TBP and Diluent Mass Balances in the PUREX Plant at Hanford 1955 - 1991

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PUREX PLANT AT HANFORD 1955-1991

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IN THE PUREX PLANT AT HANFORD
1955 - 1991**

by

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TABLE OF CONTENTS

1.0	INTRODUCTION	1
1.1	MATERIAL BALANCE SUMMARY	2
2.0	PUREX PROCESS HISTORY	5
2.1	NORMAL OPERATIONS	5
2.2	ORGANICS	6
2.3	OPERATING PERIODS, THROUGHPUT AND RECORDS OF CHEMICAL CONSUMPTION	8
3.0	PUREX TBP/NPH MASS BALANCE	26
3.1	ESTIMATED TBP/NPH DISTRIBUTION IN WASTES AND EFFLUENTS . . .	27
3.2	ESTIMATED TOTAL LOSSES AND FATE OF TBP/NPH IN THE TANK FARMS	27
4.0	OTHER SOURCES OF ORGANICS IN THE TANK FARMS	27
5.0	CONCLUSIONS AND RECOMMENDATIONS	34
6.0	REFERENCES	35

APPENDIX A: MASS BALANCE CALCULATIONS FOR PUREX ORGANIC CONSUMPTION

LIST OF TABLES AND FIGURES

Table 2-1:	Properties of TBP, DBP and MBP.....	7
Table 2-2:	Properties of Shell E-2342, Soltrol-170, and NPH.....	8
Table 2-3:	Estimated Solvent Losses from 1955 to 1967 based on HAPO and CPD Monthly Reports.....	9
Table 2-3:	Estimated Solvent Losses from 1965 to 1991 based on Essential Materials Consumption Records.....	20
Table 3-1:	Estimated Annual Distribution of Organics in Purex Plant Streams.....	28
Table 3-2:	Crib Disposal of Spent Organic.....	33
Figure 3-1:	Estimated Organic Discharged to Organic Wash Waste, Ventilation Stack, and Process Condensate from Purex.....	30
Figure 3-2:	Estimated Organic Discharged to High Level Waste and in UNH Product.....	31
Figure 3-3:	Estimated Gallons of Organic Discharged to Tank Farms in Organic Wash Waste.....	32

1.0 INTRODUCTION

The purpose of this report is to develop an estimate of the quantities of tributyl phosphate and diluent discharged in aqueous waste streams to the tank farms from the Hanford Purex Plant over its operating life. Purex was not the sole source of organics in the tank farms, but was a major contributor.

Tributyl phosphate (TBP) and diluent, which changed from Shell E-2342® to Soltrol-170® and then to normal paraffin hydrocarbon (NPH), were organic chemicals used in the Purex solvent extraction process at Hanford to separate plutonium and uranium from spent nuclear fuels. This report is an estimate of the material balances for these chemicals in the Purex Plant at Hanford over its entire operating life. The Purex Plant had cold start up in November 1955 and shut down in 1990. It's process used a solution of 30 vol% TBP in diluent.

The Purex Plant was a source for some of the organic chemicals that are mixed with the radioactive waste stored in the Hanford 200 Area Tank Farms. Early chemical processing in the Purex Plant involved diluents other than NPH. Section 2 of this report contains a discussion of the process history of the Purex Plant, including diluents, operating periods, and chemical consumption records. Section 3 contains the estimated material balance for the Purex Plant, based on flowsheet information and the plant technical manuals. This section contains the estimated quantities of organics transferred to the tank farms.

Other Hanford facilities also used organic chemicals and also were known or potential sources of organics in the tank waste. A brief discussion of these facilities is given in Section 4. Section 5 contains conclusions and recommendations.

One question that was asked as part of this study was whether an organic balance around the Magnox Plant at Sellafield, England could be used to estimate Purex Plant organic losses. The Magnox Plant, which is still operating, uses a solution of 20 vol% TBP in odorless kerosene. Both plants were designed to reprocess spent nuclear fuel. Solvent extraction equipment at Purex used pulsed columns. The Magnox Plant does not have pulsed columns, but uses mixer-settlers for solvent extraction. A review of the Magnox Plant balance indicates that such an extrapolation would not accurately reflect Purex Plant operations. There are significant differences in operating history, throughput, diluents and equipment.

1.1 MATERIAL BALANCE SUMMARY

The organic balance around the Purex Plant is described, in general, in this section. A detailed description of the calculations is located in Appendix A. The scope of the calculations includes the entire plant life, from the original cold startup in the fall of 1955 to the present. The balance is based on reported consumption of organic at Purex. For the early years, organic consumption was estimated based on information located in the Chemical Processing Department's Monthly Reports. Many of these reports included a discussions of solvent losses, in terms of percent of solvent throughput in the solvent treatment systems. Solvent throughput was then estimated, based on the tons of uranium processed in the plant during the month, and the flowsheet in effect at the time. For several years the monthly reports also list references for actual chemical consumption at Purex (1 report per month), but there was insufficient time in this task to locate and extract the information from them. Actual records of organic consumption in Purex are readily available, starting with the year 1965. These records were used in this study for the remainder of the plant life.

The major focus of this material balance is to determine what happened to the organic that was consumed in the plant. Most of the organic losses involved six streams. These streams involve:

- Disposal to the organic Crib A-2 in early operations, and later, briefly to Crib A-31.
- Soluble organic in high level (boiling) waste transferred to tank farms.
- Entrained and soluble organic in organic wash (solvent treatment) wastes transferred to tank farms.
- Entrained and soluble organic in Process Condensate disposed to a crib.
- Soluble organic in the Uranium (UNH) product stream.
- Organic evaporated into the vessel ventilation system and lost as gaseous effluent.

In addition to these losses, some of the organic was degraded due to radiolysis and acid hydrolysis during use. Most of these degradation products were removed in the solvent treatment process and left the plant with the organic wash wastes.

The purpose of solvent treatment was to remove degradation products (which affected processing) and reduce the dose rate in the organic, which was reused in the plant. Two treatment systems were employed. The first system (No.1) was used to treat the organic from first cycle solvent extraction, which contained the most contaminants, and had the highest dose rate. The second system (No. 2) was used to treat less highly contaminated solvent from subsequent separations in the plant. On occasion, solvent from the No. 2 system was added to the No. 1 system. (But not the reverse, since it was desirable to maintain a low dose rate in the No. 2 solvent.)

Solvent sometimes arrived in solvent treatment loaded with product or fission products that were not easily removed. Some of these batches were reworked in Tank F-8, beginning with a long period of acid digestion to break down the organics. The organic fragments from the digestion, being lighter, would have been more volatile and would likely have left the plant through the stack, via the vessel ventilation system. Organic that was collected in cell sumps was similarly reworked.

Flowsheet information and physical data from Purex Technical Manuals were used to estimate the fraction of the lost organic that went to the various streams. These fractions were then applied to the reported organic consumption to complete the estimate of how much organic was distributed to each location.

The current Purex Flowsheet, PFD-P-020-00001, was used as the basis for following the path of organic through the plant. The flowsheet does not show the small quantities of organic present in the aqueous streams due to solubility or entrainment. It also does not show degradation products. The material balance in Appendix A develops this information, based on solubility data, information about entrainment over Purex pulse columns, and information about TBP degradation products. The material balance begins with the organic feed to solvent extraction and follows the organic through the plant to the waste, product and effluent streams. At that point, the only organic losses not accounted for are the amount discharged via the stack and the amount entrained in the organic wash (solvent treatment) waste. The losses accounted for in the balance at this point are smaller than the fresh organic shown by the flowsheet as being added to the system. The difference between the known losses and the fresh organic was assumed to go 20% to the stack, and 80% to entrainment in the organic wash waste. There are no data available to document stack losses, however, the estimate is conservative in that it shows the majority of the material is lost to the tank farm.

The estimated total organic losses to each stream were then divided by

the flowsheet figure for fresh solvent makeup in order to develop a percent distribution. The distribution was then applied to the monthly consumption data to arrive at the overall estimated losses to each stream.

The current Purex flowsheet was used as the basis for the material balance. It does not, however, accurately reflect plant operation over its entire history, due to the many modifications that occurred over the years. To account for some of these changes, the material balance was completed for four cases, and the flowsheet information was modified to account for major plant changes. The four cases are:

- Case 1: Actual flowsheet conditions (includes recycle of process condensate). Fresh solvent makeup of 114 gallons/day. Applies to 1982 and thereafter.
- Case 2: Same as Case 1, but fresh solvent makeup is assumed to be 200 gallons per day, according to historical solvent addition rate. applies to the years 1970 - 1981.
- Case 3: Fresh solvent makeup is assumed to be 260 gallons per day (an average from monthly reports), but process condensate is not recycled, so more organic is disposed via the process condensate stream to a crib. Applies to the years 1963 to 1969.
- Case 4: Assumes fresh solvent makeup of 300 gallons per day, based on early operations, and no recycle of process condensate. Applies from startup to 1963, when the plant began recycling the spent wash solution from the No. 2 System to the No. 1 System.

The results of the material balance are presented in Sections 2 and 3 of this report. The total gallons of solvent (TBP plus diluent) estimated to have been consumed in the Purex Plant (not including crib discharge) is 1,234,000 gallons. Of this amount, about 655,000 gallons were estimated to have been discharged in the organic wash waste, 412,000 gallons in process condensate, 164,000 gallons in the stack gaseous effluent, and 2,000 gallons in the high level waste. Monthly reports indicate about 59,000 gallons of spent solvent disposed to Organic Crib A-2, while liquid waste discharge records indicate disposal of a total of 98,000 gallons of spent solvent to Cribs A-2 and A-31.

The monthly Hanford Atomic Products Operation (HAPO) and Chemical Processing Department Reports reviewed for this report (1955-1967) show that,

at least early on, the organic wash waste was sometimes discharged in two components. The bulk of the waste, also called carbonate waste, was transferred to high level waste tanks, initially in A-Farm. In 1956, organic that accumulated in a separate layer in Purex tanks TK-R8 and TK-G8 was transferred separately to C-Farm. This was done because too much organic was being distilled from the high level waste tanks. This was thought to cause percolation problems in the high level waste condensate crib. (The total flow to the high level waste condensate crib was eventually reduced significantly by replacing the tank farms contact condensers with surface condensers that did not add water to the stream in order to cool it.) The records examined for this report do not identify when the Plant stopped routinely sending the organic wash waste to the same tank as the high level waste.

2.0 PUREX PROCESS HISTORY

2.1 NORMAL OPERATIONS

Normal operations in the Purex Plant used a solution of TBP in diluent for solvent extraction, with subsequent washing of the TBP-diluent mixture to remove contaminants and degradation products. The washed organic was reused in the facility, and the aqueous wash solution was transferred to the tank farms from Purex Tanks R-8 and G-8. (In later operations, spent wash solution from the No. 2 Solvent Treatment System was reused in the No. 1 System and only Tank G-8 was used for transfers to the tank farms. This change reduced solvent losses.) Organics were present in the wash solution due to solubility and entrainment. Additional organic could also have been transferred to the tank farms depending on decanting operations, where it was necessary to detect the aqueous/organic interface to separate the layers. (In early operations, accumulated organic in these tanks was deliberately transferred to the tank farms. Later operations involved recovering and reusing the accumulated organic.)

Aqueous waste from Purex Tank F-18 could also have occasionally contained organic, since this tank was used to accumulate waste from cell sumps, including those in the organic wash area. Organics collected in Tank F-18 would usually, however, have been reworked in Tank F-8, and not sent to the tank farms.) High level waste from Purex Tank F-16 was another source of organic, due to solubility occurring during solvent extraction of uranium and plutonium.

Organics and decomposition products also left the plant during normal operations in streams that were not routed to the tank farms. These streams included condensates from the process ventilation system and gaseous effluents. During early operations, some spent organic was routed to a crib for disposal into the soil. This practice was discontinued when NPH became the diluent, since washing remained effective indefinitely for the TBP-NPH mixture. The use of diluents at Purex is described in section 2.2, below. The distribution of soluble and entrained organic is estimated in Appendix A.

2.2 ORGANICS

The Purex Plant was completed in 1955 and cold startup runs were begun in October of that year. Hot startup began in mid-January of 1956 (Raab 1977). The plant was originally designed for a nominal instantaneous rate of 8.33 tons of uranium per day, with an expansion capacity of 12 to 13 tons following minor equipment changes, according to the plant technical manual (GE, 1955). The expansion was expected to be completed prior to startup. Subsequent modifications increased the capacity even further.

At startup the solvent used in the extraction process was 30 vol% tributyl phosphate (TBP) in diluent. The original diluent, however, was not normal paraffin hydrocarbon (NPH). The original Purex Plant Technical Manual, page 436, (GE, 1955) listed 6 commercial products that met the specifications for diluent. At the time the technical manual was written, a Phillips Chemical Company product called Soltrol-170 had been tentatively selected for use in the plant. The original diluent was, however Shell E-2342. Soltrol-170 came into later use, in September of 1961 (Walser, 1966). When Soltrol-170 became the new diluent, the old TBP/Shell-E2342 solvent was not disposed to the organic crib, but was consumed in the plant by blending it in with the new TBP/Soltrol mixture.

Records show that NPH replaced Soltrol-170 as the diluent on February 15, 1966 (Zahn, 1966). Crib discharge records for 1963-1966 show 6,340 gallons of organic disposed to Crib A-31 during that time frame, which could have been some of the old TBP/Soltrol solvent. Properties of TBP and degradation products DBP and MBP, are shown in Table 2-1. Properties of Shell E-2342, Soltrol-170, and NPH are shown in Table 2-2.

