 241-C-152 diversion box (UN-216-E-10).
ARHCO 1973	2/25/1971	Leak in process line 812 from AR vault to the 241-C tank farm (UN-216-E-14).
Maxfield 1979	11/01/1972	Inlet pipe plugged at 241-S-102. About 8,600 gal of waste spilled.
ARHCO 1976a	7/22/1972	Leak in process line R-13 from B Plant tank 18-1 to the 241-BX-154 diversion box (UN-216-E-13)
Rockwell 1978a	1/27/1976	Cross-site line V362 plugged as 241-S-107 waste was transferred to 241-B-109 when power was lost to transfer pump. Line was unplugged.
Rockwell 1980c	8/22/1978	Cross-site line V360 plugged as 241-S-107 waste was transferred to 214-BX-105 when power was lost to transfer pump. Line was unplugged.
Maxfield 1979	1/16/1980	Cross-site line plugged as terminal liquor from 241-S-107 was transferred to 241-BX-105. Inadequate dilution. Line was unplugged with water at 225 psig.

Reference information is provided in Section 11.0 of this document.

PUREX = plutonium-uranium extraction.
REDOX = reduction-oxidation.
TBP = tributyl phosphate.

Table 8. Historical Pipeline Pluggage Incidents at the Hanford Site.

Source	Date	Pipeline Pluggage
Apple 1946	3/29/1946	A tie line between the 241-T-152 and 241-U-152 diversion boxes plugged with coating waste and/or first-cycle waste.
GE 1946c	4/5/1946	First-cycle (and coating) waste line from T Plant plugged. Long length of tie line from T Plant to the U diversion box plugged. Plugging due to crystallization of sodium phosphate ($Na_2HPO_4 12H_2O$).
GE 1951a	2/1/1951	Cascade line from 241-BX-102 to 241-BX-103 plugged. Approximately 91,600 gal of metal waste overflowed from 241-BX-102.
GE 1952b	11/1/1952	Plugged cascade line between 241-C-110 and 241-C-111. TBP waste re-routed to 241-T-107.
GE 1952a	12/1/1952	Cascade line between 241-C-110 and 241-C-111 plugged. Waste being transferred by overland line.
GE 1953a	3/18/1953	Three days lost at T Plant due to plugged cascade line between 241-TX-105 and 241-TX-106.
GE 1953c	09/01/1953	Plugged cascade line between 241-C-110 and 241-C-111. Overland transfer line used.
GE 1953c	09/01/1953	Plug forced TBP waste from 241-T-101 to be pumped overland to 241-C-103.
GE 1953c	09/01/1953	Pumping necessary because of plugged cascade line between 241-C-101 and 241-C-102.
GE 1954b	01/20/1954	Partially plugged transfer line from REDOX tank D-8 to 241-U-110 because of gelatinous deposits. This was a new cross-country transfer line. Spare line was activated.
GE 1955b	1/30/1956	Partially plugged line between REDOX tank D-8 and 241-S tank farm.
GE 1956c	01/01/1956	All attempts to unplug metal waste line from the 214-TX-154 diversion box and 241-U-101 were unsuccessful.
GE 1956b	11/01/1956	Two waste lines plugged from REDOX tank D-8 to 241-SX diversion box. To date, attempts to unplug lines with high-pressure water, steam, and a 4% caustic solution have failed.
GE 1957b	01/01/1957	Coating waste line to 241-C-104 plugged, necessitating transfer of coating waste to 241-C-111.
GE 1957a	01/10/1957	Emergency re-routing of REDOX waste because of plugged line. Jumpers changed in 241-S-151 diversion box to re-route solution.
GE 1958b	10/01/1958	Of the two lines available for pumping non-boiling waste from 241-SX tank farm to 241-TX tank farm, one was plugged and the other leaks.
Neilson 1992	9/3/1965	An attempt was made to unplug the original REDOX tank D-8 routing that plugged in 1956.
Isochem 1966	08/01/1966	On two occasions, line between 241-TX-116 and 241-TX-117 was restricted if not plugged.
ARHCO 1973	11/01/1972	Inlet pipe plugged at 241-S-102. About 8,600 gal of waste spilled.

Reference information is provided in Section 11.0 of this document.

REDOX = reduction-oxidation.
TBP = tributyl phosphate.

6.0 ANALYSIS OF HISTORICAL PIPELINE PLUGGAGE DATA

The historical pipelines can be sorted into two categories: 1) those pipelines that were only temporarily plugged, and 2) those that were permanently plugged. Pipelines that were temporarily plugged were identified by using the waste transaction records to determine whether additional waste transfers had occurred after the lines were plugged. This approach was most successful for tanks with only one transfer line and no spares, but was less definitive for tanks with multiple waste transfer lines. The second category includes tanks where subsequent waste transfers did not occur after the pipelines were plugged.

The waste transaction records suggest that six of the pipelines in Table 8 were only temporarily plugged, including the following:

- Tie line between the 241-T-152 and 241-U-152 diversion boxes
- Cascade line between 241-TX-105 and 241-TX-106
- Blocked cascade line between 241-C-101 and 241-C-102
- Plugged cascade line between 241-TX-116 and 241-TX-117
- Coating waste transfer line to 241-C-104
- Blocked fill line to 241-S-102.

When the waste transfer lines plugged, certain measures were usually taken to clear them. Those measures included using high-pressure pumps and fire hoses, high-pressure steam injection nozzles, bicarbonate and sodium hydroxide chemical cleaning solutions, and in one case, a "reamer" (i.e., equipment that would travel through the pipeline and bore through the waste plug) to dislodge the plugs (GE 1956a, *Chemical Processing Department Monthly Report for December 1956*). These lines were often blocked by plugs that had developed in the diversion box jumpers. These jumpers were repeatedly flushed and in extreme cases, removed and taken to T Plant or U Plant for cleaning. There are also examples where new jumpers were fabricated to replace the ones that had failed. It appears that the plugged transfer lines were only rarely abandoned and only after a concerted effort to unplug the lines in the field. While the Hanford Site monthly reports often cite the initial pluggage problem, these reports rarely mention whether the plugged pipelines were cleared. Waste transaction records were therefore used to make this determination for transfer lines that could be clearly identified from the historical text.

The tie line between the 241-T-152 and 241-U-152 diversion boxes was plugged with coating waste and/or first-cycle waste in March 1946. This 3-in.-diameter stainless steel line was approximately 5,500 ft long. Laboratory studies suggest that this blockage was caused by sodium phosphate ($Na_2H(PO_4)$-$12H_2O$) crystals (Apple 1946, *Data Pertinent to the Plugged First Cycle Waste Tie Line (241-T to 241-U)*). Sodium phosphate is water soluble, and it is likely that this line would have been flushed and returned to service. The waste transaction records show that first-cycle wastes were routinely transferred from T Plant to 241-U-110 from the third quarter of 1946 through the second quarter of 1948 (Agnew 1997b, *Waste Status and Transaction Record Summary (WSTR) Rev.4, Vol. II of II NW, SE Spreadsheet, and Graphs*). From this data, it appears that this line was only temporarily clogged.

Several other lines were also temporarily blocked, including the cascade overflow lines from 241-TX-105 to 241-TX-106, from 241-C-101 to 241-C-102, and from 241-TX-116 to 241-TX-117. The waste transaction records show that large quantities of waste were transferred

from 241-TX-105 to 241-TX-106 after the cascade line was plugged in March 1953 (Agnew 1997b). Post-pluggage transfers are reported to have occurred between 241-C-101 and 241-C-102 and between 241-TX-116 and 241-TX-117 (Agnew 1997b). These records clearly suggest that the cascade overflow lines were cleared.

The waste transfer records also show that large volumes of coating wastes were transferred to 241-C-104 several months after the fill line was reportedly clogged (in January 1957). This tank also received a considerable volume of coating waste and other wastes from 1969 through 1976. The fill line for 241-S-102 was reportedly clogged with crystallized material in November 1973 (ARHCO 1973, *Surface Spill of Radioactive Liquid Waste*). This tank, however, was used as the main feed tank for the 242-S Evaporator until 1980 (Agnew 1997b). From this record, it appears that the fill lines to 241-C-104 and 241-S-102 were successfully cleared as well.

The historical waste transfer records suggest that some lines must have remained clogged, including the following:

- Cascade overflow line between 241-BX-102 and 241-BX-103
- Cascade overflow line from 241-C-110 to 241-C-111
- Metal waste fill line to 241-U-101
- REDOX waste fill line to 241-U-110
- Several other lines that were apparently clogged with REDOX wastes.

