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Iodine Flowsheet Status Report

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June 2020

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OPERATED BY SAVANNAH RIVER NUCLEAR SOLUTIONS

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EXECUTIVE SUMMARY

A simplified flowsheet was developed to evaluate the impact of varied assumptions of I-129 decontamination factors on the overall I-129 material balance in the Direct Feed Low-Activity Waste (DFLAW) facility. The flowsheet allows inputs for I-129 feed and Decontamination Factors (DFs) for multiple DFLAW unit operations and provides information on I-129 partitioning to output streams. A series of 6 DFs were evaluated, including baseline DFs from a prior Waste Treatment and Immobilization Plant (WTP) study and refined values based on a Savannah River National Laboratory (SRNL) review. The Microsoft Excel flowsheet spreadsheet will be provided to WRPS to allow further evaluation of the impact of DF assumptions on output streams. The spreadsheet is not specific to iodine, the partitioning of any species can be estimated by entering the assumed DFs for each unit operation.

Flowsheet outputs matched results from the prior WTP study and show that different assumptions for the DFs can greatly impact iodine partitioning to primary and secondary waste streams. Results from SRNL's baseline DF values suggest less than 50% of I-129 would be retained in glass versus the 96% when using the BNI DF values. In addition, the flowsheet demonstrated that more than 5 DFLAW operational cycles are required to achieve a steady-state of I-129 to the primary waste stream.

It is not possible with the data available to determine whether the BNI approach or the approach taken in this study will be a better match for the iodine partitioning once the LAW facility begins operation.

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LIST OF ABBREVIATIONS

BNI	Bechtel National, Inc.
DEP	DFLAW EMP Process System
DF	Decontamination Factor
DFLAW	Direct Feed Low-Activity Waste
EMF	Effluent Management Facility
ETF	Effluent Treatment Facility
HEPA	High-Efficiency Particulate Air Filter
LAW	Low-Activity Waste
LCP	LAW Concentrate Receipt
LFP	LAW Melter Feed Process
LMP	LAW Melter Process System
LOP	LAW Primary Offgas Process System
LVP	LAW Secondary Offgas/Vessel Vent Process System
PNNL	Pacific Northwest National Laboratory
SBS	Submerged Bed Scrubber
SRNL	Savannah River National Laboratory
TCO	Thermal catalytic Oxidizer
VSL	Vitreous State Laboratory
WESP	Wet Electrostatic Precipitator
WTP	Waste Treatment and Immobilization Plant

Introduction

The tank waste currently stored at Hanford will be treated to divide the waste into high level and low level fractions. The low level fraction, known as Low Activity Waste (LAW), will begin treatment using the Direct Feed Low Activity Waste (DFLAW) flowsheet. The feed during the DFLAW mission will contain approximately 7 curies of I-129. Partitioning of this iodine through the DFLAW flowsheet determines how much of the iodine will be immobilized in the primary waste form (glass), in one of the secondary waste streams which will be grouted or exhausted to the atmosphere in the offgas stack.

Initial flowsheet evaluations assumed that the iodine would be captured on the guard bed of the carbon bed in the LAW offgas system. However, testing showed that the guard bed deteriorated rapidly and it was removed from the process. Additional testing indicated that removal of the iodine by the carbon bed also showed rapid deterioration. A Waste Treatment and Immobilization Plant (WTP) contractor performed an evaluation of the relevant decontamination factors (DFs) for the other offgas unit operations to establish the expected partitioning of iodine during DFLAW operations using established DFs for the iodine based on the larger scale pilot testing[1]. The contractor evaluations excluded the smaller scale testing that showed very different partitioning of iodine. As a result of a review of the WTP DFLAW program, a sensitivity study was performed by the WTP contractor [2]. The Bechtel National, Inc. (BNI) studies highlighted the uncertainty in the iodine DFs and the impact of the assumptions made during the evaluation of the VSL data.

The objective of this study was to perform an independent assessment of the expected DFs and partitioning of iodine through the DFLAW flowsheet using the available VSL data. It should be noted that the intent is not to determine replacement DFs to be used by the project but to show how assumptions made in the DF calculation impact the results.