TABLE 2-1 PROPERTIES OF TBP, DBP and MBP

	Tributyl Phosphate (TBP)	Dibutyl Phosphate (DBP)	Monobutyl Phosphate (MBP)
Formula	(n-C ₄ H ₉ O) ₃ PO	(n-C ₄ H ₉ O) ₂ (OH)PO	(n-C ₄ H ₉ O)(OH) ₂ PO
Molecular weight	266.32	210.2	154.1
Color	colorless	pale yellow	colorless
Odor	mildly sweet	-	-
Density (g/ml at 25°C)	0.9730	1.065	1.220
Refractive index (n 20/D)	1.4245	1.4260	1.419
Refractive index (n 25/D)	1.4226	1.4227	1.429
Melting point °C	<-80	-	-
Specific Heat (cal/g°C at 25°C)	0.41	-	-
Latent heat of vaporization (cal/gram mole)	14,680	-	11,400
Boiling point (°C at 760mm Hg pressure)	289	190 (decomposition temperature)	105 (decomposition temperature)
Boiling point (°C at 25 mm Hg pressure)	177	-	-
Boiling point (°C at 1mm Hg pressure)	121	-	-
Vapor pressure (mm Hg at 100°C)	ca. 1.0	-	-
Vapor pressure (mm Hg at 25°C)	0.006	-	-
Flash point (°F, Tag closed cup)	295 (146°C)	-	-
Solubility in water (g/L at 25°C)	0.39	18	-

Note: Physical properties for TBP, DBP and MBP are from the Purex Technical Manual (GE, 1955).

Losses of TBP during processing occurred through entrainment and solubility in the aqueous phase, acid hydrolysis, radiolysis, and evaporation. Identified degradation products are DBP, MBP, butanol and phosphoric acid. NPH is more resistant to chemical and radiolytic degradation, with losses occurring mainly through entrainment, evaporation and a small solubility in the aqueous phase. Prior diluents were more susceptible to degradation than NPH.

TABLE 2-2: PROPERTIES OF SHELL E-2342, SOLTROL-170, AND NPH

	Shell E-2342	Soltrol-170	Normal Paraffin Hydrocarbon (NPH)
Period of Use	1955 to 9/1961	9/1961 to 2/1966	2/1966 to 1989
Density at 25°C (g/ml)	0.801	0.773	0.76 (max)
Viscosity (centipoise at 25°C)	1.7	2.3	1.8
Boiling range and midpoint (°C)	-	208-239, (225)	174-252
Flash point	166°F	192°F	80°C (176°F) min.
Aromatic content	0.1 vol%	Nil	0.2 wt% max as 1,2,3,4 tetrahydronaphthalene
Naphthene content	about 80 vol%	Nil	-
Iodine number	-	<1.1 bromine number	0.1 wt% max olefins as wt% 1-tetradecene
Solubility in water	<0.004 g/L at 25°C and 50°C	very slight	<0.005 g/L between 25°C and 50°C
Composition	about 80 vol% 5 and 6 carbon cycloparaffins (cyclopentane, cyclohexane)	mixture of highly branched aliphatic hydrocarbons	mixture of C10 to C14 straight chain (normal) aliphatic hydrocarbons

Note: Physical properties for Shell E-2342 and Soltrol-170 are from the Purex Technical Manual (GE, 1955). Composition of Soltrol-170 is from (Walser, 1966). Properties of NPH are from the Purex Technical Manual (RHO, 1983.) Composition for Shell E-2342 is based on the definition for naphthenes given in (Merck, 1989).

2.3 OPERATING PERIODS, THROUGHPUT AND RECORDS OF CHEMICAL CONSUMPTION

The Purex Plant started up with cold runs in 1955 and initially reprocessed aluminum-clad fuel. Later modifications enabled the plant to change to process aluminum or zirconium clad fuel. Over the years there have been many process and flowsheet changes. Table 2-3 shows the uranium throughput and estimated consumption of solvent based on HAPD and Chemical Processing Department Monthly Reports from November of 1955 to August of 1967. This table also contains a list of Purex Essential Materials Consumption Report document numbers, which were not examined for this study but might be found useful in other efforts. The monthly reports frequently discussed solvent losses in terms of the percent of solvent throughput in the No. 1 and No 2 Solvent Treatment Systems. Solvent losses were estimated in this table, based on Purex Chemical Flowsheet No. 4 (HW-35225). This Flowsheet shows solvent throughput in the No.1 System of 3,001 gallons per ton of uranium processed and throughput in the No 2 Solvent Treatment System of 2,486 gallons per ton of uranium, for a total of 5,487 gallons/ton. These figures, combined with the reported uranium production numbers, were used to generate the estimated solvent throughput and solvent losses. Using this

Table 2-3: Estimated Solvent Losses from 1955 to 1967 based on HAPO and CPD Monthly Reports

Date	HAPO/CPD Monthly Report No.	Essential Materials Report No.	Tons Uranium	Est.# of Operating Days	Reported Solvent Loss* (% of throughput)	Est. solvent throughput (gal)	Est. Solvent Loss* (gal)	Notes
Nov-55	HW-40182	-	cold runs	-	0.3	-	4,700	Since start of cold runs, 46,000 gal of 30% TBP added. By 11/19, about 24,000 gallons had been discarded [to crib], due to interface control, centrifuge bowl leak and normal losses. 11/19 to 11/26 lost only 1100 gal, 0.3% of organic throughput.
Dec-55	HW-40962	-	cold runs	-	1	-	5,200	
Total 1955							9,900	
Jan-56	HW-41205	HW-40729	67	31	-	367,629	1,103	Completed cold runs Jan 22. Hot startup Jan 13. Flowsheet #1, HW-40574. About 7,000 gallons of solvent discarded [to crib]. Completely new inventory was available at startup.
Feb-56	HW-41702	HW-41321	246.8	19	0.2	1,354,192	2,708	
Mar-56	HW-42219	HW-43387	130	13	0.6	713,310	11,280	Organic losses excessive. 7,000 gallons lost during shutdown. Continue to be 0.6% of throughput.
Apr-56	HW-42626	HW-42893	197	18	0.3	1,080,939	7,243	One large solvent loss of 4,000 gallons when pre-cycle system temporarily shut down April 10.
May-56	HW-43137	HW-43482	133	14	0.5	729,771	3,649	Replaced entire organic inventory in No. 1 system. 7,000 gallons discarded [to crib]. Steady state loss 0.5% of throughput. 1OW and 2OW routed to TK-110-C. 1WW to TK-103-A.
Jun-56	HW-43938	HW-44017	341	30	-	1,871,067	9,859	No. 1 System losses >1% of throughput, decreased to 0.37%. No. 2 System losses 0.33%.
Jul-56	HW-44580	HW-44725	112.7	12	-	618,385	6,108	No. 1 losses 0.35%. No. 2 losses 0.33%. Does not include 4,000 gallons lost at shutdown/startup. No. 1 system inventory replaced with No. 2 inventory. No. 2 inventory replaced with fresh solvent.
Aug-56	HW-45115	HW-45182	239.5	24	-	1,314,137	4,733	No. 1 losses 0.41% of gallons processed. Organic waste routed to 110-C to reduce emulsion in A-8 crib. TK-103-A bumps about every 8 hrs (5-10 in WG).
Sep-56	HW-45707	HW-45691	315	26	0.25	1,728,405	4,321	CPD established. Total solvent losses of 0.25% of gallons processed in spite of a loss of 2,800 gallons due to shutdown/startup. R-8 & G-8 organic to C-Farm. Previously had gone to 103-A, distilled there & affected TF condensate crib. See quote below.

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Revision 0

Table 2-3: Estimated Solvent Losses from 1955 to 1967 based on HAPO and CPD Monthly Reports

Date	HAPO/CPD Monthly Report No.	Essential Materials Report No.	Tons Uranium	Est.# of Operating Days	Reported Solvent Loss* (% of throughput)	Est. solvent throughput (gal)	Est. Solvent Loss* (gal)	Notes
								"Organic which normally accumulates in TK-GB and TK-R8 is currently being separated and routed to C-Farm for storage. Previously, waste organic was mixed with the carbonate wastes and sent to 241-A-103 which resulted in excessive
								solvent reaching the boiling waste storage tank. Solvent distilled from this self-concentrating tank into the tank farm condensate crib probably restricted the crib percolation rate."
Oct-56	HW-46432	HW-46425	186	17	-	1,020,582	2,551	Replaced No. 1 organic column T-G2. New column has interface probe in center of column rather than in a side chamber. Recommend surface condensers in Tank Farms.
Nov-56	HW-47056	HW-47071	272	21	0.225	1,492,464	3,358	Solvent losses dropped from 0.25% to 0.20%, a \$100/day savings. Attributed to new column.
Dec-56	HW-47675	HW-47664	279	19	0.32	1,530,873	4,899	Reworked 42 tons of out-of-spec. uranium. TK-103-A boils at 6.2 gpm.
Total 1956			2,519	244			61,813	
Jan-57	HW-48132	HW-48092	300.98	25	0.52	1,651,477	8,588	241-A Tank Farm receives Neutr. 1WW, carbonate washes & cell drainage & flushes. Coating waste & organic transfer line to 104-C plugged completely.
Feb-57	HW-48835	HW-48850	284	22	-	1,558,308	5,324	Solvent loss 0.47% of throughput, including 2,000 gal spilled to cell floor and discarded. 1WW and solvent wash waste to TK-103-A.
Mar-57	HW-49503	HW-49475	299	22	0.31	1,640,613	5,086	Using flowsheet HW-47712 with some changes. TK-103-A boils 8 to 9 gpm.
Apr-57	HW-50089	HW-50073	405.85	28	0.29	2,226,899	6,458	Added used organic from TBP [U] plant: 3,200 gal of 19% TBP. Caused shutdown. Waste routes to C-Farm returned to normal (unplugged). No. 1 system has 14,000 gal. inventory.
May-57	HW-50584	HW-50589	355.9	24	0.29	1,952,823	5,663	0.29% loss excludes accidental 2,000 gal loss through the IO column vent line.
Jun-57	HW-51211	HW-51310	369.1	28	0.36	2,025,252	7,291	Current [1WW] waste routed to TK-101-A on 6/27. Until self concentration starts in 101-A, organic carbonate wastes and misc. wastes to 241-A-102, to be transferred to C-Farm.

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Table 2-3: Estimated Solvent Losses from 1955 to 1967 based on HAPO and CPD Monthly Reports

Date	HAPO/CPD Monthly Report No.	Essential Materials Report No.	Tons Uranium	Est.# of Operating Days	Reported Solvent Loss* (% of throughput)	Est. solvent throughput (gal)	Est. Solvent Loss* (gal)	Notes
Jul-57	HW-51802	HW-51810	357.6	24	0.37	1,962,151	7,260	Carbonate wastes routed to 241-A-102 on July 5. 101-A starts to boil July 14th. Then all Purex wastes except coating waste are routed to TK-101-A.
Aug-57	HW-52353	HW-52354	433.38	30	0.28	2,377,956	6,658	Solvent wash waste to 241-A-101. Organic waste batches continue to be routed to Tank 102-A for transfer to 103-CR Tank in 241-C Tank Farm.
Sep-57	HW-52864	HW-52912	263.54	20	0.7	1,446,044	10,122	Normal overall solvent loss of 0.3% was increased to 0.7% by excessive loss from a 200 pump seal plus an additional loss via the vent system during cleaning of No. 1 System centrifuges. 1OW, 2OW to 103-A.
Oct-57	HW-53449	HW-53503	477.17	29	0.3	2,618,232	7,855	Organic treatment wastes rerouted to 101-A to avoid accumulation in any single tank.
Nov-57	HW-53967	HW-54021	425	26	-	2,331,975	6,996	Reworked 129 tons out-of-spec. Uranium. Tried to reclaim 600 lb U from No. 1 organic (1,000 gal) stored in October.
Dec-57	HW-54319	HW-54418	432.8	20	0.3	2,374,774	7,124	Acidified, digested organic waste in TK-F8 for 19 days. Flowsheet brought up to date: HW-52389, "Purex Two-Cycle Flowsheet" (Rev. 1), Swift & Irish, 10-1-57.
Total 1957			4404.32	298			84,425	
Jan-58	HW-54821	HW-54878	567.11	28	0.3	3,111,733	9,335	Organic exit from bottom of the IO column primarily responsible for solvent loss increase from 0.3 to 0.5%. The solvent overflowed the IOR tank. Although the solvent was recovered from the sump, lab washing of a sample failed. Solvent discarded [crib].
Feb-58	HW-55215	HW-55230	550.76	28	0.3	3,022,020	9,066	TK-101-A boils 16 gpm.
Mar-58	HW-55571	HW-55610	423.94	26	0.29	2,326,159	6,746	TK-102-A started up March 12. Boils 0.7 to 1.6 gpm.
Apr-58	HW-55914	HW-55970	450.22	24	0.28	2,470,357	6,917	Converting to two-cycle operation. Purex staff 276.
May-58	HW-56218	HW-56296	358	21	0.2	1,964,346	3,929	Two-cycle flowsheet reduces solvent loss. Saves \$4,000/month.
Jun-58	HW-55602	HW-56664	45.2	5	-	248,012	496	Continued conversion to two-cycle flowsheet.
Jul-58	HW-56972	HW-57085	521.18	29	0.38	2,882,000	10,890	350 gallons of spilled solvent was stripped of Pu and U and sent to organic crib A-2. Combined solvent loss, including leakage, was 11,240 gallons, or 0.39% of solvent processed.