7.0 RECONCILIATION OF HISTORICAL AND CURRENT PIPELINE DATA

Table 2 provides a list of the 10 pipelines that are known to have been plugged since 1966. Table 8 provides a list of pipeline plugging incidents that were resulted in the line being temporarily or permanently plugged. The early pipelines that were permanently plugged include:

- Cascade overflow line between 241-BX-102 and 241-BX-103
- Cascade overflow line from 241-C-110 to 241-C-111
- Metal waste fill line to 241-U-101
- REDOX waste fill line to 241-U-110
- Several other lines that were apparently plugged with REDOX wastes.

These lines were not identified by unique identification numbers in the historical records; therefore it appears that duplicate pipelines have been identified in these records, especially those that were plugged with REDOX waste. This overlap was resolved by examining the detailed records for each pipeline, including the pipeline routings and waste transaction records for the wastes typically transported through different portions of the pipeline network.

The cascade overflow line between 241-BX-102 and 241-BX-103 was blocked in March 1951. This problem resulted in the overflow of approximately 346.7 kL (91,600 gal) of metal waste from 241-BX-102. While some waste is alleged to have been transferred from 241-BX-102 to 241-BX-103 during the metal waste recovery program in early 1954, other records show that large volumes of waste were pumped in the reverse direction (i.e., from 241-BX-103 to 241-BX 102) in 1968 and 1969 (Agnew 1997b). This waste transfer pathway suggests that cascade overflow line between these tanks was still blocked and because of this, a separate waste transfer pump was still required in 241-BX-102.

The 241-C-110 cascade overflow line was apparently clogged in late 1952. The waste transaction records show that these tanks were initially filled with first-cycle bismuth phosphate wastes, but these wastes were no longer being transferred from 241-C-110 to 241-C-111 after the overflow line was clogged (Agnew 1997b). This blockage may have occurred because tank 241-C-110 was over-filled with solids and solids-laden wastes were directly channeled to the cascade overflow line. Regardless of the reason, the waste transaction records suggest that this line was permanently clogged.

The metal waste transfer line to 241-U-101 was also clogged in late 1955. Several attempts were apparently made to clear this line, but these attempts were not successful (GE 1956c, *Monthly Report Hanford Atomic Products Operation for January 1956*). This line (V453) may be the same one that was previously identified in Oberg (1966) because both lines were reportedly routed to 241-U-101. If this identification is correct, line V453 must have been clogged with bismuth phosphate metal waste in 1955 and the plugged section extends from the 241-U-151 diversion box to 241-U-101. Other lines plugged with metal waste were typically cleared with high-pressure water pumps, with high-pressure steam or with a 10 wt% sodium bicarbonate solution (GE 1946a, *200-Area Monthly Production Report 25 March 1946 to 25 April 1946 Inclusive*; Finch 1955, *Tank Farms and Waste Evaporator Weekly Summary Process Unit Period 12/31/53 to 1/14/55*; Finch 1953, *Tank Farms and Waste Evaporator Weekly Summary Process Unit Period 1/23/53 to 12/31/53*).

The historical records also suggest that several waste transfer lines were blocked from the REDOX waste neutralization tank (tank D-8) to the downstream diversion boxes and waste storage tanks. These lines were apparently clogged with material that had precipitated from aluminum-rich REDOX wastes. Clogged REDOX lines were typically cleared with high-pressure water pumps and fire hoses, but occasionally the fire hoses failed and hot wastes were blown back into the REDOX operating galleries.

The REDOX waste transfer line to 241-U-110 was apparently blocked in January 1954. This line (V465) may be the same one that was previously identified by Oberg (1966) because both lines were routed to the same tank, 241-U-110. If this identification is correct, the blocked portion of this pipeline probably extends from the 241-U-153 diversion box to 241-U-110. Large quantities of REDOX waste and REDOX coating waste were transferred to this tank during the second quarter of 1957 (Agnew 1997b). If line V465 was thoroughly plugged, these transfers must have been routed through one of the spare waste transfer lines to this tank (V466 or V467) (GE 1954b, *Monthly Report Hanford Atomic Products Operation for January 1954*).

Other lines such as V392, V410, and V514 were also plugged (Oberg 1966). Line V514 was probably clogged with REDOX high-level waste because this line extends from the 240-S-151 diversion box to the 241-S-151 diversion box, the primary pathway for distributing REDOX waste to the 241-S and 241-SX tank farms (GE 1955b, *Monthly Report Hanford Atomic Products Operation for February 1955*; GE 1956b, *Chemical Processing Department Monthly Report for November 1956*).

Line V392 extends from the 241-TX-154 diversion box to the 241-TX-155 diversion box. Because of its location, this line may have been plugged with non-boiling, aged REDOX supernates from the 241-SX tank farm (especially those from 241-SX-107, 241-SX-113, and 241-SX-108). There were two major transfers of such waste to 241-TX-101 through the 241-TX-153 and 241-TX-155 diversion boxes. The first transfer included aged REDOX supernates from 241-SX-107, SX-113, and 241-SX-114, which were transferred to 241-SX-102 and then to 241-TX-101 (Agnew 1997b). The second transfer involved comparable REDOX waste from tank 241-SX-108 (Agnew 1997b).

Aged REDOX wastes were typically concentrated by a factor of 2.0 to 2.6 in the self-boiling tanks, such as 241-SX-107, 241-SX-113, and 241-SX-108 (Roberts 1966). This action not only increased the concentration of the soluble radionuclides, but also the concentration of aluminum hydroxide. Aluminum hydroxide is especially important in this context because aluminum hydroxide tends to form gelatinous deposits if the moisture content is high enough and if the free hydroxide concentration has been reduced by one of several processes. These processes include the gradual absorption of carbon dioxide from the atmosphere, radiolysis in the self-boiling tanks, and the dilution of the concentrated waste with water during the pipeline transfers of such waste. These processes may have led to gelatinous aluminum hydroxide deposits in this waste transfer line (V392).

Line V410 connects the 241-TX-155 diversion box to the 241-U-151 diversion box. Because of known waste transfers through this portion of the pipeline network, this line may have been clogged with a high temperature mixture of REDOX coating (CWR) waste and REDOX

high-level (R) waste from 241-S-107 (Agnew 1997b). This waste was transferred to 241-U-107 in 1957 and 1958 (three transfers). Although the exact pipeline routing is unknown, the 241-U-151, 241-U-152, and 241-U-153 diversion boxes served tanks in the 241-U farm, while the blocked section represented by line V410 extends from the 241-TX-155 diversion box to the 241-U-151 diversion box. These routings are consistent with the pipeline system that would have been involved in the transport of hot REDOX waste from 241-S-107 to 241-U-107. This waste is believed to have reached temperatures of 180 to 240°F in 241-S-107 (Mercier et al. 1981, *Survey of the Single-Shell Tank Thermal Histories*). While the specific data is lacking, this waste may have been concentrated by a factor of about 2.5 in 241-S-107. At this concentration, gelatinous aluminum hydroxide deposits may have formed in this pipeline, as well as in other lines transporting such wastes.

Line V412 also appears to have been utilized in the transfer of aged REDOX supernates from 241-SX-108 to 241-TY-101. This waste was initially transferred to 241-SX-103 in early 1967 and then to 241-TY-101 via the 241-U-151 and 241-TY-153 diversion boxes (Agnew 1997b). The records are not clear as to the likely concentration of this waste, but 241-SX-108 was a self-boiling tank, and there is some evidence that this waste may have been processed through the 242-T Evaporator (Agnew 1997b). Under these conditions, it would not be surprising if gelatinous aluminum hydroxide deposits also formed in this line (V412), as well in other plugged pipelines (V410, V465, and V514).

Line SL101 was apparently plugged before April 1981. This event roughly coincides to the time frame when partially neutralized REDOX waste was being transferred from the 242-S Evaporator to 241-U-107 via the 241-U-D diversion box. The waste transaction records show that these transfers mostly occurred in 1979 and in early 1980, well before line SL101 is reported to have plugged (Agnew 1997b). This pluggage incident could have been caused by residual waste or by the gradual buildup of aluminum hydroxide rich deposits in this line. This line was inspected with a video camera in 1999, but the blocked section was beyond the 50-ft reach of the video camera inserted into the 241-U-D diversion box (Elsen 1999).

Line SN216 was plugged in late 2001 or in early 2002 because of deposits that gradually accumulated in this line (Barton 2002, "Unplugging U Farm Transfer Line"). This line was being used to support the saltwell pumping campaign for 241-U-107. It was believed at the time that this problem was caused by precipitation of aluminum hydroxide as the saltwell liquid was being diluted with fresh water during the saltwell pumping campaign (Barton 2002). A video camera inspection revealed that this line was blocked about 14 ft from the 241-U-D diversion box (Elsen 1999).

Table 9 provides a consolidated list of the wastes that are thought to have been involved in these pipeline pluggage incidents.

Table 9. Predicted Waste Types in Plugged Pipelines.