In general, there are two significant differences in the manner that SRNL calculated the DFs and the approach taken by BNI.[3] First, the use of offgas sample data prior to the Thermal Catalytic Oxidizer (TCO) was not used by SRNL, instead SRNL utilized the SBS condensate samples or offgas sample data from samples after the TCO. Second, SRNL calculated average emission amounts during the run and calculated the DFs based on this data versus determining instantaneous DFs during the run and calculating the average DF based on an averaging protocol for the instantaneous DFs. In an ideal situation, the DFs calculated by either approach should be similar, but the two different approaches led to significant differences in the assumed DFs.

It should be noted that the use of a different approach to determine iodine DFs and the difference in results in this study does not mean that the approach taken by BNI is invalid since it is not possible with the data available to determine which approach will best represent the DF during actual WTP operation. For example, review of the Submerged Bed Scrubber (SBS) operation determined that DFs could be increased during WTP operation from the pilot scale tests for a variety of reasons, e.g. non-condensable flows may be less than the pilot scale systems [4].

Experimental

<u>Decontamination Factor Basis</u>

SRNL reviewed recent VSL reports (e.g., VSL-19S4740-1, VSL-18R4500-1) as well as reports on the DM1200 testing to determine DFs for the melter, SBS, WESP, carbon bed, and caustic scrubber[5],[6]. The following items were noted during the review:

1) DFs for iodine across the melter, SBS, and WESP were highly variable.

2) Applicable DF for the carbon bed cannot be ascertained due to lack of long-term test data. Short term testing showed significant amounts of iodine removal by the carbon bed but also showed that iodine removal was declining rapidly [7]. A steady-state condition was not reached during the test.
3) The caustic scrubber lacks data from a prototypical test. Data is available from a static impinger test using a solution in the same pH range as the caustic scrubber [5].
4) Mercury was not added during the pilot scale melter testing
5) Iodine was added at much higher concentrations during the testing so that iodine concentrations would be above analytical detection limits.
6) Iodine mass balances were less than desirable during the older testing, including the DM-1200 data. Mass balances for iodine have been improved by updating some of the testing and analytical protocols, but only smaller scale tests have been performed since these improvements were made by VSL.
7) Speciation of iodine in the feed was determined to impact LAW DFs and iodine speciation in the LAW feed is uncertain.
8) Pacific Northwest National Laboratory (PNNL) and SRNL melter tests with actual tank waste did not include measurement of I-129.

Collectively, the items in the list above lead to considerable uncertainty in the DFs for iodine through the LAW process. Initial DFs, shown in Table 1, were selected based on a SRNL review that estimated DFs for the melter, SBS, and WESP to be 1.25, 2, and 1.75 respectively (SRNL-L3300-2020-00019). Note that these values are lower than the BNI counterparts included in Table 1 for comparison. The EMF Evaporator DF was listed at 500 based on testing that showed iodine partitioned to the EMF concentrate when the LAW condensate is neutralized prior to evaporation which matches the BNI value[8]. No decontamination is assumed for the HEPA,e TCO and Selective Catalytic Reducer (SCR) as no significant removal of iodine is expected. It is likely some iodine will accumulate on the carbon bed, but no data is available to determine the expected DF for long-term operations; a value of 1 was assumed for all but one run. Small scale impinger data suggests a significant amount of iodine will be absorbed by the caustic scrubber[5], so a DF of 2 was used as the baseline but one run was performed with the caustic scrubber DF set to 1.04.

Table 1: Assumed DFs for Flowsheet Calculations

Unit Operations	BNI DF	SRNL Baseline DF	SRNL DF - 100%	SRNL DF + 100%	SRNL DF with CB DF of 2	SRNL DF with CS DF of 1.04
Melter	2.5	1.25	1.125	2.5	1.25	1.25
SBS	3.6	2	1.5	4	2	2
WESP	4.8	1.75	1.375	3.5	1.75	1.75
EMF Evaporator	500	500	500	500	500	500
HEPA	1	1	1	1	1	1
Carbon Bed	1	1	1	1	2	1
TCO/SCR	1	1	1	1	1	1
Caustic Scrubber	1.04	2	1.5	4	2	1.04

Due to the large uncertainty in the DFs for iodine through the LAW process, two cases were evaluated using SRNL baseline values increased and reduced by a factor of 2, labeled as "+ 100%" or "- 100%" in Table 1. "CB 2" assumes SRNL's baseline DFs, but with 50% iodine retention on the carbon bed. And "CS 1.04" assumes SRNL's baseline DFs using the lower caustic scrubber DF of 1.04 assumed in the BNI study.