WHC-MR-0483
 Revision 0

Table 2-3: Estimated Solvent Losses from 1955 to 1967 based on HAPO and CPD Monthly Reports

Date	HAPO/CPD Monthly Report No.	Essential Materials Report No.	Tons Uranium	Est.# of Operating Days	Reported Solvent Loss* (% of throughput)	Est. solvent throughput (gal)	Est. Solvent Loss* (gal)	Notes
Aug-58	HW-57328	HW-57375	196.72	16	-	1,079,403	3,778	Transferred 60% of No. 2 solvent to No. 1 system to reduce activity. Pre-heating TK-104-A.
Sep-58	HW-57640	HW-57710	551	28	0.31	3,023,337	9,372	Sampled tank farm A-24 crib. Black tarry substance - expected condensation product of diluent, due to high temperature and high radiation.
Oct-58	HW-58051	HW-58114	470.35	23	0.3	2,580,810	7,742	HW-58329 Seven Year Waste Program, Authors Shaw and Cooper. Discusses final disposal and responsibility to the public.
Nov-58	HW-58305	HW-58412	523.3	22	-	-	6,280	
Dec-58	HW-58711	HW-58805	584.33	28	-	-	7,012	
Total 1958			5242.11	278			81,563	
Jan-59	HW-59079	HW-59146	376.5	19	-	-	7,530	Organic consumption was app. 20 gal/ton vs about 12 gal/ton in previous months. Cost increase \$10/ton. (Increased washing in R-Cell & inadequate decanting of wash solution.) A-Farm gets solvent washes.
Feb-59	HW-59434	HW-59553	291.18	13	-	-	3,494	Solvent washes to boiling waste tanks.
Mar-59	HW-59849	HW-60118	538.68	25	-	-	6,464	
Apr-59	HW-60236	HW-60378	270.04	25	-	-	3,240	About 800 gallons of solvent discarded to the organic crib - high residual gamma.
May-59	HW-60559	HW-60625	353.56	27	-	-	4,243	Flash points of new and used solvent taken. FP goes up for used solvent.
Jun-59	HW-60915	HW-61072	625.65	29	-	-	7,508	Excessive degradation products in solvent. Poor solvent quality causes problems.
Jul-59	HW-61366	HW-61454	214.86	19	-	-	2,578	No. 1 system flushed. Crystalline, carbonate & gelatinous solids in TK-G1. Solvent washes routed to 102-A until 104-A boils. Batch of un-neutralized fission product waste accidentally sent to A-Farm. NO2 fumes.
Aug-59	HW-61736	HW-61800	628.79	31	-	-	7,545	
Sep-59	HW-62179	HW-62361	494.7	28	-	-	5,936	Recovering other radionuclides. Preparing for Ronald Reagan's visit to the 200 Areas (bus service). 9-16-59 new surface condensers replace contact condensers in A-Farm.

WHC-MR-0483
Revision 0

Table 2-3: Estimated Solvent Losses from 1955 to 1967 based on HAPO and CPD Monthly Reports

Date	HAPO/CPD Monthly Report No.	Essential Materials Report No.	Tons Uranium	Est.# of Operating Days	Reported Solvent Loss* (% of throughput)	Est. solvent throughput (gal)	Est. Solvent Loss* (gal)	Notes
Oct-59	HW-62593	HW-62654	305.9	18	-	-	3,671	6,000 gallon fresh solvent makeup replaces solvent lost to the waste collection tank as HA column overflow. After solvent extraction of HAP, remaining 2,000 gallons of solvent washed & processed through the No. 1 system.
Nov-59	HW-62864	HW-63037	441.97	23	-	-	5,304	Problems with polyethylene plates in HA column.
Dec-59	HW-63313	HW-63423	443.9	21	-	-	7,998	Organic consumption was app. 25 gal/ton vs normal consumption of 12 gal/ton. Degraded organic appeared in 2nd cycle U feed tank K-1. App. 3,100 gal of organic were lost - went to outside U-tank P-2. Not recoverable, since passed through concentrator.
Total 1959			4985.73	278			65,511	
Jan-60	HW-63706	HW-63811	600.87	31	-	-	7,210	
Feb-60	HW-64089	HW-64298	375.7	20	-	-	4,508	Fire in N-Cell (welding accident)
Mar-60	HW-64576	HW-64872	233.6	12	-	-	2,803	Reworked degraded solvent from TK-P2. (Solvent was heavier than aqueous.) Was carbonate washed then discarded to the organic crib. Entire 27,000 gallon solvent inventory was moved to an outside storage tank and new
								organic brought in to improve decontamination. App. 13,000 gal of organic were not accounted for after all the organic was transferred. Discrepancy attributed to accumulative inventory error.
Apr-60	HW-64991	HW-65180	727.2	30	-	-	8,726	Carbonate changes in TK-R1 resulted in excessive solvent entrainment from that tank (0.5% of solvent throughput) Operating procedures being modified to return to normal 0.15% of throughput.
May-60	HW-65165	HW-65565	300.5	22	-	-	3,606	
Jun-60	HW-65935	HW-66040	251.9	10	-	-	3,023	
Jul-60	HW-66271	HW-66357	423.3	19	-	-	5,080	Organic in No. 1 system was damaged by 10% caustic wash & discarded to A-2 Crib. Used organic, which had been stored in TK-P2 since March, was brought back in & made ready for use.
Aug-60	HW-66646	HW-66828	754	28	-	-	9,048	
Sep-60	HW-66958	HW-67079	782.7	30	-	-	9,392	

WHC-MR-0483
 Revision 0

Table 2-3: Estimated Solvent Losses from 1955 to 1967 based on HAPO and CPD Monthly Reports

Date	HAPO/CPD Monthly Report No.	Essential Materials Report No.	Tons Uranium	Est.# of Operating Days	Reported Solvent Loss* (% of throughput)	Est. solvent throughput (gal)	Est. Solvent Loss* (gal)	Notes
Oct-60	HW-67252	HW-67387	403.7	27	-	-	4,844	
Nov-60	HW-67459	HW-67743	685.7	30	-	-	8,228	
Dec-60	HW-67985	HW-68117	702.9	26	0.3	3,856,812	11,570	200 gallon purge of TK-G1 caused 0.1% increase in overall normal solvent loss (0.3%)
Total 1960			6242.07	285			78,040	
Jan-61	HW-68345	HW-68422	331.8	22	-	1,820,587	5,462	
Feb-61	HW-68700	HW-68758	474.9	19	-	2,605,776	7,817	Accelerated solvent washing to control quality. High level waste routed to TK-106-A for preheating. Cs recovery in Purex.
Mar-61	HW-69051	HW-69089	564.8	29	-	3,099,058	9,297	HW-68146 proposal to replace A-2 Crib.
Apr-61	HW-69443	HW-69474	360.76	22	-	1,979,490	5,938	Replacing more polyethylene cartridges with stainless steel.
May-61	HW-69803	HW-69872	694.95	27	-	3,813,191	28,599	Solvent losses from the No. 1 system have been 3 fold above flowsheet. Were substantially reduced to 0.6% of throughput, which is twice the regular loss.
Jun-61	HW-70165	HW-70311	580.36	27	0.36	3,184,435	11,464	
Jul-61	HW-70588	-	480.18	22	-	2,634,748	7,904	
Aug-61	HW-70918	-	634.63	28	-	3,482,215	10,447	In order to test a new diluent, the entire plant inventory of organic was removed from the plant and stored for later use. New diluent charging activities begun.
Sep-61	HW-71187	-	496.54	20	-	2,724,515	8,174	Testing Soltrol.
Oct-61	HW-71577	-	371.42	14	-	2,037,982	6,114	Purex running out of aged feed.
Nov-61	HW-71895	-	282.11	14	-	1,547,938	4,644	
Dec-61	HW-72154	-	678.87	29	-	-	14,500	Test of carbonate wash re-use terminated when excessive emulsion transferred to TK-G1. Replacement of solvent to No. 2 System was about 500 gal/day, compared to a normal loss of about 80 gallons/day.
Total 1961			5951.32	273			120,360	
Jan-62	HW-72551	-	313.29	22	-	1,719,022	5,157	
Feb-62	HW-72890	-	144.79	10	-	794,463	2,383	During the shutdown period, used, stored solvent (composed of TBP and Shell E-2342) was used to replenish the No. 1 Solvent System inventory.

WMC-MR-0483
Revision 0

Table 2-3: Estimated Solvent Losses from 1955 to 1967 based on HAPO and CPD Monthly Reports

Date	HAPO/CPD Monthly Report No.	Essential Materials Report No.	Tons Uranium	Est.# of Operating Days	Reported Solvent Loss* (% of throughput)	Est. solvent throughput (gal)	Est. Solvent Loss* (gal)	Notes
Mar-62	HW-73193	-	305	20	-	1,673,535	5,021	
Apr-62	HW-73525	-	302.39	20	-	1,659,214	4,978	Criticality at 234-5 on April 7th. Purex operations slowed.
May-62	HW-73884	-	620.56	31	-	3,405,013	10,215	Solvent losses from the No. 2 System increased a factor of four to 400 gallons/day. However, the "lost" solvent was segregated from the washes and stored for future recovery.
Jun-62	HW-74151	-	555.25	25	-	3,046,657	9,140	Flushed No. 1 Organic System. New policy requires sampling all waste streams leaving Purex.
Jul-62	HW-74505	-	776.79	31	-	4,262,247	12,787	Processed 1030 cans of button line supernatant. Solvent losses from 2O column reduced about 17%.
Aug-62	HW-74804	-	271.05	17	-	1,487,251	4,462	
Sep-62	HW-75145	-	498.97	23	-	2,737,848	8,214	Numerous equipment failures. Testing Cs recovery with ferrocyanide (HW-75051). Transfer of used organic wash solutions from No. 2 to No. 1 systems for reuse and disposal started on Sept 19. R1 jetted to G1. R2 jetted to G2.
								Purpose is to reduce solvent losses and reduce chemical consumption in the solvent treatment systems.
Oct-62	HW-75470	-	772.43	28	-	4,238,323	8,900	Reused all No. 2 System washes in No. 1 Solvent treatment system. Result is 50% reduction in organic wash solutions and 30% reduction in solvent losses.
Nov-62	HW-75702	-	695.01	25	-	3,813,520	8,008	
Dec-62	HW-76054	-	784.51	29	-	4,304,606	9,040	
Total 1962			6040.04	281			88,304	
Jan-63	HW-76443	-	9.63	0	-	52,840	111	Shut down all month - lack of feed. 2nd cycle U system operated 4 days. Following the run, No. 2 System did not repositnd completely to treatment & was set aside for additional batch treatment.
Feb-63	HW-76848	-	405.62	17	-	2,225,637	4,674	The last of the mixed diluent (Shell E-2342, Soltrol-170) was introduced into the plant and a transition to all Soltrol-170 was started. The 3,900 gal of solvent (48% TBP) which passed through the 1CU concentrator was stored for future use.
Mar-63	HW-77138	-	867.24	29	-	4,758,546	9,993	Testing sugar denitration of high level waste.

WHC-MR-0483
Revision 0

Table 2-3: Estimated Solvent Losses from 1955 to 1967 based on HAPO and CPD Monthly Reports

Date	HAPO/CPD Monthly Report No.	Essential Materials Report No.	Tons Uranium	Est.# of Operating Days	Reported Solvent Loss* (% of throughput)	Est. solvent throughput (gal)	Est. Solvent Loss* (gal)	Notes
Apr-63	HW-77504	-	13.12	2	-	71,989	151	Used up available feed. Boron raschig rings installed in E-Cell sump. Replaced HS Column.
May-63	HW-77795	-	669.07	24	-	3,671,187	7,709	Replaced HA Column.
Jun-63	HW-78076	-	773.9	30	-	4,246,389	8,917	50% NaOH added to A-3 dissolver heel - violent reaction.
Jul-63	HW-78484	-	12.28	0	-	67,380	141	Plant scale test of triaurylamine for extraction of Pu and Np from 1WW.
Aug-63	HW-78817	-	202.3	14	-	1,110,020	2,331	Degraded solvent in both systems. 5,100 gallons inadvertently boiled in the 1CU concentrator during Np recovery period.
Sep-63	HW-79097	-	621.29	30	-	3,409,018	7,159	
Oct-63	HW-79480	-	453.56	28	-	2,488,684	5,226	
Nov-63	HW-79768	-	721.07	27	-	3,956,511	8,309	Preparing for additional triaurylamine studies.
Dec-63	HW-80243	-	668.02	24	-	3,665,426	7,697	
Total 1963			5417.1	225			62,420	
Jan-64	HW-80672	-	235	24	-	1,289,445	2,708	
Feb-64	HW-81078	-	3	3	-	16,461	35	Triaurylamine tests resumes after installing high efficiency agitator.
Mar-64	HW-81620	-	805	29	-	4,417,035	9,276	
Apr-64	HW-82809	-	298	20	-	1,635,126	3,434	Ammonium nitrate on Purex Canyon filter decreases air flow.
May-64	HW-82526	-	471	22	-	2,584,377	5,427	
Jun-64	HW-83102	-	727	29	-	3,989,049	8,377	
Jul-64	HW-83508	-	289	16	-	1,585,743	3,330	Testing with triaurylamine.
Aug-64	HW-83876	-	856	31	-	4,696,872	9,863	Starting process design for Thorium separations.
Sep-64	HW-84354	-	508	28	-	2,787,396	5,854	
Oct-64	RL-SEP-52	-	843	29	-	4,625,541	9,714	
Nov-64	RL-SEP-112	-	606	30	-	3,325,122	6,983	Studying new diluent from Hot Semiworks - NPH
Dec-64	RL-SEP-197	-	118	7	-	647,466	1,360	Conducting operability tests in AX Tank Farm. RL-SEP-9
Total 1964			5759	268			66,359	
Jan-65	RL-SEP-282	-	0	0	-	0	0	Whole month involved thorium test run. 40 hrs of solvent extraction. TK-105-A bumped, first instance where circulators were believed to be operating.
Feb-65	RL-SEP-332	-	391	14	-	2,145,417	4,505	Thoria test finished Feb 4th. Poor solvent quality.