Pipeline	Tank Farm (241-)	Predicted Waste Types
SL101	S and U	Partially neutralized 242-S Evaporator waste being transferred to 241-U-107
SN216	S and U	241-U-107 saltwell liquid
V392	TX	Aged REDOX supernate from 241-SX tank farm being transferred to 241-TX-101
V410	TX and U	Concentrated REDOX waste and REDOX coating waste from 241-S-107
V412	TX and TY	Aged REDOX supernate from 241-SX-108, which was concentrated in the 242-T Evaporator
V453	U	Metal waste being transferred to 241-U-101
V465	U	REDOX high-level waste from 202-S Evaporator transferred to 241-U-110
V514	S	REDOX high-level waste from 202-S Evaporator
Cascade line from 241-BX-102 to 241-BX-103	BX	Metal waste being transferred from 241-BX-102 to 241-BX-103
Cascade line from 241-C-110 to 241-C-111	C	First-cycle waste being transferred from 241-C-110 to 241-C-111

REDOX = reduction-oxidation.

8.0 DEVELOPMENT OF WASTE COMPOSITION PROFILES FOR THE PLUGGED PIPELINES

The HDW model has been extensively used to determine the concentration of some chemicals and most radionuclides in the SSTs and double-shell tanks at the Hanford Site (Kupfer et al. 1999; Agnew 1997a; Place and Higley 2004). This model also provides waste composition profiles for most waste types, including those implicitly involved with the pipeline pluggage incidents. The HDW model waste composition profiles are listed in Appendix B, Tables B-1 through B-4 of Place and Higley (2004). These profiles were used, together with the information in Table 9, to develop waste composition estimates for the residual wastes in the plugged pipelines. Some of this data is presented in Tables 10 and 11, which list the projected solids and liquid waste compositions, respectively for standard wastes in the plugged pipelines. The nomenclature used in Tables 10 and 11 is as follows: MW2 refers to bismuth phosphate metal waste produced from 1950 to 1956, 1C2 refers to bismuth phosphate first-cycle waste produced from 1950 to 1956, R1 refers to REDOX high-level waste produced from 1952 to 1958, and CWR1 refers to REDOX coating waste produced from 1952 to 1960 (Agnew 1997a).

Each waste type is represented by two vectors, one for solids and the other for liquid. The solids vectors in Table 10 represent the composition of the solids that likely settled in the first waste receiver tank, while the liquid vectors in Table 11 represent the composition of the liquids that overflowed from the first tank or were pumped from this tank to other storage tanks in the tank farms.

The original waste compositions can be reproduced by combining the solids and liquid vectors in the correct ratio. This ratio can be determined by calculating the material balance for a common analyte, based on the known concentration of this analyte in the published flowsheet for each fuel separation process (Schneider 1951, *Flow Sheets and Flow Diagrams of Precipitation Separations Process*; Merrill and Stevenson 1955, *REDOX Chemical Flowsheet HW No. 5*). The REDOX flowsheet, for example, can be used to calculate the correct ratios for reconstituting the R waste or CWR waste from the solids and liquid vectors for these wastes. This approach was used to estimate the composition of the REDOX waste trapped in line V465, metal waste in line V453 and in the 241-BX-102 cascade overflow line, and first-cycle waste in the 241-C-110 cascade overflow line. These four wastes are unique in that the liquids were not separated or concentrated before these wastes were transported through one of the pipeline systems that plugged. Aluminum was chosen as the common element for reconstituting the composition of the REDOX waste that plugged line V465, while phosphate was chosen as the common analyte for reconstituting the MW2 and 1C2 wastes that plugged line V453 and the 241-BX-102 and 241-C-110 cascade overflow lines.

The following equation was used to compute the volume fraction of R1 solids in the R1 waste that clogged line V465:

$$X = \textit{volume fraction of R1 solids} \qquad \text{Eq.1}$$

$$1\text{-}X = \textit{volume fraction of R1 liquid}$$

Table 10. Hanford Defined Waste Model Solids Waste Composition Profiles. (2 sheets)

Analyte	Units	Waste Type			
		MW2 Solids	1C2 Solids	R1 Solids	CWR1 Solids
Al	µg/g	0.00E+00	8.45E+03	1.12E+05	1.60E+05
Bi	µg/g	5.23E+00	1.23E+04	0.00E+00	0.00E+00
Ca	µg/g	2.65E+03	3.04E+03	7.74E+03	4.51E+03
Cl	µg/g	1.01E+01	7.11E+02	1.35E+03	1.65E+02
TIC as CO_3	µg/g	3.49E+04	4.55E+03	1.16E+04	6.76E+03
Cr	µg/g	1.45E+01	1.55E+02	4.05E+04	6.98E+01
F	µg/g	0.00E+00	1.62E+03	0.00E+00	0.00E+00
Fe	µg/g	3.61E+03	1.37E+04	3.30E+04	5.80E+03
Hg	µg/g	4.50E+01	1.05E+01	1.99E+01	0.00E+00
K	µg/g	2.41E+00	1.71E+02	4.18E+02	3.96E+01
La	µg/g	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn	µg/g	0.00E+00	0.00E+00	3.80E+03	0.00E+00
Na	µg/g	8.19E+04	1.08E+05	5.38E+04	9.57E+04
Ni	µg/g	8.21E+00	4.31E+01	1.72E+03	3.94E+01
NO_2	µg/g	3.93E+02	1.12E+03	5.53E+04	2.86E+04
NO_3	µg/g	4.72E+02	4.63E+04	2.88E+02	2.40E+04
Free OH	µg/g	—	—	—	—
Pb	µg/g	0.00E+00	0.00E+00	0.00E+00	1.12E+04
PO_4	µg/g	5.04E+04	1.10E+05	0.00E+00	0.00E+00
Si	µg/g	9.82E+00	6.24E+03	1.69E+03	4.40E+03
SO_4	µg/g	4.43E+04	3.07E+03	7.40E+02	3.90E+02
Sr	µg/g	1.82E+00	3.79E-03	1.51E+01	5.53E-03
Th	µg/g	—	—	—	—
TOC	µg/g	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U Total	µg/g	2.55E+05	1.02E+03	7.08E+03	6.61E+03
Zr	µg/g	0.00E+00	3.12E+01	0.00E+00	0.00E+00
H-3	µCi/g	2.03E-03	2.64E-03	1.10E-02	6.65E-02
C-14	µCi/g	4.14E-04	3.50E-05	6.03E-04	7.30E-04
Ni-59	µCi/g	1.08E-05	1.15E-05	2.85E-03	8.78E-04
Co-60	µCi/g	3.78E-05	1.38E-04	8.14E-04	4.03E-03
Ni-63	µCi/g	9.50E-04	1.59E-03	2.57E-01	8.56E-02
Se-79	µCi/g	1.87E-06	1.15E-06	2.79E-05	3.08E-07
Sr-90	µCi/g	8.16E+01	1.69E-01	7.78E+02	2.84E-01
Y-90	µCi/g	8.16E+01	1.69E-01	7.79E+02	2.85E-01
Zr-93	µCi/g	5.00E-07	1.43E-03	1.67E-03	1.84E-05
Nb-93m	µCi/g	4.38E-07	1.26E-03	1.44E-03	1.58E-05
Tc-99	µCi/g	9.04E-04	8.76E-05	1.06E-02	1.34E-04
Ru-106	µCi/g	7.94E-16	5.71E-13	2.23E-11	5.49E-13
Cd-113m	µCi/g	6.16E-05	6.99E-05	1.15E-03	8.47E-04

Table 10. Hanford Defined Waste Model Solids Waste Composition Profiles. (2 sheets)