Description of Simplified Flowsheet

A simplified flowsheet was developed to evaluate the impact of decontamination factors on the overall material balance of DFLAW. The flowsheet allows user defined DFs for the discrete operations listed in Table 2. Inputs are user defined and represent receipt in the LAW Concentrate Receipt (LCP) from AP-106 and miscellaneous effluents in the DFLAW EMF Process (DEP) system (e.g., lab, line flush, etc.). Outputs include retention in the glass, HEPA or carbon bed, and exiting the LAW though the LAW Secondary Offgas/Vessel Vent Process System (LVP) stack or the Liquid Effluent Retention Facility (LERF) and Effluent Treatment Facility (ETF). The spreadsheet starts assuming the LAW is empty and calculates the initial recycle stream from the first batch processed. This recycle is added to the feed and the recycle from the second batch is calculated. This cycle repeats for 15 cycles and results in an approximation of the steady state conditions in the facility when using the 15th cycle as the results. The ETF is included in the flowsheet, but limited DFs are available for ETF unit operations. All DFs for ETF unit operations were set to 2 to allow the ETF portion of the spreadsheet to be mathematically checked; the results from the spreadsheet will not reflect ETF operations until suitable DFs are added to the sheet; therefore, the ETF results are not included in the results or discussed. Returns are added as an additional input for subsequent cycles. While the flowsheet is configured to accept DFs for any species, I-129 was utilized for the present study.

Table 2: Operations with User-Defined DFs in the Simplified LAW flowsheet

LCP/LFP/LMP	LOP	LVP	DEP	LERF-ETF
Melter, Vents	SBS, WESP	HEPA, Carbon Bed, TCO, Caustic Scrubber	Filter, Evaporator	Filter, Peroxide Decomposer (PD), PD Carbon Bed, Degasser, Reverse Osmosis, Ion Exchange, Evaporator, Thin Film Dryer, Off-Gas System

Results and Discussion

Results from the simplified flowsheet using the BNI DF assumptions listed in Table 1 match the values calculated in the WTP Iodine Sensitivity Study. The percent fraction of I-129 in select steady-state output streams using both the BNI and SRNL baseline DFs are listed in Table 3. Whereas the BNI values result in the majority of I-129 being retained in the glass, the lower Melter, SBS, and WESP DFs assumed in the SRNL baseline results in less than half the I-129 retained in the melter with ~53% exiting DFLAW via the stack or LERF-ETF.

Table 3: Baseline Results

	BNI Baseline	SRNL Baseline
Glass	96.2 %	46.5 %
Carbon Bed	0	0
HEPA	0	0
LAW Stack	3.57 %	25.6 %
LERF-ETF	0.26 %	26.9 %

Table 4 shows the steady-state partitioning of I-129 in the DFLAW output streams derived from the simplified flow sheet using the DFs listed in Table 1. A graphical representation of Table 4 is found in Figure 1. The feed input assumed the 6.94 curies of I-129 expected to be in the DFLAW feed. It should be noted that while the BNI baseline resulted in > 50% more I-129 retained in the glass, the results are plausible considering the factor 2 of uncertainty considered in the baseline SRNL DFs

Table 4: I-129 Curies in DFLAW Output Streams Using DFs in Table 1

	Glass	Carbon Bed	Stack	LERF-ETF
BNI Baseline	6.67	0.00	0.25	0.02
SRNL Baseline	3.23	0.00	1.85	1.86
SRNL - 100%	1.42	0.00	3.67	1.85
SRNL + 100%	6.62	0.00	0.08	0.24
SRNL CS DF 1.04	3.23	0.00	3.55	0.16
SRNL CB DF 2.0	3.23	1.85	0.92	0.94