MHC-MR-0483
Revision 0

Table 2-3: Estimated Solvent Losses from 1955 to 1967 based on HAPO and CPD Monthly Reports

Date	HAPO/CPD Monthly Report No.	Essential Materials Report No.	Tons Uranium	Est.# of Operating Days	Reported Solvent Loss* (% of throughput)	Est. solvent throughput (gal)	Est. Solvent Loss* (gal)	Notes
Mar-65	RL-SEP-405	-	807	26	-	4,428,009	9,299	103-AX boiled at end of month.
Apr-65	RL-SEP-476	-	909	29	-	4,987,683	10,474	Earth tremor April 29th.
May-65	RL-SEP-509	-	884	31	-	4,850,508	10,186	
Jun-65	RL-SEP-618	-	529	23	-	2,902,623	6,096	No. 1 Solvent System chemically flushed. No. 2 solvent transferred to No. 1 System and replaced with fresh.
Jul-65	RL-SEP-654	-	262	10	-	1,437,594	3,019	Purex staff 366.
Aug-65	RL-SEP-706	-	459	25	-	2,518,533	5,289	Renovating A-Cell, new annular dissolver installed.
Sep-65	RL-SEP-755	-	506	23	-	2,776,422	5,830	Recovering Np, Sr.
Oct-65	RL-SEP-837	-	389	27	-	2,134,443	4,482	Preparing to install new B-Cell dissolver.
Nov-65	RL-SEP-874	-	211	13	-	1,157,757	2,431	Lab investigation concludes reactions between solid nitrate salts and ferrocyanides occur only at abnormally high concentrations of the constituents and at elevated temperature. There appears no possibility of a reaction with
						0	0	the 0.005 M concentrations specified in the flowsheet. An efficient method of destroying cyanide complexes even at low concentrations is being sought.
Dec-65	RL-SEP-913	-	425	23	-	2,331,975	4,897	Effective midnight on 12/31 Chemical Processing Department is transferred to Isochem.
Total 1965			5772	244			66,509	
Jan-66	ISO-89	-	413	21		2,266,131	4,759	BNWL-CC-1070, "A Survey of B-Plant Wasteform Explosion Hazards, J. F. Phillips Jr., 1967.
Feb-66	ISO-143	-	398	24	-	2,183,826	4,586	Entire working volume of solvent was replaced in mid February. New diluent is NPH from South Hampton Oil Co.
Mar-66	ISO-210	-	632	27	-	-	5670	Dissolution & first production campaign of zircaloy clad fuel.
Apr-66	ISO-276	-	279	13	-	-	2730	Preparing for thorium processing.
May-66	ISO-315	-	17	-	-	-	840	Production is tons of thorium. Thorium charged to dissolvers May 11th.
Jun-66	ISO-365	-	130	27	-		11,097	Production is tons of thorium. Severe emulsification in No. 2 washes. Overall solvent losses for June averaged 411 gal/day vs 210 gal/day average during previous experience with NPH.

WMC-MR-0483
 Revision 0

Table 2-3: Estimated Solvent Losses from 1955 to 1967 based on HAPO and CPD Monthly Reports

Date	HAPO/CPD Monthly Report No.	Essential Materials Report No.	Tons Uranium	Est.# of Operating Days	Reported Solvent Loss* (% of throughput)	Est. solvent throughput (gal)	Est. Solvent Loss* (gal)	Notes
Jul-66	ISO-428	-	41	7	-	-	1470	Production is tons of thorium. "SECRETARY" computer program calculates tank data. Includes heat, salt, rad. inventory for all tanks. Includes decay and waste transfers.
Aug-66	ISO-476	-	29	4	-	-	840	Uranium restarted August 28.
Sep-66	ISO-512	-	578	28	-	-	5880	New annular dissolver in C-Cell. NPH process test continues. "SECRETARY" program includes OH, CO ₃ , AlO ₂ , F, Cl, NO ₃ , CN, pH. Adding intertank transfer subroutine. Report to be issued: ISO-489.
Oct-66	ISO-563	-	915	31	-	-	6510	Resumed 3-dissolver operations Oct. 8th. Lab tests show negligible degradation products are formed using NPH vs Soltrol.
Nov-66	ISO-610	-	491	22	-	-	4620	Discussion of KOH metathesis step.
Dec-66	ISO-642	-	431	20	-	-	4200	Developed rapid go-no-go method for cyanide at 100 ppm level for tank farm waste samples.
Total 1966			4354	224			53,202	
Jan-67	ISO-707	-	751	30	-	-	6300	
Feb-67	ISO-708	-	221	8	-	-	1680	Fission product recovery contract cancelled. Deactivating the REDOX Plant.
Mar-67	ISO-709	-	293	12	-	-	2520	
Apr-67	ISO-710	-	701	28	-	-	5880	
May-67	ISO-711	-	487	24	-	-	5040	
Jun-67	ISO-712	-	195	11	-	-	2310	New HA column - unidiameter. Installed ammonia monitor on coating waste tank.
Jul-67	ISO-713	-	177	22	-	-	4620	
Aug-67	ISO-714	-	400	18	-	-	3780	Ammonia monitor on Tank 102-C.
Notes:								
*Solvent losses do not include amounts disposed to crib.								
Estimated solvent throughput is based on Purex Chemical flowsheet No. 4, HW-35225, March 4, 1955.								
This flowsheet shows a No. 1 System throughput of 3,001 gal/ton of uranium,								
and a No. 2 System throughput of 2,486 gal/ton of uranium, with a total of 5,487 gal/ton.								

MHC-MR-0483
Revision 0

technique, the estimated losses could be somewhat low in some months, because the production numbers would not include solutions that were set aside for rework because they did not meet specifications, and therefore were not counted as product.

Readily available records of actual consumption of diluent and TBP at Purex are extensive, beginning in 1965 (Logbooks HWN-3610, ARH-N-134, WHC-N-676, and essential materials monthly consumption reports). These records are summarized in Table 2-4. The original essential materials records used in this study recorded consumption in pounds, except the diluent, which was originally recorded in gallons. For some years, the data were repeated in more than one portion of the logbook. In 1966/67 the units for NPH were changed to pounds, but the exact point of the change is not clear. A subsequent repetition of the 1967 data, however, was positive on the use of pounds. Negative entries indicated that the plant had transferred some of its NPH or TBP to another plant.

Record keeping in the logbooks was eventually discontinued, with essential material consumption being recorded on monthly data sheets only. For the most part, the data sheets identified each plant with a cost code. While there is no index to these codes, the plants can be identified by their consumption of unique chemicals. Purex, for example, used AFAN (ammonium fluoride/ammonium nitrate) and B-Plant used ammonia. Units for TBP and NPH in the monthly reports were in units of pounds. The code on the monthly records for units for these chemicals was listed as "C," meaning hundredweight. However, this code was merely an instruction for personnel to divide by 100 when sending information out. The dates used to compile the monthly figures are not exact for each month, but rather are for a period covering most of the month, for example, 12-20-82 to 1-24-83 was listed as January 1983. The essential materials records differ from the Chemical Processing Department Monthly Reports, in that the Plant was not ordering chemicals on a day to day basis, but would wait until stocks were reduced. As a result, the essential materials records are not useful to reflect consumption in the short term, but are more reasonable when summed for the year.

The CPD Monthly Reports and the Essential Materials Records overlap for the years 1965 and 1966. In these years, the essential materials records indicate higher consumption than the CPD Monthly Reports. For 1965, the essential materials consumption was 102,000 gallons and the monthly reports indicate losses of 67,000 gallons. For 1966, the essential materials consumption was 71,000 gallons and the monthly reports indicate losses of 53,000 gallons. The records do not shed any light on the discrepancy, although the diluent was changed from Soltrol-170 to NPH in February of 1966.

Table 2-4: Estimated Solvent Losses from 1965 to 1991 Based on Essential Materials Consumption Records

Month	Tons U*	lb TBP	lb Diluent	Gal TBP	Gal Diluent	Total Gal Solvent	Gal/Ton U	
Jan-65	0	25,995	0	3,201	0	3,201	-	Soltrol
Feb-65	391	47,127	79,781	5,804	12,371	18,175	46	
Mar-65	807	27,989	42,589	3,447	6,604	10,051	12	
Apr-65	909	47,671	48,064	5,871	7,453	13,324	15	
May-65	884	0	64,064	0	9,934	9,934	11	
Jun-65	529	44,228	11,621	5,447	1,802	7,249	14	
Jul-65	262	3,558	9,686	438	1,502	1,940	7	
Aug-65	459	24,508	41,532	3,018	6,440	9,458	21	
Sep-65	506	16,644	34,070	2,050	5,283	7,333	14	
Oct-65	389	21,363	32,903	2,631	5,102	7,733	20	
Nov-65	211	16,023	24,003	1,973	3,722	5,695	27	
Dec-65	425	18,458	34,102	2,273	5,288	7,561	18	
Total 1965	5,772	293,564	422,416	36,153	65,501	101,654	18	
Jan-66	413	21,115	29,053	2,600	4,505	7,105	17	
Feb-66	398	84,787	1,902	10,442	300	10,742	27	NPH
Mar-66	632	13,495	0	1,662	0	1,662	3	
Apr-66	279	9,995	0	1,231	0	1,231	4	
May-66	17	25,493	0	3,140	0	3,140	185	
Jun-66	130	3,827	70,196	471	11,072	11,543	89	
Jul-66	41	97,262	0	11,978	0	11,978	292	
Aug-66	29	-63,707	33,397	-7,846	5,343	-2,503	-86	
Sep-66	578	30,223	32,664	3,722	5,152	8,874	15	
Oct-66	915	20,746	35,846	2,555	5,654	8,209	9	
Nov-66	491	18,208	23,033	2,242	3,633	5,875	12	
Dec-66	431	8,515	16,135	1,049	2,545	3,594	8	
Total 1966	4,354	269,959	242,227	33,246	38,204	71,450	16	
Jan-67	751	18,914	57,315	2,329	9,040	11,370	15	
Feb-67	221	0	52,820	0	8,331	8,331	38	
Mar-67	293	14,622	3,490	1,801	550	2,351	8	
Apr-67	701	19,415	3,201	2,391	505	2,896	4	
May-67	487	10,493	-71,634	1,292	-11,299	-10,006	-21	
Jun-67	195	10,839	50,014	1,335	7,889	9,223	47	
Jul-67	177	12,725	-44,699	1,567	-7,050	-5,483	-31	
Aug-67	400	9,512	20,674	1,171	3,261	4,432	11	
Sep-67	504	26,045	-21,868	3,208	-3,449	-242	0	
Oct-67	434	8,484	14,012	1,045	2,210	3,255	7	
Nov-67	587	10,427	16,013	1,284	2,526	3,810	6	
Dec-67	120	5,968	126,100	735	19,890	20,625	172	
Total 1967	4,870	147,444	205,438	18,158	32,404	50,562	10	
Jan-68	289	17,089	-12,019	2,105	-1,896	209	1	

Table 2-4: Estimated Solvent Losses from 1965 to 1991 Based on Essential Materials Consumption Records

Month	Tons U*	lb TBP	lb Diluent	Gal TBP	Gal Diluent	Total Gal Solvent	Gal/Ton U	
Feb-68	179	3,770	0	464	0	464	3	
Mar-68	543	7,199	-64,722	887	-10,209	-9,322	-17	
Apr-68	345	16,652	7,496	2,051	1,182	3,233	9	
May-68	269	9,286	18,363	1,144	2,896	4,040	15	
Jun-68	680	26,088	46,579	3,213	7,347	10,560	16	
Jul-68	103	8,482	12,013	1,045	1,895	2,939	29	
Aug-68	486	8,670	28,018	1,068	4,419	5,487	11	
Sep-68	192	21,526	20,019	2,651	3,158	5,809	30	
Oct-68	570	-1,609	23,169	-198	3,654	3,456	6	
Nov-68	354	7,540	16,013	929	2,526	3,454	10	
Dec-68	299	2,827	10,006	348	1,578	1,926	6	
Total 1968	4,309	127,520	104,935	15,704	16,551	32,256	7	
Jan-69	0	13,446	18,013	1,656	2,841	4,497	-	
Feb-69	128	8,484	6,006	1,045	947	1,992	16	
Mar-69	346	2,762	10,006	340	1,578	1,918	6	
Apr-69	270	12,254	30,025	1,509	4,736	6,245	23	
May-69	460	9,425	0	1,161	0	1,161	3	
Jun-69	110	6,598	10,006	813	1,578	2,391	22	
Jul-69	18	-65	0	-8	0	-8	0	
Aug-69	369	5,655	12,013	696	1,895	2,591	7	
Sep-69	384	6,598	5,546	813	875	1,687	4	
Oct-69	318	14,886	0	1,833	0	1,833	6	
Nov-69	304	10,987	26,019	1,353	4,104	5,457	18	
Dec-69	318	6,847	14,012	843	2,210	3,053	10	
Total 1969	3,025	97,877	131,646	12,054	20,764	32,818	11	
Jan-70	246	6,598	18,013	813	2,841	3,654	15	
Feb-70	84	5,656	10,006	697	1,578	2,275	27	
Mar-70	9.6	4,585	14,012	565	2,210	2,775	289	
Apr-70	312	7,541	38,032	929	5,999	6,927	22	
May-70	62	6,596	-14,013	812	-2,210	-1,398	-23	
Jun-70	52	944	38,032	116	5,999	6,115	118	
Jul-70	0	5,655	43,677	696	6,889	7,586	-	
Aug-70	0	18,724	-74,202	2,306	-11,704	-9,398	-	
Sep-70	122	29,218	136,044	3,598	21,458	25,056	205	Thorium
Oct-70	28	12,442	18,013	1,532	2,841	4,373	156	Thorium
Nov-70	155	18,859	24,018	2,323	3,788	6,111	39	Thorium
Dec-70	90	7,343	-1,416	904	-223	681	8	Thorium
Total 1970	1,161	124,161	250,216	15,291	39,466	54,757	47	
Jan-71	0	0	4,000	0	631	631	-	
Feb-71	0.4	0	0	0	0	0	0	Thorium
Mar-71	0	0	0	0	0	0	-	