Analyte	Units	Waste Type			
		MW2 Solids	1C2 Solids	R1 Solids	CWR1 Solids
Sb-125	µCi/g	2.16E-06	2.01E-06	7.10E-05	8.35E-06
Sn-126	µCi/g	7.19E-06	4.49E-06	1.13E-04	1.24E-06
I-129	µCi/g	1.03E-06	7.65E-07	1.70E-05	1.89E-07
Cs-134	µCi/g	2.47E-08	2.34E-09	1.58E-06	2.62E-08
Cs-137	µCi/g	2.07E+00	1.98E-01	3.00E+01	3.36E-01
Ba-137m	µCi/g	1.95E+00	1.87E-01	2.83E+01	3.17E-01
Sm-151	µCi/g	6.86E-02	9.18E-02	1.17E+00	1.29E-02
Eu-152	µCi/g	3.28E-06	5.03E-06	1.19E-04	1.45E-06
Eu-154	µCi/g	2.41E-04	3.52E-04	8.03E-03	9.63E-05
Eu-155	µCi/g	1.32E-04	1.60E-04	3.30E-03	4.00E-05
Ra-226	µCi/g	1.01E-07	3.79E-09	1.60E-09	5.38E-10
Ac-227	µCi/g	2.73E-07	1.15E-08	6.88E-09	2.56E-09
Ra-228	µCi/g	5.97E-13	2.46E-14	9.01E-15	4.97E-15
Th-229	µCi/g	1.90E-12	1.71E-11	3.38E-11	7.41E-13
Pa-231	µCi/g	2.92E-10	2.51E-07	1.02E-08	5.43E-09
Th-232	µCi/g	1.62E-14	1.44E-13	9.68E-15	6.09E-15
U-232	µCi/g	1.27E-06	6.03E-09	9.39E-08	8.53E-08
U-233	µCi/g	9.96E-08	4.56E-10	4.62E-07	4.36E-09
U-234	µCi/g	8.32E-02	3.33E-04	2.31E-03	2.26E-03
U-235	µCi/g	3.68E-03	1.47E-05	9.93E-05	9.60E-05
U-236	µCi/g	1.13E-03	4.94E-06	4.77E-05	4.63E-05
Np-237	µCi/g	5.20E-06	2.02E-06	7.71E-05	8.90E-07
Pu-238	µCi/g	5.02E-05	8.93E-04	5.43E-03	3.91E-03
U-238	µCi/g	8.50E-02	3.40E-04	2.36E-03	2.20E-03
Pu-239	µCi/g	5.66E-03	8.78E-02	2.86E-01	2.46E-01
Pu-240	µCi/g	7.18E-04	1.24E-02	5.55E-02	4.67E-02
Am-241	µCi/g	3.64E-04	2.25E-04	1.45E-01	2.76E-03
Pu-241	µCi/g	1.58E-03	2.87E-02	1.93E-01	1.72E-01
Cm-242	µCi/g	9.70E-08	4.46E-08	4.35E-06	5.15E-08
Pu-242	µCi/g	1.15E-08	2.17E-07	1.69E-06	1.39E-06
Am-243	µCi/g	5.64E-08	2.59E-08	5.28E-05	3.01E-08
Cm-243	µCi/g	1.17E-09	5.42E-10	7.79E-08	9.46E-10
Cm-244	µCi/g	2.75E-08	1.27E-08	1.92E-06	2.31E-08
Density	g/mL	1.85E+00	1.38E+00	1.72E+00	1.60E+00
Water	wt%	4.14E+01	6.51E+01	4.08E+01	3.14E+01

1C2 = bismuth phosphate first-cycle metal waste produced from 1950 to 1956.
CWR1 = REDOX coating waste produced from 1952 to 1960.
MW2 = bismuth phosphate metal waste produced from 1950 to 1956.
R1 = REDOX high-level waste produced form 1952 to 1958.

Table 11. Hanford Defined Waste Model Liquid Waste Composition Profiles. (2 sheets)

Analyte	Units	Waste Type			
		MW2 Liquid	1C2 Liquid	R1 Liquid	CWR1 Liquid
Al	µg/mL	0.00E+00	0.00E+00	2.29E+04	3.62E+04
Bi	µg/mL	6.66E+01	9.60E+01	0.00E+00	0.00E+00
Ca	µg/mL	1.50E+02	1.50E+02	1.50E+02	1.50E+02
Cl	µg/mL	1.28E+02	1.64E+03	3.39E+03	3.83E+02
TIC as CO3	µg/mL	3.76E+04	2.25E+02	2.25E+02	2.25E+02
Cr	µg/mL	1.85E+02	3.59E+02	2.88E+03	1.62E+02
F	µg/mL	0.00E+00	3.75E+03	0.00E+00	0.00E+00
Fe	µg/mL	1.05E+02	1.05E+02	1.05E+02	1.05E+02
Hg	µg/mL	3.24E-01	3.24E-01	3.24E-01	0.00E+00
K	µg/mL	3.08E+01	3.94E+02	1.05E+03	9.20E+01
La	µg/mL	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn	µg/mL	0.00E+00	0.00E+00	3.05E+01	0.00E+00
Na	µg/mL	4.40E+04	5.64E+04	1.28E+05	8.58E+04
Ni	µg/mL	1.05E+02	9.96E+01	1.07E+02	9.15E+01
NO_2	µg/mL	1.06E+03	2.42E+03	3.54E+04	6.63E+04
NO_3	µg/mL	1.13E+04	1.07E+05	1.40E+05	5.59E+04
Free OH	µg/mL	—	—	—	—
Pb	µg/mL	0.00E+00	0.00E+00	0.00E+00	1.49E+02
PO_4	µg/mL	6.70E+03	6.71E+03	0.00E+00	0.00E+00
Si	µg/mL	1.25E+02	2.96E+02	2.96E+02	2.96E+02
SO_4	µg/mL	1.19E+04	7.09E+03	1.85E+03	9.06E+02
Sr	µg/mL	5.55E-02	8.75E-03	4.81E-02	1.28E-02
Th	µg/mL	—	3.02E-06	—	—
TOC	µg/mL	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U Total	µg/mL	9.52E+02	3.10E+01	3.10E+01	3.10E+01
Zr	µg/mL	0.00E+00	2.69E+01	0.00E+00	0.00E+00
H-3	µCi/mL	2.59E-02	6.10E-03	2.76E-02	1.54E-01
C-14	µCi/mL	4.31E-04	8.09E-05	1.51E-03	1.69E-03
Ni-59	µCi/mL	1.37E-04	2.66E-05	1.77E-04	2.04E-03
Co-60	µCi/mL	4.82E-04	3.18E-04	2.04E-03	9.37E-03
Ni-63	µCi/mL	1.21E-02	3.68E-03	1.60E-02	1.99E-01
Se-79	µCi/mL	2.38E-05	2.66E-06	6.98E-05	7.15E-07
Sr-90	µCi/mL	2.48E+00	3.91E-01	2.48E+00	6.61E-01
Y-90	µCi/mL	2.48E+00	3.91E-01	2.48E+00	6.61E-01
Zr-93	µCi/mL	6.37E-06	1.23E-03	4.18E-03	4.28E-05
Nb-93m	µCi/mL	5.59E-06	1.09E-03	3.59E-03	3.66E-05
Tc-99	µCi/mL	1.15E-02	2.02E-04	2.65E-02	3.11E-04
Ru-106	µCi/mL	1.01E-14	1.32E-12	5.57E-11	1.27E-12
Cd-113m	µCi/mL	7.85E-04	1.61E-04	2.87E-03	1.97E-03

Table 11. Hanford Defined Waste Model Liquid Waste Composition Profiles. (2 sheets)

Analyte	Units	Waste Type			
		MW2 Liquid	1C2 Liquid	R1 Liquid	CWR1 Liquid
Sb-125	µCi/mL	2.75E-05	4.64E-06	1.78E-04	1.94E-05
Sn-126	µCi/mL	9.17E-05	1.04E-05	2.83E-04	2.89E-06
I-129	µCi/mL	1.31E-05	1.77E-06	4.24E-05	4.39E-07
Cs-134	µCi/mL	3.14E-07	5.42E-09	3.96E-06	6.09E-08
Cs-137	µCi/mL	2.64E+01	4.58E-01	7.50E+01	7.79E-01
Ba-137m	µCi/mL	2.49E+01	4.32E-01	7.08E+01	7.36E-01
Sm-151	µCi/mL	8.75E-01	2.12E-01	2.93E+00	3.00E-02
Eu-152	µCi/mL	4.18E-05	1.16E-05	2.97E-04	3.36E-06
Eu-154	µCi/mL	3.07E-03	8.12E-04	2.01E-02	2.24E-04
Eu-155	µCi/mL	1.69E-03	3.69E-04	8.25E-03	9.29E-05
Ra-226	µCi/mL	6.20E-08	8.76E-09	4.01E-09	1.25E-09
Ac-227	µCi/mL	3.60E-07	2.65E-08	1.72E-08	5.94E-09
Ra-228	µCi/mL	3.66E-13	5.69E-14	2.25E-14	1.15E-14
Th-229	µCi/mL	2.42E-11	3.94E-11	8.46E-11	1.72E-12
Pa-231	µCi/mL	3.73E-09	5.80E-07	2.55E-08	1.26E-08
Th-232	µCi/mL	2.06E-13	3.33E-13	2.42E-14	1.41E-14
U-232	µCi/mL	4.74E-09	1.84E-10	4.11E-10	4.01E-10
U-233	µCi/mL	3.72E-10	1.39E-11	2.02E-09	2.05E-11
U-234	µCi/mL	3.11E-04	1.01E-05	1.01E-05	1.06E-05
U-235	µCi/mL	1.38E-05	4.46E-07	4.35E-07	4.51E-07
U-236	µCi/mL	4.23E-06	1.50E-07	2.09E-07	2.17E-07
Np-237	µCi/mL	6.62E-05	4.65E-06	1.93E-04	2.07E-06
Pu-238	µCi/mL	4.61E-05	5.27E-05	9.69E-05	8.13E-05
U-238	µCi/mL	3.18E-04	1.03E-05	1.03E-05	1.04E-05
Pu-239	µCi/mL	5.20E-03	5.18E-03	5.10E-03	5.11E-03
Pu-240	µCi/mL	6.59E-04	7.34E-04	9.91E-04	9.71E-04
Am-241	µCi/mL	4.64E-03	5.20E-04	6.73E-03	6.42E-03
Pu-241	µCi/mL	1.45E-03	1.69E-03	3.45E-03	3.57E-03
Cm-242	µCi/mL	1.24E-06	1.03E-07	1.09E-05	1.20E-07
Pu-242	µCi/mL	1.05E-08	1.28E-08	3.01E-08	2.88E-08
Am-243	µCi/mL	7.18E-07	5.98E-08	2.46E-06	6.98E-08
Cm-243	µCi/mL	1.49E-08	1.25E-09	1.95E-07	2.20E-09
Cm-244	µCi/mL	3.51E-07	2.94E-08	4.81E-06	5.37E-08
Density	g/mL	1.10E+00	1.13E+00	1.26E+00	1.16E+00
wt% Water	wt%	8.96E+01	8.32E+01	7.01E+01	7.50E+01