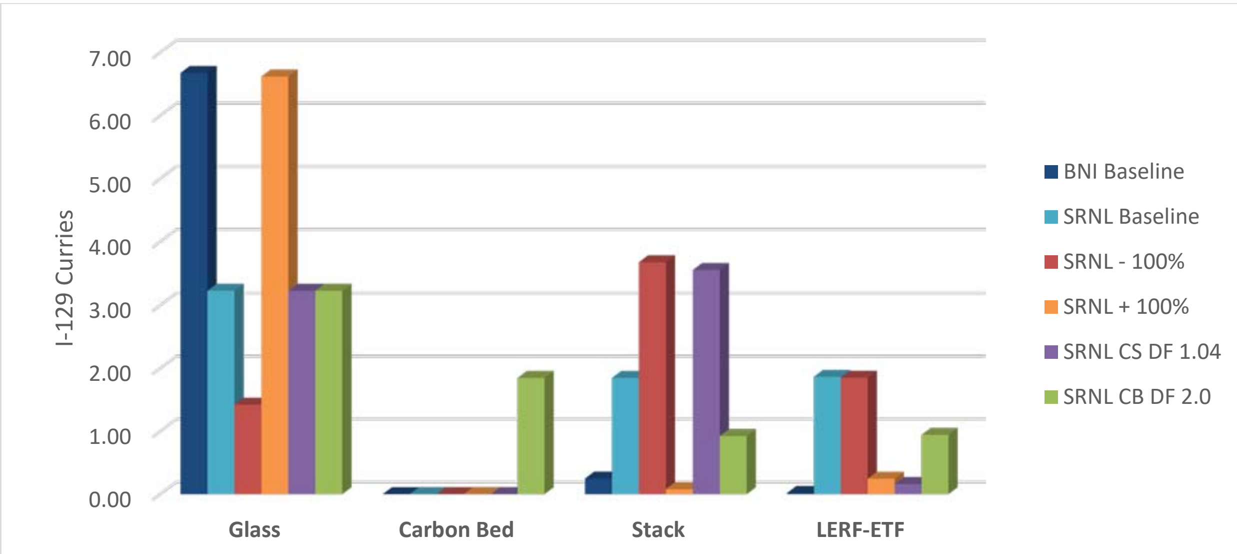

Figure 1: Graphical Representation of I-129 Partitioning in DFLAW Using DFs in Table 1

Also shown in Table 4 are calculated values using SRNL's baseline DFs with differing DF's for the carbon bed and caustic scrubber. Both systems are located downstream of the LOP and do not affect I-129 partitioning in the melter. Retention of I-129 on the carbon-bed will result in an analogous decrease in I-129 downstream; a result reflected in Table 4 with I-129 at the Stack and LERF-ETF being collectively reduced by the same fraction collected on the carbon bed.

Very little experimental data exists to derive DFs for the off-gas stream after the TCO and a DF for the caustic scrubber was based on an assumed iodine speciation.[9] It is noted that higher pH (above 10.5) for the caustic scrubber solution would result in a much higher DF for iodine than the nominal 9.5 pH planned for operations. Changes in the scrubber DF largely direct the fraction of I-129 sent to the stack vs. LERF-ETF. Decreasing the scrubber DF from 2.0 to 1.04 nearly doubles the I-129 exiting the stack and conversely minimized the activity sent to LERF-ETF.

Table 5 shows the I-129 partitioning as a function of DFLAW operational cycle for first 10 cycles using SRNL's baseline DFs. During the first pass-through, only 43% of the I-129 is included in an output stream with the remainder added to the following cycle's feed. The total fraction of I-129 in output streams continually increases with the number of cycles and a near-steady state achieved after about 5 cycles. Idling DFLAW operations (or running in a non-continuous mode) can greatly affect I-129 outputs.

Table 5: I-129 Partitioning Per DFLAW Operational Cycle – SRNL Baseline

Cycle Number	1	2	3	4	5	6	7	8	9	10
I-129 in Feed	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94
Returns from Previous Cycle	0.00	3.96	6.21	7.50	8.24	8.65	8.89	9.03	9.11	9.15
Sent to Glass Canistor	1.39	2.18	2.63	2.89	3.04	3.12	3.17	3.19	3.21	3.22
Retained on Carbon Bed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sent to Stack	0.79	1.25	1.50	1.65	1.73	1.78	1.81	1.83	1.83	1.84
Sent to LERF/ETF	0.80	1.26	1.52	1.67	1.75	1.80	1.83	1.84	1.85	1.86
Total Iodine in Output Streams	2.98	4.68	5.65	6.21	6.52	6.70	6.80	6.86	6.90	6.91
% of Iodine in Output Streams	43%	67%	81%	89%	94%	97%	98%	99%	99%	>99%

Conclusions

The following conclusions are drawn from the study:

- Different approaches to determining the DFs for the LAW melter and offgas system have led to very different values for the expected DFs.
- The iodine partitioning to primary and secondary wasteforms is significantly changed by the different values for unit operation DFs.
- Actual DFs during LAW operation could be different than the expected values due to differences in feed speciation, impact of mercury, impact of feed concentration, or other factors that differ between the actual operation and the pilot scale testing.
- This study may not bound iodine partitioning to any of the primary or secondary waste streams.