WHC-MR-0483
Revision 0

Table 2-4: Estimated Solvent Losses from 1965 to 1991 Based on Essential Materials Consumption Records

Month	Tons U*	lb TBP	lb Diluent	Gal TBP	Gal Diluent	Total Gal Solvent	Gal/Ton U
Apr-71	401	21,679	30,031	2,670	4,737	7,407	18
May-71	728	12,187	28,019	1,501	4,419	5,920	8
Jun-71	497	31,200	23,006	3,842	3,629	7,471	15
Jul-71	210	0	26,262	0	4,142	4,142	20
Aug-71	648	-4,224	-8,007	-520	-1,263	-1,783	-3
Sep-71	628	20,736	30,013	2,554	4,734	7,288	12
Oct-71	77	6,408	10,006	789	1,578	2,367	31
Nov-71	123	0	0	0	0	0	0
Dec-71	238	13,446	20,019	1,656	3,158	4,813	20
Total 1971	3,550	101,432	163,349	12,492	25,765	38,256	11
Jan-72	90	7,226	16,019	890	2,527	3,417	38
Feb-72	51	6,542	12,012	806	1,895	2,700	53
Mar-72	576	12,507	18,013	1,540	2,841	4,381	8
Apr-72	26	1,571	0	193	0	193	7
May-72	0	0	5,692	0	898	898	-
Jun-72	0.7	501	-2,019	62	-318	-257	-367
Jul-72	159	7,539	9,982	928	1,574	2,503	16
Aug-72	207	0	0	0	0	0	0
Sep-72	32	2,953	0	364	0	364	11
Oct-72	0.2	0	0	0	0	0	0
Nov-72	0	0	0	0	0	0	-
Dec-72	0	0	0	0	0	0	-
Total 1972	1,142	38,839	59,699	4,783	9,416	14,199	12
Jan-73	0	-8,360	0	-1,030	0	-1,030	-
Feb-73	0	8,360	0	1,030	0	1,030	-
Mar-73	0	0	0	0	0	0	-
Apr-73	0	0	0	0	0	0	-
May-73	0	0	0	0	0	0	-
Jun-73	0	0	0	0	0	0	-
Jul-73	0	-2,517	0	-310	0	-310	-
Aug-73	0	0	0	0	0	0	-
Sep-73	0	0	0	0	0	0	-
Oct-73	0	0	0	0	0	0	-
Nov-73	0	0	0	0	0	0	-
Dec-73	0	0	0	0	0	0	-
Total 1973	0	-2,517	0	-310	0	-310	
CY 1974	0	No records, plant shut down.					
CY 1975	0	No records, plant shut down.					
CY 1976	0	No records, plant shut down.					
CY 1977	0	No records, plant shut down.					
CY 1978	0	0	0	0	0	0	-

Table 2-4: Estimated Solvent Losses from 1965 to 1991 Based on Essential Materials Consumption Records

Month	Tons U*	lb TBP	lb Diluent	Gal TBP	Gal Diluent	Total Gal Solvent	Gal/Ton U
CY 1979	0	0	1,892	0	298	298	-
CY 1980	0	0	0	0	0	0	-
CY 1981	0	0	0	0	0	0	-
CY 1982	0	6,697	0	825	0	825	-
Jan-83	0	0	8,003	0	1,262	1,262	-
Feb-83	0	0	0	0	0	0	-
Mar-83	0	4,748	12,009	585	1,894	2,479	-
Apr-83	0	0	0	0	0	0	-
May-83	0	481	0	59	0	59	-
Jun-83	0	6,735	14,008	829	2,209	3,039	-
Jul-83	0	943	0	116	0	116	-
Aug-83	0	0	0	0	0	0	-
Sep-83	0	11,310	0	1,393	0	1,393	-
Oct-83	0	6,593	24,017	812	3,788	4,600	-
Nov-83	43	5,655	12,075	696	1,905	2,601	60
Dec-83	55	944	17,853	116	2,816	2,932	53
Total 1983	98	37,409	87,965	4,607	13,875	18,482	189
Jan-84	113	11,311	4,031	1,393	636	2,029	18
Feb-84	46	12,253	14,188	1,509	2,238	3,747	81
Mar-84	136	9,436	6,600	1,162	1,041	2,203	16
Apr-84	136	0	0	0	0	0	0
May-84	100	20,736	31,887	2,554	5,029	7,583	76
Jun-84	113	1,885	-754	232	-119	113	1
Jul-84	160	0	0	0	0	0	0
Aug-84	172	5,655	14,038	696	2,214	2,911	17
Sep-84	80	6,597	15,554	812	2,453	3,266	41
Oct-84	0	0	0	0	0	0	-
Nov-84	34	18,529	24,010	2,282	3,787	6,069	178
Dec-84	115	11,169	18,007	1,375	2,840	4,216	37
Total 1984	1,205	97,571	127,561	12,016	20,120	32,136	27
Jan-85	160	8,526	10,002	1,050	1,578	2,628	16
Feb-85	90	0	0	0	0	0	0
Mar-85	168	5,690	13,915	701	2,195	2,896	17
Apr-85	166	0	0	0	0	0	0
May-85	56	10,341	10,102	1,274	1,593	2,867	51
Jun-85	45	942	1,686	116	266	382	8
Jul-85	132	6,599	18,006	813	2,840	3,653	28
Aug-85	166	15,080	10,002	1,857	1,578	3,435	21
Sep-85	33	9,362	5,991	1,153	945	2,098	64
Oct-85	78	0	10,010	0	1,579	1,579	20
Nov-85	133	0	0	0	0	0	0

Table 2-4: Estimated Solvent Losses from 1965 to 1991 Based on Essential Materials Consumption Records

Month	Tons U*	lb TBP	lb Diluent	Gal TBP	Gal Diluent	Total Gal Solvent	Gal/Ton U
Dec-85	33	2,175	9,204	268	1,452	1,720	52
Total 1985	1,260	58,715	88,918	7,231	14,025	21,256	17
Jan-86	54.3	12,969	8,802	1,597	1,388	2,985	55
Feb-86	118	8,484	7,290	1,045	1,150	2,195	19
Mar-86	229	4,711	8,663	580	1,366	1,947	9
Apr-86	109	0	8,602	0	1,357	1,357	12
May-86	104	4,000	23,691	493	3,737	4,229	41
Jun-86	67	1,655	2,725	204	430	634	9
Jul-86	163	2,828	3,599	348	568	916	6
Aug-86	98	4,940	3,758	608	593	1,201	12
Sep-86	0	4,486	6,245	552	985	1,537	-
Oct-86	0	0	0	0	0	0	-
Nov-86	0	0	0	0	0	0	-
Dec-86	0	0	0	0	0	0	-
Total 1986	942	44,073	73,375	5,428	11,573	17,001	18
Jan-87	0	0	0	0	0	0	-
Feb-87	8	0	0	0	0	0	0
Mar-87	8	6,655	13,425	820	2,118	2,937	367
Apr-87	8	4,467	13,472	550	2,125	2,675	334
May-87	8	4,750	10,802	585	1,704	2,289	286
Jun-87	8	2,015	10,218	248	1,612	1,860	232
Jul-87	33	3,075	43	379	7	385	12
Aug-87	65	3,733	8,462	460	1,335	1,794	28
Sep-87	0	8,011	6,005	987	947	1,934	-
Oct-87	0	0	0	0	0	0	-
Nov-87	0	0	0	0	0	0	-
Dec-87	0	0	0	0	0	0	-
Total 1987	138	32,706	62,427	4,028	9,847	13,874	101
Jan-88	22	0	0	0	0	0	0
Feb-88	71	3,111	5,592	383	882	1,265	18
Mar-88	53	0	0	0	0	0	0
Apr-88	0	0	0	0	0	0	-
May-88	11	5,843	11,210	720	1,768	2,488	226
Jun-88	84	0	0	0	0	0	0
Jul-88	42	4,525	2,402	557	379	936	22
Aug-88	103	3,394	9,607	418	1,515	1,933	19
Sep-88	103	4,501	9,605	554	1,515	2,069	20
Oct-88	62	0	0	0	0	0	0
Nov-88	65	1,750	9,600	216	1,514	1,730	27
Dec-88	32	5,655	9,609	696	1,516	2,212	69
Total 1988	648	28,779	57,625	3,544	9,089	12,633	19

Table 2-4: Estimated Solvent Losses from 1965 to 1991 Based on Essential Materials Consumption Records

Month	Tons U*	lb TBP	lb Diluent	Gal TBP	Gal Diluent	Total Gal Solvent	Gal/Ton U
Jan-89	0	0	0	0	0	0	-
Feb-89	0	0	0	0	0	0	-
Mar-89	0	0	0	0	0	0	-
Apr-89	0	0	0	0	0	0	-
May-89	0	0	0	0	0	0	-
Jun-89	0	0	0	0	0	0	-
Jul-89	0	0	0	0	0	0	-
Aug-89	0	0	0	0	0	0	-
Sep-89	0	0	0	0	0	0	-
Oct-89	0	0	0	0	0	0	-
Nov-89	0	0	0	0	0	0	-
Dec-89	0	0	0	0	0	0	-
Total 1989	0	0	0	0	0	0	-
Jan-90	0	0	5,259	0	829	829	-
Feb-90	60	0	0	0	0	0	0
Mar-90	0	0	2,454	0	387	387	-
Apr-90	0	0	0	0	0	0	-
May-90	0	0	0	0	0	0	-
Jun-90	0	0	0	0	0	0	-
Jul-90	0	0	4,784	0	755	755	-
Aug-90	0	1,702	0	210	0	210	-
Sep-90	0	0	0	0	0	0	-
Oct-90	0	0	0	0	0	0	-
Nov-90	0	0	0	0	0	0	-
Dec-90	0	0	0	0	0	0	-
Total 1990	60	1,702	12,497	210	1,971	2,181	36
Jan-91	0	0	2,393	0	377	377	-
Feb-91	0	0	0	0	0	0	-
Mar-91	0	0	0	0	0	0	-
Apr-91	0	0	0	0	0	0	-
May-91	0	0	0	0	0	0	-
Total 1991	0	0	2,393	0	377	377	-
*Tons of Uranium are as reported in CPD Monthly Reports, in HW-89085, and per Ron Walser.							

The method for disposing of the TBP/Soltröl mixture was not discussed. The estimated Purex solvent losses in this report are based on using the higher figures from the essential materials consumption records for 1965 and 1966.

According to a 1968 note found in the essential material history file for NPH, the Purex Plant required approximately 20,000 gallons "to fill system and maintain an operating inventory." Since TBP was 30 vol% of the mixture used for solvent extraction, the operating inventory would also have included about 8,600 gallons of TBP. When the plant was shut down in 1972, the inventory of TBP and NPH was stored at Purex, and used when the plant was restarted in 1983.

Following shutdown of the plant in 1989, the unused NPH (44,000 lb, about 6,900 gallons) and TBP (99,000 lb, about 12,200 gallons) were sold as excess (WHC, 1993). The used solvent mixture, about 21,000 gallons that is 25 vol% TBP, is still located at the plant. This solvent contains very low levels of radioactive contamination. Tanks G-5 and R-7 in the building contain heels which total about 500 gallons. Another 3,500 gallons are located in a tank car outside the building. The balance is stored in Tank 40 in the 211-A chemical storage area. The solvent is being stored pending completion of efforts to find a suitable location for beneficial use. If reuse or chemical exchange options are exhausted, plans call for commercial incineration of the solvent.

3.0 PUREX TBP/NPH MASS BALANCE

The Purex Flowsheet (Allen, et al, 1985) and Purex Plant Technical Manuals (GE 1955 and Rockwell 1980) contain a great deal of information about processing in the Purex Plant and the properties of TBP and NPH. These references were used to estimate the distribution of TBP, NPH, and TBP degradation products that were lost via several streams leaving the plant. Appendix A contains the detailed calculations along with a discussion and list of assumptions. Four distributions were estimated, due to changing operations in the plant. The data are presented on an annual basis because the monthly essential materials consumption records lag behind the operations (the plant would order fresh solvent after in-plant stock was depleted), and sometimes are negative (when the plant supplied chemicals to other plants). As a result, annual consumption is a better indicator of actual operations.