1C2 = bismuth phosphate first-cycle metal waste produced from 1950 to 1956.
CWR1 = REDOX coating waste produced from 1952 to 1960.
MW2 = bismuth phosphate metal waste produced from 1950 to 1956.
R1 = REDOX high-level waste produced form 1952 to 1958.

The neutralized REDOX high-level (R1) waste contained 1.29 g-moles/L of aluminum based on the REDOX #5 flowsheet (Merrill and Stevenson 1955).

Additional data: aluminum concentration in R1 solids =112,000 µg/g
aluminum concentration in R1 liquid = 22,900 µg/mL
bulk density of R1 solids = 1.77 g/ mL
specific gravity of R1 liquid = 1.26 g/ mL.

Mass balance for aluminum based on one liter of reconstituted R1 waste:

$$1.29 \text{ g-moles/L} * 26.98 \text{ g/g-mole} = 1.77 \text{ g/mL} * 112{,}000 \ \mu\text{g/g} * (X/1{,}000) + 1.26 \text{ g/mL} * (22{,}900 \ \mu\text{g/mL}/ 1.26 \text{ g/mL}) * ((1-X)/1{,}000)$$

Calculated volume fraction of R1 solids in R1 waste:

R1 solids volume fraction = 0.068
R1 liquid volume fraction = 0.932.

Table 12 summarizes the relevant data and calculated volume fractions of R1 solids in the reconstituted R1 waste, MW2 solids in the reconstituted MW2 waste and 1C2 solids in the reconstituted 1C2 waste.

Table 12. Predicted Fraction of R1 Solids, MW2 Solids, and 1C2 Solids in Reconstituted R1, MW2, and 1C2 Wastes.

Waste	Analyte	Concentration	Units	Density	Units	Calculated Volume Fraction in Reconstituted Waste
Neutralized REDOX (R1) waste	Al	1.29	g-mole/L			
R1 solids	Al	112,000	µg/g	1.77	g/mL	0.068
R1 liquid	Al	22,900	µg/mL	1.26	g/mL	0.932
Metal waste	PO_4	0.265	g-mole/L			
MW2 solids	PO_4	50,400	µg/g	1.85	g/mL	0.213
MW2 liquid	PO_4	6,700	µg/mL	1.10	g/mL	0.787
First-cycle waste	PO_4	0.265	g-mole/L			
1C2 solids	PO_4	110,000	µg/g	1.38	g/mL	0.134
1C2 liquid	PO_4	6,710	µg/mL	1.13	g/mL	0.866

1C2 = bismuth phosphate first-cycle metal waste produced from 1950 to 1956.
MW2 = bismuth phosphate metal waste produced from 1950 to 1956.
R1 = REDOX high-level waste produced form 1952 to 1958.
REDOX = reduction-oxidation.

9.0 RESIDUAL WASTE INVENTORIES IN PLUGGED PIPELINES

Residual waste inventory predictions for the plugged pipelines are based on data in Tables 9, 10, 11, and 12. The residual wastes in each line are listed in Table 9, while Tables 10 and 11 list the HDW model solids and liquid composition vectors, respectively, for these wastes. Table 12 provides the data needed to reconstitute the composition of some wastes (e.g., R1, MW2, and 1C2 wastes) trapped in several of the plugged pipelines. Liquid wastes such as those listed in Table 11 were often concentrated in one of the self-boiling tanks or waste evaporators. Based on the historical records, it appears that the wastes in tanks 241-SX-107 and 241-SX-108 were typically concentrated by a factor of 2.0 to 2.6 (Roberts 1966). For the partially neutralized REDOX waste, the overall concentration factor was 3.9, based on an average composition of the final waste solutions (Reynolds 1982, *242-S Evaporator Crystallizer Third Partial Neutralization Campaign*) and the aluminum concentration for R1 liquid waste in Table 11. These concentration factors were incorporated into the residual waste inventory estimates for the pipelines that contained these wastes.

Table 13 summarize the residual waste inventory predictions for lines SL101, SN216, V392, V410, V412, V453, V465, V514, and the plugged cascade lines from 241-BX-102 and 241-C-110. All radionuclides have been decayed to January 1, 2001. Waste inventory predictions for line SN216 are based on the current saltwell liquid composition in 241-U-107. The composition for S2SltSlry (S2 salt slurry) liquid was taken from the best basis calculation detail report for 241-U-107 in the Tank Waste Information Network System (TWINS) database (as of April 1, 2004), with all radionuclides decayed to January 1, 2004 (TWINS 2004).

Table 13. Residual Waste Inventories in Plugged Pipelines. (3 sheets)

Waste Parameters		Plugged Pipeline									
		SL101	SN216	V392	V410	V412	V453	V465	V514	241-BX-102 Cascade	241-C-110 Cascade
Residual Waste Volume (l)		861	1,988	4,086	5,096	1,711	614	153	2,492	28	28
Waste Type		Partially neutralized REDOX supernate	241-U-107 saltwell liquid	Concentrated REDOX supernate	50% REDOX and 50% coating waste supernate	Concentrated REDOX supernate	Metal waste	REDOX waste	REDOX waste	Metal waste	First-cycle waste
Solids Volume Fraction		0	0	0	0	0	0.213	0.068	0.068	0.213	0.134
Liquid Volume Fraction		1	1	1	1	1	0.787	0.932	0.932	0.787	0.866
Waste Concentration Factor		3.9	1	2.6	2.6	2.6	1	1	1	1	1
Analyte	Units										
Al	kg	7.69E+01	8.14E+01	2.43E+02	3.91E+02	1.02E+02	0.00E+00	5.26E+00	8.57E+01	0.00E+00	4.36E-02
Bi	kg	0.00E+00	4.66E-02	0.00E+00	0.00E+00	0.00E+00	3.34E-02	0.00E+00	0.00E+00	1.53E-03	6.58E-02
Ca	kg	5.05E-01	1.25E-01	1.60E+00	1.99E+00	6.68E-01	7.15E-01	1.60E-01	2.60E+00	3.26E-02	1.97E-02
Cl	kg	1.14E+01	2.10E+01	3.60E+01	2.50E+01	1.51E+01	6.44E-02	5.07E-01	8.27E+00	2.94E-03	4.80E-02
TIC as CO_3	kg	7.56E-01	3.20E+01	2.39E+00	2.98E+00	1.00E+00	2.66E+01	2.39E-01	3.89E+00	1.21E+00	2.96E-02
Cr	kg	9.67E+00	1.26E-01	3.06E+01	2.01E+01	1.28E+01	9.31E-02	1.13E+00	1.85E+01	4.25E-03	1.05E-02
F	kg	0.00E+00	2.88E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-01
Fe	kg	3.52E-01	1.22E-02	1.11E+00	1.39E+00	4.65E-01	9.23E-01	6.05E-01	9.86E+00	4.21E-02	7.33E-02
Hg	kg	1.09E-03	5.23E-04	3.44E-03	2.15E-03	1.44E-03	1.10E-02	4.02E-04	6.54E-03	5.04E-04	6.27E-05
K	kg	3.51E+00	6.82E+00	1.11E+01	7.54E+00	4.65E+00	1.54E-02	1.57E-01	2.55E+00	7.04E-04	1.15E-02
La	kg	0.00E+00	2.37E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn	kg	1.02E-01	9.31E-03	3.24E-01	2.02E-01	1.36E-01	0.00E+00	7.22E-02	1.18E+00	0.00E+00	0.00E+00
Na	kg	4.30E+02	4.07E+02	1.36E+03	1.42E+03	5.70E+02	4.11E+01	1.92E+01	3.13E+02	1.87E+00	2.08E+00
Ni	kg	3.59E-01	3.05E-02	1.14E+00	1.32E+00	4.76E-01	5.25E-02	4.59E-02	7.48E-01	2.40E-03	2.91E-03
NO_2	kg	1.19E+02	2.54E+02	3.76E+02	6.73E+02	1.57E+02	6.06E-01	6.03E+00	9.83E+01	2.76E-02	7.13E-02
NO_3	kg	4.69E+02	2.82E+02	1.48E+03	1.30E+03	6.21E+02	5.59E+00	1.99E+01	3.24E+02	2.55E-01	3.13E+00
Free OH	kg	0.00E+00	1.52E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb	kg	0.00E+00	2.88E-02	0.00E+00	9.89E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PO_4	kg	0.00E+00	8.07E+00	0.00E+00	0.00E+00	0.00E+00	1.54E+01	0.00E+00	0.00E+00	7.05E-01	7.46E-01
Si	kg	9.94E-01	8.27E-02	3.14E+00	3.92E+00	1.32E+00	6.28E-02	7.24E-02	1.18E+00	2.87E-03	4.02E-02
SO_4	kg	6.22E+00	8.67E+00	1.97E+01	1.83E+01	8.23E+00	1.65E+01	2.77E-01	4.52E+00	7.52E-01	2.07E-01