3.1 ESTIMATED TBP/NPH DISTRIBUTION IN WASTES AND EFFLUENTS

Table 3-1 shows the estimated total organic loss and distribution for TBP and Diluent over the entire operating life of the Purex Plant. Figures 3-1, 3-2 and 3-3 show the organic losses for combined TBP and diluent in individual streams including the main stack, process condensate and organic wash waste, and high level waste and UNH product. Of these streams, the high level waste and organic wash waste were routed to the tank farms. The process condensate was routed to the process condensate crib. Table 3-2 is a summary of records of spent organic sent to the organic disposal crib. (Very little organic would likely have been discharged via any other streams leaving the Purex Plant.)

3.2 ESTIMATED TOTAL LOSSES AND FATE OF TBP/NPH IN THE TANK FARMS

The estimated total loss of organic from the plant is 452,000 gallons of TBP and 782,000 gallons of diluent, for a total of 1,234,000 gallons. The amount going to the tank farms is estimated to be about 2,000 gallons to high level waste and 655,000 gallons to organic wash waste.

In early operations, the organic wash waste was combined with the high level waste prior to transfer to the tank farms (both streams went to the high level waste tanks). Later operations separated the two streams, sending them to different tanks. This is significant, because boiling in the high level waste tanks would have distilled a lot of the organic, so that the organic would have ended up in a crib, via the condensate from the high level waste tanks. Organic wash waste stored in a non-boiling tank would be at a lower temperature and therefore would evaporate more slowly. In addition, TBP is also subject to alkaline hydrolysis (as well as radiolysis) and could be expected to degrade in the tank farms.

4.0 OTHER SOURCES OF ORGANICS IN THE TANK FARMS

Several of Hanford's other process plants have used of organic chemicals. U-Plant, Z-Plant, B-Plant, and Hot Semiworks (C-Plant) all involved the use of organic chemicals that may have been discharged to the tank farms as soluble or entrained species. While these facilities were not part of the scope of this study, their operations should be noted if the data are ever used to estimate total organic input to the tank farms.

Table 3-1: Estimated Annual Distribution of Organics in Purex Plant Streams

Year	Total Gal Solvent*	Gal TBP	Gal Diluent	Organic Wash Waste TBP (gal)	Organic Wash Waste TBP-dp** (gal)	Organic Wash Waste Diluent (gal)	Organic Wash Waste Organic (gal)	Main Stack Organic (gal)	High Level Waste Organic (gal)	UNH Product Organic (gal)	Process Condensate Organic (gal)	Organic Crib Organic (gal)
1955	9,900	3,663	6,237	1610	31	3543	5184	1318	15	3	3374	24,000
1956	61,813	22,871	38,942	10051	195	22119	32365	8229	93	19	21066	14,000
1957	84,425	31,237	53,188	13728	266	30211	44205	11239	127	26	28772	4,000
1958	81,563	30,178	51,385	13263	257	29187	42706	10858	123	25	27797	6,574
1959	65,511	24,239	41,272	10653	206	23442	34302	8721	99	20	22326	.800
1960	78,040	28,875	49,165	12690	246	27926	40862	10389	118	24	26596	10,100
1961	120,360	44,533	75,827	19572	379	43070	63020	16022	181	37	41019	
1962	88,304	32,672	55,632	14359	278	31599	46236	11755	133	27	30094	
1963	62,420	23,095	39,325	9116	215	20803	30133	7676	106	22	24509	
1964	66,359	24,553	41,806	9691	228	22115	32035	8160	112	23	26056	
1965	101,654	36,153	65,501	14270	336	34650	49256	12536	166	35	39703	
1966	71,450	33,246	38,204	13122	309	20210	33641	8620	150	28	29042	
1967	50,562	18,158	32,404	7167	169	17142	24478	6231	83	17	19773	
1968	32,255	15,704	16,551	6198	146	8755	15100	3874	71	13	13212	
1969	32,818	12,054	20,764	4758	112	10984	15854	4038	55	11	12873	
1970	54,757	15,291	39,466	7340	1835	28613	37787	9171	83	23	7707	
1971	38,257	12,492	25,765	5996	1499	18680	26175	6313	68	16	5694	
1972	14,199	4,783	9,416	2296	574	6827	9696	2336	26	6	2138	
1973	0	0	0	0	0	0	0	0	0	0	0	
1974	0	0	0	0	0	0	0	0	0	0	0	
1975	0	0	0	0	0	0	0	0	0	0	0	
1976	0	0	0	0	0	0	0	0	0	0	0	
1977	0	0	0	0	0	0	0	0	0	0	0	
1978	0	0	0	0	0	0	0	0	0	0	0	
1979	298	0	298	0	0	216	216	54	0	0	28	
1980	0	0	0	0	0	0	0	0	0	0	0	
1981	0	0	0	0	0	0	0	0	0	0	0	
1982	825	825	0	266	149	0	415	79	6	1	323	
1983	18,482	4,607	13,875	1483	834	9033	11350	2704	39	12	4359	
1984	32,136	12,016	20,120	3868	2176	13098	19142	4433	98	22	8412	
1985	21,256	7,231	14,025	2328	1309	9130	12767	2980	59	14	5415	
1986	17,001	5,428	11,573	1747	983	7534	10264	2407	45	11	4257	
1987	13,875	4,028	9,847	1297	729	6410	8436	1992	33	9	3391	

MHC-MR-0483
Revision 0

Table 3-1: Estimated Annual Distribution of Organics in Purex Plant Streams

Year	Total Gal Solvent*	Gal TBP	Gal Diluent	Organic Wash Waste TBP (gal)	Organic Wash Waste TBP-dp** (gal)	Organic Wash Waste Diluent (gal)	Organic Wash Waste Organic (gal)	Main Stack Organic (gal)	High Level Waste Organic (gal)	UNH Product Organic (gal)	Process Condensate Organic (gal)	Organic Crib Organic (gal)
1988	12,633	3,544	9,089	1141	642	5917	7700	1822	29	8	3062	
1989	0	0	0	0	0	0	0	0	0	0	0	
1990	2,181	210	1,971	68	38	1283	1389	341	2	1	445	
1991	377	0	377	0	0	245	245	61	0	0	69	
Total	1,233,711	451,687	782,024	188,078	14,141	452,741	654,960	164,360	2,119	456	411,513	59,474
Notes:												
[1] *Total solvent does not include disposal to the organics crib from startup through 1964.												
[2] **TBP-dp denotes TBP degradation products.												
[3] Data for 1955 to 1964 are from HAPO/Chemical Processing Department Monthly Reports.												
These records provide estimates of the total monthly loss of solvent.												
The distribution is assumed to be 37% TBP and 63% diluent, based on consumption from 1965-1972.												
[4] Data for 1965 through 1991 are from Essential Material Consumption Records.												
These records show actual amounts of TBP and NPH consumed by the plant.												
[5] Figures for disposal of organic to crib are from Monthly Reports only.												
See Table 2-4 for crib discharge records.												
[6]	Case 4: 1955-1962											
	Case 3: 1963 - 1969											
	Case 2: 1970-1981											
	Case 1: 1982-1991											

WMC-MR-0483
Revision 0

Figure 3-1: Estimated Organic Discharged to Organic Wash Waste, Ventilation Stack, and Process Condensate from Purex

Figure 3-2: Estimated Organic Discharged to High Level Waste and in UNH Product

WHC-MR-0483
Revision 0

Figure 3-3: Estimated Gallons of Organic Discharged to Tank Farms in Organic Wash Waste

MHC-MR-0483
Revision 0

Table 3-2: Crib Disposal of Spent Organic

Date	Location	Volume of Spent Organic (gal)	Record
1955 - May 1956	unknown	31,000	HAPO Monthly Reports
May 1956 - June 1958	A-2 Crib	20,605	HW-57649, "Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through June 1958," K. F. Baldrige, October 3, 1958.
June 1958-Dec 1958	A-2 Crib	264	HW-59359, "Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through December 1958," K. F. Baldrige.
Dec 1958-Dec 1959	A-2 Crib	11,624	HW-64375, "Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through December 1959."
Dec 1959- June 1960	A-2 Crib	8,189	HW-69071, "Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through June 1960," R. C. Henle, April 7, 1961.
June 1960 - Dec 1960	A-2 Crib	20,077	HW-69072, "Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through December 1960," R. C. Henle, April 14, 1961.
Shows A-2 Crib Abandoned. No additions after Dec. 1960.			HW-72956, "Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through December 1961," G. E. Backman.
Shows no active organic crib in 1962.			HW-76638, "Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through December 1962," G. E. Backman.
Could not locate this report.			HW-80877, "Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through December 1963," R. H. Wilson.
Shows no active organic crib in 1964. A-31 crib is called a "specific retention crib."			BNWC-91, "Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through December 1964," R. H. Wilson, May 4, 1965.
No entry for active organic crib in 1965.			ISO-98, "Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through December 1965," B. J. McMurray.
"Purex organic wastes from Jan 1963-Dec 1966"	A-31 Crib	6,340	ISO-698, "Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through December 1966," B. J. McMurray, February 15, 1967.
	TOTAL	98,100	

5.0 CONCLUSIONS AND RECOMMENDATIONS

The Purex Plant material balance for diluent and TBP should be regarded as a rough estimate. Fairly complete records exist for total consumption of organics. The distribution of lost organic among the waste streams is less certain because operations at the Purex seldom remained the same for any length of time. Numerous changes in the plant and process occurred over the years. Plant capacity, rate of operations, condensate recycle, and changing diluents all affected the rate of organic consumption and the paths by which organic was lost.

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APPENDIX A

MASS BALANCE CALCULATIONS FOR PUREX ORGANIC CONSUMPTION

DISCUSSION OF MASS BALANCE CALCULATIONS

The purpose of the mass balance calculations is to estimate the mass flow rates of TBP, NPH and DBP through the plant to the eventual discharge streams. The result is used to develop a rough estimate of the percent of lost organics distributed to the various wastes. Mass flow rates are used to avoid extensive calculations of density changes that occur with changes in temperature and uranium and nitric acid content.

The flowsheet that forms the basis for these calculations is PFD-P-020-00001, Rev. A-8, "Purex Flowsheet - Reprocessing N-Reactor Fuels," September 20, 1985. In particular, the flowsheet information used in this report is for processing 12% Pu-240 fuel at a rate of 10 short tons per day. Figures A-1 through A-6 and Table A-1 follow this discussion. The figures are simplified versions of Purex Flowsheet Figures. Table A-1 shows the results of the calculations. The calculations discussed below refer to both the figure in this Appendix and to the reference figure in the Purex Flowsheet. The Purex Flowsheet figures are the source of volumetric flow rate, temperature, specific gravity and nitric acid concentration information shown in Table A-1.

1. HAX STREAM - Figure A-1 (Purex Flowsheet Figure 13)

The HAX stream is the organic feed stream to the HA solvent extraction column from the Solvent Treatment System. This stream enters the bottom of the column, and exits the top, after extracting uranium and plutonium from the HA column feed. The Purex Flowsheet shows an organic flow rate of 87.8 liters/minute. The organic is assumed to have the mass fraction of TBP and NPH found in a 30 vol% TBP solution in NPH at 25°C. This is about 35.4 wt% TBP and 64.6 wt% NPH, based on densities of 0.972 g/L for TBP and 0.76 g/L for NPH at 25°C.

2. HAW STREAM - Figure A-1 (Purex Flowsheet Figure 13)

The HAW stream is the aqueous waste stream that exits from the bottom of the HA column. This stream contains most of the fission products from the reactor fuel. Assume 0.055 vol% of the organic (HAX) stream is entrained in the HAW stream. This is the midpoint of the range of 0.01 vol% - 0.1 vol% given on page 4-80 of the Purex Technical Manual (RHO-MA-116). The original Purex Technical Manual (HW-31000, p. 584) describes entrainment as follows:

"Entrainment refers to a normally very small fraction (typically 0.01 to 0.1%) of the other phase which is carried out with an effluent stream. It usually consists of very fine droplets, some

of which may be colloidal in size, which have little tendency to settle out in the disengaging sections. ...Entrainment of the organic phase in the aqueous effluents represents a potentially economically important loss of solvent, and adds an additional amount of TBP to be steam stripped by the product and waste (acid) concentrators."

In addition, the solubility of TBP is assumed to be 0.22 g/L in this stream, which contains 3.09 M Nitric Acid. (Table 6-9 of RHO-MA-116 shows that solubility of TBP in HNO₃ and UNH solutions is relatively insensitive to temperature. Figure 6-1 of RHO-MA-116 gives solubilities of TBP in various solutions. The 0.22 figure is the result of an interpolation between 1.0 M and 7.0 M HNO₃ at 20°C. The solubility of NPH is less than 0.005 g/L in water between 25 and 50°C. Its solubility is assumed to be the same for process solutions. The calculations in Table A-1 show both the entrained and soluble mass flow in the HAW stream. The entrained portion is 0.055% of the flow in the HAX stream and the soluble portion is assumed to be TBP and NPH at the limits of solubility in the HAW stream. Calculations similar to these are performed throughout the flowsheet in the items below.

3. 1WW STREAM - Figure A-5 (Purex Flowsheet Figure 16)

The 1WW stream is the concentrated bottoms stream from the 1WW acid waste concentrator. The feed to the concentrator comes from the HAW stream described above. The 1WW stream is assumed to contain TBP and NPH at the limit of solubility, but no entrained organic. Entrained organic is assumed to have been distilled in the 1WW concentrator. The mass flow rate of this stream is the amount estimated to be discharged to the high level waste tanks from Tank F-16.

4. AAA STREAM - Figure A-5 (Purex Flowsheet Figure 16)

This stream contains concentrated nitric acid (4.1 molar) from acid absorber T-F5. Since T-F5 boils the liquid to concentrate the acid, the TBP in this stream will be significantly degraded by acid hydrolysis. TBP degradation products are assumed to be present at the limit of TBP solubility. (Entrained organic would have been removed in the overhead stream from the acid absorber. Estimated solubility is about 0.18 g/L for TBP and 0.005 g/L for NPH.

5. AAD STREAM - Figure A-5 (Purex Flowsheet Figure 16)

The AAD stream is the condensate leaving condenser E-F5. This stream has a flow rate of 111.9 L/min. Of this, all but 12.45 L/min are recycled. (The 12.45 L/min goes to Tank F-10.) A balance around the incoming HAW stream and the outgoing stream to TK-F10 and streams 1WW

and AAA yields the following equation for the mass flows of organics, since IWW, AAA and HAW are known: $AAD = (111.9/12.45)(HAW - IWW - AAA)$. Since the AAD stream is the condensate from the boiling concentrated nitric acid solution in the T-F5 acid absorber, the TBP is assumed to be degraded by acid hydrolysis, as in the case of the AAA stream. A portion of the degraded organics in this stream actually exits the plant via the stack ventilation system. The estimate, however, assumes no stack losses.

6. AAD-F10 STREAM - Figures A-4 and A-5 (Purex Flowsheet Figure 16)
This stream is simply a 12.45 L/min portion of the AAD stream, described in item 5, above.
7. AFF STREAM - Figure A-5 (Purex Flowsheet Figure 16)
The AFF stream is the solution leaving TK-U5 as feed to the T-U6 acid fractionator. (The fractionator concentrates nitric acid for re-use in the plant.) The AFF stream contains the same mass flow rate of organics as stream AAA (item 4).
8. AFD EXCESS AND FLOW TO XA TOWER - Figure A-5 (Purex Flowsheet Figure 16)
The AFD stream is the distillate leaving the top of the T-U6 acid vacuum fractionator, combined with some vacuum jet condensate. The AFF stream flows to the acid vacuum fractionator, which concentrates nitric acid to 10.4 molarity. All of the organic and degradation products from the AFF stream are assumed to go with the overhead from the fractionator. Half of the organic mass flow of the AFF stream goes to TK-F10 and the other half goes to the XA tower. At the XA tower, fragments may exit via the main stack, or be recycled back to the AFF stream. The AFD Excess stream is the portion going to TK-F10.
9. HAP STREAM - Figure A-1 (Purex Flowsheet Figure 13)
This stream is the overhead organic product stream leaving the HA column. It contains uranium and plutonium extracted from the feed stream. The amounts of organics are the difference between the incoming HAX (item 1) stream and the exiting HAW stream (item 2).
10. 1BXF STREAM - Figure A-1 (Purex Flowsheet Figure 13)
This stream originates in TK-J3 and forms the feed for the 1BX column. The organic mass flow through this tank is the sum of organic inputs from streams HAP (item 9); 2BW, 3BW and 2PW (item 11), and 1BSU (item 12).

11. 2BW, 3BW, 2PW STREAMS - Figures A-1,3 & 4

(Purex Flowsheet Figures 14 & 15)

The 2BW stream is the organic overhead from the 2B column. It is assumed to contain entrained aqueous to the extent of 0.055 vol% of the bottom stream (2BP). The balance of the mass flow of this stream, minus the uranium (0.055 g/l), plutonium (0.001 g/l) and nitric acid (0.064 M) is assumed to be 35.4 wt% TBP and 64.6 wt% NPH.

Similar exercises yield mass flow rates in stream 3BW (U=0, Pu=0.019 g/l), which is the overhead organic from the 3B column, and stream 2PW (U=13.14 g/l, Np=0.01 g/l), which is the overhead organic from the 2P column (which was used to separate neptunium).

12. IBSU STREAM - Figure A-1 (Purex Flowsheet Figure 13)

The IBSU stream is the overhead organic from the IBS column. It is assumed to contain entrained aqueous to the extent of 0.055 vol% of the bottom stream (IBP). The balance of the mass flow of the stream, minus the uranium (16.49 g/l), plutonium (0.071 g/l), and nitric acid (0.75 M), is assumed to be 35.4 wt% TBP and 64.6 wt% NPH.

12. IBXP STREAM - Figure A-1 (Purex Flowsheet Figure 13)

This stream is the aqueous stream leaving the bottom of the IBX column. At 2.1 molar HNO₃ and 18.24 g/l uranium (0.08 Molar), the solubility of TBP is about 0.25 g/l. Solubility of NPH is assumed constant, at 0.005 g/l. As in the case of the HA column, the entrained organic is assumed to be 0.055 vol% of the incoming organic stream IBXF.

13. IBP STREAM - Figure A-1 (Purex Flowsheet Figure 13)

This stream is the aqueous stream leaving the bottom of the IBS column. At 3.52 molar HNO₃ the TBP solubility is about 0.20 g/L. NPH solubility is assumed to be 0.005 g/L. In addition this stream is assumed to contain 0.055 vol% (entrained) of the IBS stream, which is the organic feed (17.2 l/min) to the column from the Solvent Treatment System.

14. IBU STREAM - Figure A-1 (Purex Flowsheet Figure 13)

The IBU stream is the organic overhead from the IBX column. The organic in this stream is the difference between the incoming IBXF stream (item 10) and the bottoms IBXP stream (item 12).

15. 1CU STREAM - Figure A-1 (Purex Flowsheet Figure 13)

The 1CU stream is the aqueous stream leaving the bottom of the 1C column. At 0.047 molar nitric acid and 0.24 molar uranium, the

solubility of TBP is about 0.18 g/L. Solubility of NPH is 0.005 g/L. In addition, the 1CU stream is assumed to contain entrained organic to the extent of 0.055 vol% of the 1BU stream, which is the organic phase feed to the column.

16. 2NW STREAM - Figure A-4 (Purex Flowsheet Figure 15)
The 2NW stream is the aqueous discharge from the bottom of the 2N column. At 5.03 M nitric acid, the TBP solubility is about 0.16 g/L. NPH solubility is assumed to be 0.005 g/L. This stream is also assumed to contain entrained organic equal to 0.055 vol% of the incoming 2NX stream, which is the organic feed (12.8 l/min) to the 2N column from the Solvent Treatment System.
17. 2DW STREAM - Figure A-2 (Purex Flowsheet Figure 13)
The 2DW stream is the aqueous discharge from the bottom of the 2D column. At 0.94 M nitric acid and 0.07 molar uranium, the TBP solubility is about 0.28 g/L. NPH solubility is assumed to be 0.005 g/L. This stream is also assumed to contain entrained organic equal to 0.055 vol% of the incoming 2DX stream. The 2DX stream is the organic feed (75.7 l/min) feed to the 2D column from the Solvent Treatment System.
18. 2AW STREAM - Figure A-3 (Purex Flowsheet Figure 14)
The 2AW stream is the aqueous discharge from the bottom of the 2A column. At 2.95 M nitric acid, the TBP solubility is about 0.22 g/L. NPH solubility is assumed to be 0.005 g/L. This stream is also assumed to contain entrained organic equal to 0.055 vol% of the incoming 2AX stream. The 2AX stream is the organic feed to the 2A column (3.9 l/min) from Solvent Treatment System.
19. 3WF STREAM - Figure A-4 (Purex Flowsheet Figure 15)
The 3WF stream contains the sum of the organics from the aqueous streams 2DW, 2AW, 2NW, AAD and AFD excess streams, described above. They are combined in TK-F10. Other contributors to this stream are steam condensates and are assumed not to contain organic.
20. 3WW STREAM - Figure A-4 (Purex Flowsheet Figure 15)
This stream contains concentrated nitric acid (8.3 molar) from the 3WB concentrator. Since the concentrator boils the liquid to concentrate the acid, the TBP in this stream will be significantly degraded by acid hydrolysis. TBP degradation products are assumed present at the limit of TBP solubility. (Entrained organic is removed in the overhead stream from the acid absorber, so only soluble organics would be present.) Solubility is about 0.11 g/L for TBP and 0.005 g/L for NPH.

21. 3WD STREAM - Figure A-4 (Purex Flowsheet Figure 15)
The 3 WD stream is the distillate from the 3WB Concentrator. The 3WD stream organic content is the difference between the 3WF (item 19) and 3WW (item 20) streams. TBP content is assumed to be degradation products due to acid hydrolysis in the 3WB concentrator.
22. 1UC STREAM - Figure A-1 (Purex Flowsheet Figure 13)
The 1UC stream contains concentrated solution from the 1CU Concentrator. Organics are assumed present at the limit of solubility, with no entrainment, due to heating in the concentrator. Since the nitric acid content is 0.78 molar, acid hydrolysis of TBP is assumed not to have occurred. Uranium content is 2.1 molar. TBP solubility is assumed to be 0.095 g/L (see RHO-MA-116 page 6-25). NPH solubility is assumed to be 0.005 g/L. The distribution between TBP and its decomposition products is assumed to be the same ratio as found in the incoming streams 1CU (item 15) and 3WD (item 21).
23. 1UD STREAM - Figure A-1 (Purex Flowsheet Figure 13)
The 1UD stream contains the difference between the 1CU and 3WD streams, and the outgoing 1UC stream. The 1UD stream, which is condensate from the 1CU Concentrator, is recycled to several locations. If not recycled, it would be disposed to the 216-A-10 Crib. Under conditions indicated in the flowsheet, some water must be added to this stream in order to make up all of the solution required in other vessels (i.e., there is no excess).
24. 2DF STREAM - Figure A-1 (Purex Flowsheet Figure 13)
This stream contains the same organic mass flow as the 1UC stream (item 22). It is the feed to the 2D column, collected in TK-K1.
25. 2DU STREAM - Figure A-2 (Purex Flowsheet Figure 13)
The 2DU stream is the overhead organic product from the 2D column. The organic mass flow rate is the difference between the incoming 2DX (75.7 l/min from Solvent Treatment) and 2DF (item 17) streams and the outgoing 2DW (item 24) stream. Degradation products in the 2DF stream are assumed to go out in the 2DU stream.
26. 2EX STREAM - Figure A-2 (Purex Flowsheet Figure 13)
The 2EX stream consists of 110.71 L/min of the 1UD (item 23) recycled condensate.

27. 2EU STREAM - Figure A-2 (Purex Flowsheet Figure 13)
The 2EU stream is the aqueous stream that leaves the bottom of the 2E column. This stream is 0.01 molar in nitric acid and 0.24 molar in uranium. TBP solubility is assumed to be 0.18 g/L. NPH solubility is assumed to be 0.005 g/L. In addition to the soluble species, 2EU is assumed to contain all of the degradation products from the 2EX stream and entrained organic of 0.055 vol% of the incoming 2DU stream (item 25).
28. 2EW STREAM - Figure A-2 (Purex Flowsheet Figure 13)
The 2EW stream is the overhead organic from the 2E column. This stream contains the difference between the incoming 2EX (item 26) and 2DU (item 25) streams, and the outgoing 2EU stream (item 27). The 2EW stream is fed to solvent treatment tank R-1 (No. 2 Solvent Treatment System).
29. UNH PRODUCT STREAM - Figure A-2 (Purex Flowsheet Figure 13)
This stream is assumed to contain TBP and NPH at the limits of solubility. Uranium is 2.13 molar. TBP solubility is about 0.011 g/L. NPH solubility is assumed to be 0.005 g/L.
30. 2UD STREAM - Figure A-2 (Purex Flowsheet Figure 13)
This stream contains the difference between the incoming 2EU stream (item 27) and the outgoing UNH product stream. It is discharged to the 216-A-10 Crib.
31. 1CX STREAM - Figure A-1 (Purex Flowsheet Figure 13)
The 1CX stream is the aqueous extractant fed to the 1C column. The 1CX stream contains 114 L/min of the 1UD recycled condensate (item 23).
32. 1CW STREAM - Figure A-1 (Purex Flowsheet Figure 13)
The 1CW stream is the organic leaving the top of the 1C column. The 1CW stream is the difference between the incoming 1CX (item 31) and 1BU (item 14) streams, and the outgoing 1CU stream (item 15). The 1CW stream is then transferred to the No. 1 Solvent Treatment System.

SOLVENT TREATMENT

The 1CW (item 32) and 2EW (item 28) streams form the feeds to the No. 1 and No. 2 Solvent Treatment Systems. At this point, estimates for these streams include TBP degradation products resulting from acid hydrolysis in concentrators. According to the original Purex Plant Technical Manual,

however, TBP degradation also occurs in the amount of 10 to 20 ppm of solvent while passing through the solvent extraction columns, 90% of which goes to solvent treatment (HW-31000, p. 903.) For solvent treatment, the estimates for TBP degradation products include this extra amount based on 15 ppm of total solvent (TBP + NPH). The extra amount is rather small. The remainder of the mass balance is for solvent treatment.

33. 10W STREAM (Purex Flowsheet Figure 17)

The 10W stream is the combined organic wash waste from both solvent treatment systems. This stream is assumed to contain all of the TBP degradation products from the feed streams 1CW and 2EW. It is also assumed to contain soluble TBP and NPH. Soluble TBP is assumed present at 0.12 g/L which is the solubility in water at 50°C. (Feed streams to Tank G-8 are at 50°C). Soluble NPH is assumed present at 0.005 g/L.

At this point, all of the organic losses, except entrainment in the organic wash waste and evaporation have been accounted for. As expected, the sum of the losses estimated thus far is less than the 114 gallons per operating day identified in the flowsheet as fresh organic makeup.