Table 13. Residual Waste Inventories in Plugged Pipelines. (3 sheets)

Waste Parameters		Plugged Pipeline									
		SL101	SN216	V392	V410	V412	V453	V465	V514	241-BX-102 Cascade	241-C-110 Cascade
Analyte	Units										
Sr	kg	1.62E-04	3.12E-04	5.12E-04	4.04E-04	2.14E-04	4.69E-04	2.77E-04	4.51E-03	2.14E-05	2.56E-07
Th	kg	0.00E+00	9.03E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOC	kg	0.00E+00	1.25E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U Total	kg	1.04E-01	4.30E-03	3.29E-01	4.11E-01	1.38E-01	6.21E+01	1.31E-01	2.13E+00	2.83E+00	6.09E-03
Zr	kg	0.00E+00	1.70E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.86E-04
H-3	Ci	9.28E-02	2.12E-03	2.94E-01	1.21E+00	1.23E-01	1.30E-02	4.14E-03	6.74E-02	5.93E-04	1.78E-04
C-14	Ci	5.07E-03	1.93E-03	1.60E-02	2.12E-02	6.71E-03	3.08E-04	2.26E-04	3.68E-03	1.41E-05	2.37E-06
Ni-59	Ci	5.96E-04	1.35E-03	1.89E-03	1.47E-02	7.89E-04	6.88E-05	7.62E-05	1.24E-03	3.14E-06	7.78E-07
Co-60	Ci	6.84E-03	6.63E-03	2.16E-02	7.56E-02	9.06E-03	2.42E-04	3.05E-04	4.97E-03	1.10E-05	9.30E-06
Ni-63	Ci	5.38E-02	1.26E-01	1.70E-01	1.42E+00	7.12E-02	6.08E-03	6.87E-03	1.12E-01	2.77E-04	1.08E-04
Se-79	Ci	2.35E-04	2.95E-03	7.42E-04	4.67E-04	3.11E-04	1.20E-05	1.05E-05	1.70E-04	5.45E-07	7.78E-08
Sr-90	Ci	8.33E+00	8.84E-01	2.63E+01	2.08E+01	1.10E+01	2.09E+01	1.43E+01	2.32E+02	9.56E-01	1.14E-02
Y-90	Ci	8.33E+00	8.84E-01	2.63E+01	2.08E+01	1.10E+01	2.10E+01	1.43E+01	2.32E+02	9.56E-01	1.14E-02
Zr-93	Ci	1.40E-02	6.21E-02	4.44E-02	2.80E-02	1.86E-02	3.20E-06	6.26E-04	1.02E-02	1.46E-07	4.07E-05
Nb-93m	Ci	1.21E-02	5.17E-02	3.82E-02	2.40E-02	1.60E-02	2.80E-06	5.38E-04	8.77E-03	1.28E-07	3.58E-05
Tc-99	Ci	8.90E-02	6.93E-01	2.82E-01	1.78E-01	1.18E-01	5.78E-03	3.97E-03	6.46E-02	2.64E-04	5.92E-06
Ru-106	Ci	1.87E-10	1.07E-08	5.91E-10	3.77E-10	2.48E-10	5.08E-15	8.34E-12	1.36E-10	2.32E-16	3.86E-14
Cd-113m	Ci	9.64E-03	5.60E-02	3.05E-02	3.21E-02	1.28E-02	3.94E-04	4.30E-04	7.00E-03	1.80E-05	4.72E-06
Sb-125	Ci	5.97E-04	3.84E-03	1.89E-03	1.31E-03	7.90E-04	1.38E-05	2.66E-05	4.33E-04	6.31E-07	1.36E-07
Sn-126	Ci	9.50E-04	1.30E-02	3.00E-03	1.89E-03	1.26E-03	4.60E-05	4.23E-05	6.90E-04	2.10E-06	3.03E-07
I-129	Ci	1.43E-04	5.85E-04	4.51E-04	2.84E-04	1.89E-04	6.60E-06	6.35E-06	1.04E-04	3.01E-07	5.17E-08
Cs-134	Ci	1.33E-05	1.93E-04	4.21E-05	2.66E-05	1.76E-05	1.58E-07	5.93E-07	9.66E-06	7.20E-09	1.58E-10
Cs-137	Ci	2.52E+02	6.80E+02	7.96E+02	5.02E+02	3.33E+02	1.32E+01	1.12E+01	1.83E+02	6.04E-01	1.34E-02
Ba-137m	Ci	2.38E+02	6.40E+02	7.52E+02	4.74E+02	3.15E+02	1.25E+01	1.06E+01	1.73E+02	5.70E-01	1.26E-02
Sm-151	Ci	9.86E+00	7.86E+00	3.12E+01	1.96E+01	1.31E+01	4.39E-01	4.39E-01	7.16E+00	2.00E-02	6.20E-03
Eu-152	Ci	9.99E-04	8.10E-04	3.16E-03	1.99E-03	1.32E-03	2.10E-05	4.45E-05	7.25E-04	9.57E-07	3.40E-07
Eu-154	Ci	6.75E-02	6.57E-02	2.13E-01	1.35E-01	8.94E-02	1.54E-03	3.01E-03	4.90E-02	7.03E-05	2.38E-05

Table 13. Residual Waste Inventories in Plugged Pipelines. (3 sheets)