As a result, the amount of organic entrained in the organic stream is assumed to be 80% of the balance of the organic losses needed to add up to the 114 gallons per day of fresh solvent. (The other 20% is assumed to have been evaporated.)

The organic loss to each stream leaving the plant estimated above is not used directly to estimate losses during Purex Plant operations. Rather, the fractions of organics lost to each location are calculated below. Then, the fractions are applied to the organic losses from Purex (Table 2-3), as recorded in monthly reports and essential materials consumption records.

RESULTS

Four cases were evaluated in estimating the distribution of organic losses among the exit streams. These cases are shown on the last four pages of Table A-1. They are necessary due to operating changes during the life of the plant. Purex experienced numerous process and capacity changes.

Case 1 corresponds to flowsheet conditions (PFD-P-020-00001) and would be applicable to operations in 1982 and thereafter. Flowsheet total solvent losses were 114 gallons per day. This case includes recycling of process condensate within the plant.

Case 2 also includes recycling of process condensate, but adjusts the total solvent losses upward to 200 gallons per day. The 200 gallon per day rate was identified as the historical solvent addition rate prior to restart in 1983 (RHO-MA-116, p 4-138). (The reduction in 1983 was expected to occur due to closer control over transfers from Tank G-8.) Case 2 is assumed to apply to the years 1970-1981.

Case 3 assumes 260 gallon per day losses (based on average losses per operating day in 1963-1966), but does not include recycle of process condensate, since the condensate was not recycled during earlier plant operations. When the process condensate is not recycled, more of the organic is discharged via the condensate to a crib. A larger portion of the TBP degradation products is also disposed to the crib. Case 3 is assumed to be applicable to operations with Soltrol from 1963 to 1966 and NPH from 1966 to 1969.

Case 4 assumes total losses of 300 gallons per day and no condensate recycle. This rate is based on average losses per operating day in 1956-1962. The change between 1962 and 1963 occurred in October of 1962, when the Plant began recycling organic wash solution from the No. 2 Solvent Treatment System to the No.1 Solvent Treatment System. This resulted in a reduction in solvent losses. Case 4 is assumed to apply to operations from 1955 to 1962.

Please note that these are very rough estimates, which are not verified by sample data. Waste samples were visually inspected for organic layers, but were not analyzed for the organics. The actual distribution of TBP degradation products is not extremely reliable, since the behavior of DBP, MBP, butanol and phosphoric acid differs. DBP tends to follow the organic phase (until it is washed out in solvent treatment), while MBP, butanol and phosphoric acid are more soluble in water. In the estimate, however, the degradation products are assumed to travel as a group. Not enough information is available to estimate the individual distributions. The most prevalent species, however, appears to be DBP. In addition, flowsheet changes that occurred over the years have not been accounted for, except for the change in condensate recycle, and wash waste recycle.

The diagram illustrates the process flow for the 216-A-10 Crib. It features two distillation columns, TK-K1 (2DF) and TK-K2 (2D Column T-K2), and a treatment system, TK-R1 (No. 2 Solvent Treatment System). The flow starts with 'From Figure 1' entering TK-K1. TK-K1's output goes to TK-K2. TK-K2 also receives input from (2DS) and has a side stream (2DX) going to 'To TK-F10'. TK-K2's output goes to (2DU), which then feeds into TK-K3 (2E Column T-K3). TK-K3 also receives 'Recycled Condensate From Figure 1' (2EX). TK-K3 has two outputs: one to (2EW) which goes to TK-R1, and another to (2EU). TK-R1's output goes to (2UD), which then feeds into '2EU Concn. E-K4'. This concentrator has a side stream going to 'To 216-A-10 Crib' and a main output to (2UNH), which is the final 'Product'.

Figure A-4: Purex Flowsheet Backcycle Waste System Phase 1 and Second Neptunium Cycle Phase 1

WHC-MR-0483
Revision 0

Figure A-5: Purex Flowsheet Waste Concentration and Acid Recovery

Figure A-6: Purex Flowsheet - Solvent Treatment

Table A-1: Purex Plant TBP/Diluent Material Balance Calculations

	Soluble TBP	Entrained TBP	Total TBP TBP	TBP d-prod.	Soluble NPH	Entrained NPH	Total NPH	flow rate		SpG	HNO3	Notes
Stream	g/min	g/min	g/min	g/min	g/min	g/min	g/min	L/min	T °C	g/ml	Molar	
HAX	25,358	-	25,358		46,199	-	46,199	87.8	40	0.815	0.01	
HAW	8.49	13.9	22.4		0.19	25.4	25.6	38.61	50	1.11	3.09	
1WW	1.06	-	1.06		0.02	-	0.02	4.82	50	1.25	2.83	
AAA				4.63	0.13		0.13	25.72	50	1.13	4.1	
AAD				150.6			228.7	111.9	55	1.0	0.1	
Note: some AAD organics would actually go to the stack via the vent system.												
AAD-F10				16.8			25.5	12.45	55	1.0	0.1	
AFF				4.63	0.13		0.13	54.04	50	1.1	3.76	
To XA				2.31	0.06		0.06	18.09	25	1.0	0.005	Exit system - assume main stack
AFD excessTo F-10				2.31	0.06		0.06	18.09	25	1.00	0.01	
TK-F16												
ZAW	1.06	-	1.06		0.02	-	0.02	5.12	50	1.2		
NZAW	1.06	-	1.06		0.02	-	0.02	7.35	70	1.25	-	Exit system - high level waste
NZAW High Level Waste												
	TBP	0.42	gallons/day									
	NPH	0.01										
HAP	25,335	-	25,335		46,174	-	46,174	91.1	45	0.92	0.214	
1BXF	36,035	-	36,035		65,712	-	65,712	127.6	50	0.9	0.26	
2BW	1,783	-	1,783		3,255	-	3,255	6.2	amb.	0.817	0.064	

WHC-MR-0483
 Revision 0

Table A-1: Purex Plant TBP/Diluent Material Balance Calculations

	Soluble	Entrained	Total TBP	TBP	Soluble	Entrained	Total					Notes
	TBP	TBP	TBP	d-prod.	NPH	NPH	NPH	flow rate		SpG	HNO3	
Stream	g/min	g/min	g/min	g/min	g/min	g/min	g/min	L/min	T °C	g/ml	Molar	
3BW	190	-	190		346	-	346	0.655	amb.	0.82	0.013	
2PW	3,716	-	3,716		6,784	-	6,784	12.86	40	0.83	trace	
1BSU	5,010	-	5,010		9,153	-	9,153	17.82	50	0.86	0.75	
1BXP	3.84	19.8	23.7		0.08	36.1	36.2	15.34	50	1.1	2.1	
1BP	3.93	2.7	6.7		0.10	5.0	5.07	19.63	45	1.12	3.52	
1BU	-	-	36,011		-	-	65,676	126.4	50	0.89	0.042	
1CU	20.9	19.8	40.7		0.58	36.1	36.70	116.3	55	1.08	0.047	
2NW	2.6	2.03	4.67		0.08	3.70	3.79	16.5	45	1.17	5.03	
2DW	6.6	12.00	18.56		0.12	21.90	22.02	23.42	amb.	1.05	0.94	
2AW	5.3	0.62	5.92		0.12	1.13	1.25	24.11	45	1.1	2.95	
3WF	14.5	14.7	29.2	19.1	0.38	26.74	52.57	153.8	amb.	1.04	1.15	
3WW	-	-	-	2.3	0.1	-	0.1	20.71	110	1.3	8.3	
3WD	-	-	-	45.9	0.67	51.80	52.47	133.1	50	1	0.04	
1UC	0.60	-	0.6	0.7	0.07	-	0.07	13.49	110	1.69	0.78	
1UD	-	-	40.1	45.3	-	-	89.10	235.9	50	1	tr.	Goes to A-10 Crib if not recycled.
2DF	-	-	0.6	0.7	0.07	-	0.07	14.58	50	1.66	1.5	
2DX	-	-	21,823				39,824	75.7	40	0.815	0.01	
2DU	-	-	21,805	0.7	-	-	39,803	78.15	amb.	0.92	0.008	

MHC-MR-0483
Revision 0

Table A-1: Purex Plant TBP/Diluent Material Balance Calculations

	Soluble	Entrained	Total TBP	TBP	Soluble	Entrained	Total					Notes
	TBP	TBP	TBP	d-prod.	NPH	NPH	NPH	flow rate		SpG	HNO3	
Stream	g/min	g/min	g/min	g/min	g/min	g/min	g/min	L/min	T °C	g/ml	Molar	
2EX	-	-	18.8	21.2	-	-	41.8	110.8	50	1	0.01	
2EU	20.3	12.0	32.3	21.2	0.56	21.9	22.46	112.9	50	1.08	0.01	
2EW	-	-	21,792	0.7	-	-	39,822	75.67	55	0.815	tr.	Goes to No. 2 Solvent Treatment System
UNH Pr.	0.14	-	0.14	-	0.06	-	0.06	12.48	50	1.68	0.08	Product Stream
2UD	-	-	32.2	21.2	-	-	22.4	100.4	50	1	tr.	Goes to 216-A-10 Crib
1CX	-	-	19.4	21.9	-	-	43.1	114	55	1	0.01	
1CW	-	-	35,990	21.9	-	-	65,682	123.6	55	0.815	tr.	Goes to No. 1 Solvent Treatment.
SOLVENT TREATMENT												
1CW	-	-	35,990	23.2	-	-	65,682	123.6	55	0.815	tr.	No. 1 Solvent Treatment Feed
2EW	-	-	21,792	1.5	-	-	39,822	75.67	55	0.815	tr.	No. 2 Solvent Treatment Feed
1OW	0.47			24.8	0.02			3.92	40	1.02	-	

WHC-MR-0483
Revision 0

Table A-1: Purex Plant TBP/Diluent Material Balance Calculations

SUMMARY MASS BALANCE												
Case 1 - Flowsheet Input (est 1982-1991 operations)												
Fresh Solvent	114.1	gallons per day TBP + NPH						0.3	amb.	0.82	-	
Outgoing Streams												
		TBP	TBP-dp	NPH	Total	Destination						
Stream		gal/day	gal/day	gal/day	gal/day							
To XA		0.0	0.9	0.03	0.9	assume main stack						
NZAW		0.4	0.0	0.01	0.4	aging waste						
UNH Pr.		0.1	0.0	0.03	0.1	uranium product						
2UD		12.6	8.3	11.21	32.1	216-A-10 Crib						
1OW		0.2	9.7	0.01	9.9	organic wash waste (solubles)						
Subtotal		13.2	18.9	11.3	43.4							
Balance Gallons		21.2		49.5	70.7	assume 20% to stack, balance entrained in organic wash waste						
Total		34.4	18.9	60.8	114.1		46.75	vol% TBP				
1UD*		15.7	17.7	44.60	78.0	would have gone to A-10 crib without condensate recycle.						
ESTIMATED DISTRIBUTION IN OUTGOING STREAMS WITH CONDENSATE RECYCLE												
		% of lost	% of lost	TBP	NPH	Total						
		TBP	NPH	gal/day	gal/day	gal/day	Fraction TBP that is dp					
Main Stack		9.6	16.3	5.15	9.93	15.07	0.18					
Aging Waste		0.78	0.02	0.42	0.01	0.43	0					
Uranium Product		0.10	0.05	0.05	0.03	0.08	0					
A-10 Crib		39.2	18.4	20.9	11.21	32.12	0.40					
Organic Wash Waste		50.3	65.1	26.8	39.59	66.42	0.36					
Total		100.0	100.0	53.4	60.77	114.12						

WHC-MR-0483
Revision 0

Table A-1: Purex Plant TBP/Diluent Material Balance Calculations

Case 2 - ESTIMATED DISTRIBUTION IN OUTGOING STREAMS FOR EARLIER OPERATIONS										
ASSUMING CONDENSATE IS RECYCLED AND TOTAL ORGANIC LOSSES ARE 200 GALLONS/DAY.										
(est. 1970-1981 operations)										
Outgoing Streams										
		TBP	TBP-dp	NPH	Total	Destination				
Stream		gal/day	gal/day	gal/day	gal/day					
To XA		0.0	0.9	0.0	0.9	assume main stack				
NZAW		0.4	0.0	0.0	0.4	aging waste				
UNH Pr.		0.1	0.0	0.0	0.1	uranium product				
2UD		12.6	8.3	11.2	32.1	216-A-10 Crib				
1OW		0.2	9.7	0.0	9.9	organic wash waste (solubles)				
Subtotal		13.2	18.9	11.3	43.4					
Balance Gallons		47.0		109.6	156.6					
Total		60.2	18.9	120.9	200					
ESTIMATED DISTRIBUTION IN OUTGOING STREAMS										
		% of lost	% of lost	TBP	NPH	Total				
		TBP	NPH	gal/day	gal/day	gal/day	Fraction TBP that is dp			
Main Stack		13.0	18.2	10.30	21.95	32.25	0.09			
Aging Waste		0.52	0.01	0.42	0.01	0.43	0			
Uranium Product		0.07	0.03	0.05	0.03	0.08	0			
A-10 Crib		26.4	9.3	20.91	11.21	32.12	0.40			
Organic Wash Waste		60.0	72.5	47.45	87.68	135.12	0.20			
Total		100.0	100.0	79.1	120.88	200.00				

WHC-MR-0483
Revision 0

WHC-MR-0483
Revision 0

A-22

WHC-MR-0483
Revision 0

A-23

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