Waste Parameters		Plugged Pipeline									
		SL101	SN216	V392	V410	V412	V453	V465	V514	241-BX-102 Cascade	241-C-110 Cascade
Analyte	Units										
Eu-155	Ci	2.77E-02	2.04E-02	8.77E-02	5.53E-02	3.67E-02	8.47E-04	1.24E-03	2.01E-02	3.86E-05	1.08E-05
Ra-226	Ci	1.35E-08	9.47E-08	4.26E-08	3.48E-08	1.78E-08	5.44E-08	6.00E-10	9.78E-09	2.48E-09	2.56E-10
Ac-227	Ci	5.78E-08	3.28E-06	1.83E-07	1.53E-07	7.65E-08	2.40E-07	2.58E-09	4.20E-08	1.09E-08	7.76E-10
Ra-228	Ci	7.57E-14	8.35E-06	2.39E-13	2.26E-13	1.00E-13	3.21E-13	3.37E-15	5.50E-14	1.47E-14	1.66E-15
Th-229	Ci	2.84E-10	2.86E-08	8.99E-10	5.72E-10	3.76E-10	1.21E-11	1.27E-11	2.06E-10	5.54E-13	1.15E-12
Pa-231	Ci	8.58E-08	3.03E-05	2.71E-07	2.53E-07	1.14E-07	1.87E-09	3.82E-09	6.23E-08	8.54E-11	1.70E-08
Th-232	Ci	8.13E-14	9.92E-08	2.57E-13	2.54E-13	1.08E-13	1.03E-13	3.63E-15	5.91E-14	4.72E-15	9.73E-15
U-232	Ci	1.38E-09	4.90E-08	4.36E-09	5.37E-09	1.83E-09	3.10E-07	1.74E-09	2.83E-08	1.41E-08	3.61E-11
U-233	Ci	6.79E-09	3.03E-06	2.15E-08	1.35E-08	9.00E-09	2.43E-08	8.54E-09	1.39E-07	1.11E-09	2.72E-12
U-234	Ci	3.39E-05	1.54E-06	1.07E-04	1.37E-04	4.49E-05	2.03E-02	4.27E-05	6.95E-04	9.27E-04	1.99E-06
U-235	Ci	1.46E-06	6.42E-08	4.62E-06	5.87E-06	1.93E-06	8.99E-04	1.84E-06	2.99E-05	4.10E-05	8.77E-08
U-236	Ci	7.02E-07	3.71E-08	2.22E-06	2.82E-06	9.29E-07	2.76E-04	8.82E-07	1.44E-05	1.26E-05	2.95E-08
Np-237	Ci	6.48E-04	9.64E-05	2.05E-03	1.29E-03	8.58E-04	3.32E-05	2.89E-05	4.71E-04	1.52E-06	1.36E-07
Pu-238	Ci	3.26E-04	2.78E-06	1.03E-03	1.18E-03	4.31E-04	3.44E-05	1.11E-04	1.81E-03	1.57E-06	6.03E-06
U-238	Ci	3.47E-05	1.43E-06	1.10E-04	1.37E-04	4.60E-05	2.07E-02	4.37E-05	7.12E-04	9.46E-04	2.03E-06
Pu-239	Ci	1.71E-02	7.97E-05	5.42E-02	6.77E-02	2.27E-02	3.88E-03	5.83E-03	9.51E-02	1.77E-04	5.92E-04
Pu-240	Ci	3.33E-03	1.71E-05	1.05E-02	1.30E-02	4.41E-03	4.92E-04	1.13E-03	1.85E-02	2.24E-05	8.39E-05
Am-241	Ci	2.26E-02	5.47E-03	7.15E-02	8.71E-02	2.99E-02	2.33E-03	3.54E-03	5.77E-02	1.06E-04	1.52E-05
Pu-241	Ci	1.16E-02	1.13E-04	3.66E-02	4.65E-02	1.53E-02	1.08E-03	3.94E-03	6.42E-02	4.93E-05	1.94E-04
Cm-242	Ci	3.66E-05	1.76E-05	1.16E-04	7.29E-05	4.84E-05	6.21E-07	1.63E-06	2.65E-05	2.83E-08	3.01E-09
Pu-242	Ci	1.01E-07	1.07E-09	3.20E-07	3.90E-07	1.34E-07	7.86E-09	3.44E-08	5.61E-07	3.59E-10	1.47E-09
Am-243	Ci	8.26E-06	3.18E-06	2.61E-05	1.67E-05	1.09E-05	3.61E-07	1.29E-06	2.11E-05	1.65E-08	1.75E-09
Cm-243	Ci	6.55E-07	6.00E-07	2.07E-06	1.31E-06	8.67E-07	7.50E-09	2.92E-08	4.76E-07	3.42E-10	3.66E-11
Cm-244	Ci	1.62E-05	1.40E-05	5.11E-05	3.22E-05	2.14E-05	1.76E-07	7.20E-07	1.17E-05	8.04E-09	8.60E-10

REDOX = reduction-oxidation.

10.0 PROPORTIONAL WASTE INVENTORIES IN PLUGGED PIPELINES

The final table, Table 14, provides estimates of the proportional amount of residual waste in the plugged pipelines located in each tank farm, based on the data in Tables 4, 5, and 13.

Table 14. Proportional Amount of Residual Waste in Plugged Pipelines in Tank Farms. (4 sheets)

Waste Parameters		Plugged Pipeline								
		SL101	SL101	SN216	SN216	V412	V453	V465	Cascade line from 241-BX-102 to 241-BX-103	Cascade line from 241-C-110 to 241-C-111
Blockage Location		241-S-152	241-U-D	241-S-152	241-U-D	241-TY-153	241-U-101	241-U-153	241-BX-102	241-C-110
Residual Waste Volume (l)		19.6	111.5	45.2	257.5	102.0	183.9	153.0	28	28
Tank Farm (241-)		S	U	S	U	TX	U	U	BX	C
Waste Type		Partially neutralized REDOX supernate	Partially neutralized REDOX supernate	241-U-107 Saltwell liquid	241-U-107 Saltwell liquid	Concentrated REDOX supernate	Metal waste	REDOX waste	Metal waste	First-cycle waste
Solids Volume Fraction		0	0	0	0	0	0.213	0.068	0.213	0.134
Liquid Volume Fraction		1	1	1	1	1	0.787	0.932	0.787	0.866
Waste Concentration Factor		3.9	3.9	1	1	2.6	1	1	1	1
Analyte	Units									
Al	kg	1.75E+00	9.96E+00	1.85E+00	1.05E+01	6.07E+00	0.00E+00	5.26E+00	0.00E+00	4.36E-02
Bi	kg	0.00E+00	0.00E+00	1.06E-03	6.03E-03	0.00E+00	1.00E-02	0.00E+00	1.53E-03	6.58E-02
Ca	kg	1.15E-02	6.54E-02	2.85E-03	1.62E-02	3.98E-02	2.14E-01	1.60E-01	3.26E-02	1.97E-02
Cl	kg	2.59E-01	1.47E+00	4.77E-01	2.72E+00	8.99E-01	1.93E-02	5.07E-01	2.94E-03	4.80E-02
TIC as CO_3	kg	1.72E-02	9.78E-02	7.27E-01	4.14E+00	5.96E-02	7.97E+00	2.39E-01	1.21E+00	2.96E-02
Cr	kg	2.20E-01	1.25E+00	2.86E-03	1.63E-02	7.63E-01	2.79E-02	1.13E+00	4.25E-03	1.05E-02
F	kg	0.00E+00	0.00E+00	6.54E-03	3.73E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-01
Fe	kg	7.99E-03	4.55E-02	2.76E-04	1.57E-03	2.78E-02	2.77E-01	6.05E-01	4.21E-02	7.33E-02
Hg	kg	2.47E-05	1.41E-04	1.19E-05	6.77E-05	8.60E-05	3.31E-03	4.02E-04	5.04E-04	6.27E-05
K	kg	7.98E-02	4.55E-01	1.55E-01	8.83E-01	2.77E-01	4.63E-03	1.57E-01	7.04E-04	1.15E-02
La	kg	0.00E+00	0.00E+00	5.38E-08	3.07E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn	kg	2.33E-03	1.33E-02	2.12E-04	1.21E-03	8.09E-03	0.00E+00	7.22E-02	0.00E+00	0.00E+00
Na	kg	9.78E+00	5.57E+01	9.25E+00	5.27E+01	3.40E+01	1.23E+01	1.92E+01	1.87E+00	2.08E+00
Ni	kg	8.16E-03	4.65E-02	6.93E-04	3.95E-03	2.84E-02	1.57E-02	4.59E-02	2.40E-03	2.91E-03
NO_2	kg	2.70E+00	1.54E+01	5.76E+00	3.29E+01	9.38E+00	1.82E-01	6.03E+00	2.76E-02	7.13E-02
NO_3	kg	1.07E+01	6.07E+01	6.41E+00	3.65E+01	3.70E+01	1.68E+00	1.99E+01	2.55E-01	3.13E+00
Free OH	kg	0.00E+00	0.00E+00	3.46E-02	1.97E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb	kg	0.00E+00	0.00E+00	6.54E-04	3.73E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Analyte	Units									

Table 14. Proportional Amount of Residual Waste in Plugged Pipelines in Tank Farms. (4 sheets)

Waste Parameters		Plugged Pipeline								
		SL101	SL101	SN216	SN216	V412	V453	V465	Cascade line from 241-BX-102 to 241-BX-103	Cascade line from 241-C-110 to 241-C-111
PO_4	kg	0.00E+00	0.00E+00	1.83E-01	1.04E+00	0.00E+00	4.63E+00	0.00E+00	7.05E-01	7.46E-01
Si	kg	2.26E-02	1.29E-01	1.88E-03	1.07E-02	7.84E-02	1.88E-02	7.24E-02	2.87E-03	4.02E-02
SO_4	kg	1.41E-01	8.05E-01	1.97E-01	1.12E+00	4.91E-01			—	—
Sr	kg	3.67E-06	2.09E-05	7.10E-06	4.05E-05	1.28E-05	4.94E+00	2.77E-01	7.52E-01	2.07E-01
Th	kg	0.00E+00	0.00E+00	2.05E-05	1.17E-04	0.00E+00	1.40E-04	2.77E-04	2.14E-05	2.56E-07
TOC	kg	0.00E+00	0.00E+00	2.83E-01	1.62E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U Total	kg	2.37E-03	1.35E-02	9.77E-05	5.57E-04	8.22E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zr	kg	0.00E+00	0.00E+00	3.86E-05	2.20E-04	0.00E+00	1.86E+01	1.31E-01	2.83E+00	6.09E-03
H-3	Ci	2.11E-03	1.20E-02	4.82E-05	2.75E-04	7.33E-03	0.00E+00	0.00E+00	0.00E+00	8.86E-04
C-14	Ci	1.15E-04	6.56E-04	4.39E-05	2.50E-04	4.00E-04	3.89E-03	4.14E-03	5.93E-04	1.78E-04
Ni-59	Ci	1.35E-05	7.72E-05	3.06E-05	1.75E-04	4.71E-05	9.24E-05	2.26E-04	1.41E-05	2.37E-06
Co-60	Ci	1.55E-04	8.86E-04	1.51E-04	8.58E-04	5.40E-04	2.06E-05	7.62E-05	3.14E-06	7.78E-07
Ni-63	Ci	1.22E-03	6.97E-03	2.86E-03	1.63E-02	4.25E-03	7.24E-05	3.05E-04	1.10E-05	9.30E-06
Se-79	Ci	5.33E-06	3.04E-05	6.71E-05	3.83E-04	1.85E-05	1.82E-03	6.87E-03	2.77E-04	1.08E-04
Sr-90	Ci	1.89E-01	1.08E+00	2.01E-02	1.15E-01	6.57E-01	3.58E-06	1.05E-05	5.45E-07	7.78E-08
Y-90	Ci	1.89E-01	1.08E+00	2.01E-02	1.15E-01	6.57E-01	6.28E+00	1.43E+01	9.56E-01	1.14E-02
Zr-93	Ci	3.19E-04	1.82E-03	1.41E-03	8.04E-03	1.11E-03	6.28E+00	1.43E+01	9.56E-01	1.14E-02
Nb-93m	Ci	2.74E-04	1.56E-03	1.17E-03	6.69E-03	9.53E-04	9.59E-07	6.26E-04	1.46E-07	4.07E-05
Tc-99	Ci	2.02E-03	1.15E-02	1.57E-02	8.97E-02	7.03E-03	8.40E-07	5.38E-04	1.28E-07	3.58E-05
Ru-106	Ci	4.25E-12	2.42E-11	2.43E-10	1.39E-09	1.48E-11	1.73E-03	3.97E-03	2.64E-04	5.92E-06
Cd-113m	Ci	2.19E-04	1.25E-03	1.27E-03	7.26E-03	7.61E-04	1.52E-15	8.34E-12	2.32E-16	3.86E-14
Sb-125	Ci	1.36E-05	7.73E-05	8.73E-05	4.98E-04	4.71E-05	1.18E-04	4.30E-04	1.80E-05	4.72E-06
Sn-126	Ci	2.16E-05	1.23E-04	2.96E-04	1.69E-03	7.50E-05	4.14E-06	2.66E-05	6.31E-07	1.36E-07
I-129	Ci	3.24E-06	1.85E-05	1.33E-05	7.58E-05	1.13E-05	1.38E-05	4.23E-05	2.10E-06	3.03E-07
Cs-134	Ci	3.02E-07	1.72E-06	4.39E-06	2.50E-05	1.05E-06	1.98E-06	6.35E-06	3.01E-07	5.17E-08

Table 14. Proportional Amount of Residual Waste in Plugged Pipelines in Tank Farms. (4 sheets)

Waste Parameters		Plugged Pipeline								
		SL101	SL101	SN216	SN216	V412	V453	V465	Cascade line from 241-BX-102 to 241-BX-103	Cascade line from 241-C-110 to 241-C-111
Analyte	Units									
Cs-137	Ci	5.72E+00	3.26E+01	1.54E+01	8.80E+01	1.99E+01	4.73E-08	5.93E-07	7.20E-09	1.58E-10
Ba-137m	Ci	5.40E+00	3.08E+01	1.45E+01	8.29E+01	1.88E+01	3.97E+00	1.12E+01	6.04E-01	1.34E-02
Sm-151	Ci	2.24E-01	1.28E+00	1.79E-01	1.02E+00	7.78E-01	3.75E+00	1.06E+01	5.70E-01	1.26E-02
Eu-152	Ci	2.27E-05	1.29E-04	1.84E-05	1.05E-04	7.88E-05	1.32E-01	4.39E-01	2.00E-02	6.20E-03
Eu-154	Ci	1.53E-03	8.74E-03	1.49E-03	8.51E-03	5.33E-03	6.28E-06	4.45E-05	9.57E-07	3.40E-07
Eu-155	Ci	6.30E-04	3.59E-03	4.65E-04	2.65E-03	2.19E-03	4.61E-04	3.01E-03	7.03E-05	2.38E-05
Ra-226	Ci	3.06E-10	1.74E-09	2.15E-09	1.23E-08	1.06E-09	2.54E-04	1.24E-03	3.86E-05	1.08E-05
Ac-227	Ci	1.31E-09	7.49E-09	7.44E-08	4.24E-07	4.56E-09	1.63E-08	6.00E-10	2.48E-09	2.56E-10
Ra-228	Ci	1.72E-15	9.80E-15	1.90E-07	1.08E-06	5.98E-15	7.19E-08	2.58E-09	1.09E-08	7.76E-10
Th-229	Ci	6.46E-12	3.68E-11	6.50E-10	3.70E-09	2.24E-11				
Pa-231	Ci	1.95E-09	1.11E-08	6.88E-07	3.92E-06	6.77E-09	9.62E-14	3.37E-15	1.47E-14	1.66E-15
Th-232	Ci	1.85E-15	1.05E-14	2.25E-09	1.28E-08	6.42E-15	3.64E-12	1.27E-11	5.54E-13	1.15E-12
U-232	Ci	3.14E-11	1.79E-10	1.11E-09	6.35E-09	1.09E-10	5.61E-10	3.82E-09	8.54E-11	1.70E-08
U-233	Ci	1.54E-10	8.80E-10	6.88E-08	3.92E-07	5.36E-10	3.10E-14	3.63E-15	4.72E-15	9.73E-15
U-234	Ci	7.71E-07	4.39E-06	3.49E-08	1.99E-07	2.68E-06	9.28E-08	1.74E-09	1.41E-08	3.61E-11
U-235	Ci	3.32E-08	1.89E-07	1.46E-09	8.31E-09	1.15E-07	7.28E-09	8.54E-09	1.11E-09	2.72E-12
U-236	Ci	1.59E-08	9.09E-08	8.43E-10	4.81E-09	5.54E-08	6.08E-03	4.27E-05	9.27E-04	1.99E-06
Np-237	Ci	1.47E-05	8.40E-05	2.19E-06	1.25E-05	5.12E-05	2.69E-04	1.84E-06	4.10E-05	8.77E-08
Pu-238	Ci	7.40E-06	4.22E-05	6.32E-08	3.60E-07	2.57E-05	8.27E-05	8.82E-07	1.26E-05	2.95E-08
U-238	Ci	7.89E-07	4.50E-06	3.25E-08	1.85E-07	2.74E-06	9.96E-06	2.89E-05	1.52E-06	1.36E-07
Pu-239	Ci	3.90E-04	2.22E-03	1.81E-06	1.03E-05	1.35E-03	1.03E-05	1.11E-04	1.57E-06	6.03E-06
Pu-240	Ci	7.56E-05	4.31E-04	3.88E-07	2.21E-06	2.63E-04	6.21E-03	4.37E-05	9.46E-04	2.03E-06
Am-241	Ci	5.13E-04	2.93E-03	1.24E-04	7.09E-04	1.78E-03	1.16E-03	5.83E-03	1.77E-04	5.92E-04
Pu-241	Ci	2.63E-04	1.50E-03	2.56E-06	1.46E-05	9.14E-04	1.47E-04	1.13E-03	2.24E-05	8.39E-05
Cm-242	Ci	8.31E-07	4.73E-06	4.01E-07	2.29E-06	2.89E-06	6.98E-04	3.54E-03	1.06E-04	1.52E-05

Table 14. Proportional Amount of Residual Waste in Plugged Pipelines in Tank Farms. (4 sheets)

Waste Parameters		Plugged Pipeline								
		SL101	SL101	SN216	SN216	V412	V453	V465	Cascade line from 241-BX-102 to 241-BX-103	Cascade line from 241-C-110 to 241-C-111
Analyte	Units									
Pu-242	Ci	2.30E-09	1.31E-08	2.43E-11	1.39E-10	7.98E-09	3.24E-04	3.94E-03	4.93E-05	1.94E-04
Am-243	Ci	1.88E-07	1.07E-06	7.23E-08	4.12E-07	6.52E-07	1.86E-07	1.63E-06	2.83E-08	3.01E-09
Cm-243	Ci	1.49E-08	8.48E-08	1.36E-08	7.77E-08	5.17E-08	2.35E-09	3.44E-08	3.59E-10	1.47E-09
Cm-244	Ci	3.67E-07	2.09E-06	3.17E-07	1.81E-06	1.28E-06	1.08E-07	1.29E-06	1.65E-08	1.75E-09

REDOX = reduction-oxidation.

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