Recommendations, Path Forward or Future Work

The following recommendations were determined from the conclusions drawn:

- Options to address higher than expected iodine partitioning to each of the secondary waste streams should be evaluated.
- Additional studies, if performed, should focus on improving the understanding of the caustic scrubber and carbon bed unit operations.
- Iodine DFs for LERF-ETF unit operations need to be determined and added to the spreadsheet.
- The Microsoft Excel flowsheet spreadsheet will be provided to WRPS to allow further evaluation of the impact of DF assumptions on output streams. The spreadsheet is not specific to iodine, the partitioning of any species can be estimated by entering the assumed DFs for each unit operation.

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Appendix A. Flowsheet Screenshots of SRNL Baseline

Row	A	B	C
1	Inputs:		
2			
3	**LCP-LFP-LMP**		
4	Iodine in AP-106	6.94	Ci
5	LCP/LFP Venting (%)	0	%
6	Melter (LMP) DF	1.25	DF
7			
8	**LOP**		
9	SBS DF	2	DF
10	WESP Operation		
11	% Operational	100	%
12	WESP DF	1.5	DF
13			
14	**LVP**		
15	HEPA DF	1	DF
16	Carbon Bed DF	1	DF
17	TCO DF	1	DF
18	Caustic Scrubber DF	2.00	DF
19			
20	**DEP**		
21	LCP-VSL-0001 (Transfer Line Drain Line Flus	0	Ci
22	RLD-VSL-00003 (Misc Effluents)	0	Ci
23	LAB RLD (From Lab)	0	Ci
24	5 Micron Filter DF	1	DF
25	Evaporator Emission	0.2	%
26			
27	**LERF-ETF**		
28	Rough/Fine Filter DF	1	DF
29	Peroxide Decomposer Emission	0.2	%
30	Peroxide Decomposer (carbon bed) DF	2	DF
31	Degasser Emission	0.2	%
32	Reverse Osmosis DF	1	DF
33	Ion Exchange DF	2	DF
34	Evaporator Emission	0.2	%
35	Thin Film Dryer (Solid Fraction)	10	%
36	Thin Film Dryer Emission	0.2	%
37	Off-Gas System DF	2	DF
38			
39	Assumptions:		
40	No Heels in Tanks		
41	No change in DFs due to concentration, cycles, etc.		
42	WESP DF assumed an average of On/Deluge cycles		
43			
44	KEY		
45	Input Required (this tab only)		
46	**Calculated Value**		
47	Linked to Value in Another tab		
48	**Iodine Input from Other tab**		
49	**Iodine Output to Other tab**		

E	# of Cycles 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LCP-LFP-LMP															
From AP-106	6.9400	6.9400	6.9400	6.9400	6.9400	6.9400	6.9400	6.9400	6.9400	6.9400	6.9400	6.9400	6.9400	6.9400	6.9400
LCP With Returns from Previous Cycle	6.9400	10.6339	12.6001	13.6466	14.2036	14.5001	14.6579	14.7419	14.7866	14.8104	14.8231	14.8298	14.8334	14.8353	14.8364
LCP/LFP Vents	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sent to Glass Canistor	1.3880	2.1268	2.5200	2.7293	2.8407	2.9000	2.9316	2.9484	2.9573	2.9621	2.9646	2.9660	2.9667	2.9671	2.9673
To SBS	5.5520	8.5071	10.0801	10.9173	11.3629	11.6001	11.7263	11.7935	11.8293	11.8483	11.8585	11.8639	11.8667	11.8683	11.8691
To WESP	2.7760	4.2536	5.0400	5.4586	5.6815	5.8000	5.8632	5.8968	5.9147	5.9242	5.9292	5.9319	5.9334	5.9341	5.9345
SBS Returns	2.7760	4.2536	5.0400	5.4586	5.6815	5.8000	5.8632	5.8968	5.9147	5.9242	5.9292	5.9319	5.9334	5.9341	5.9345
WESP Returns	0.9253	1.4179	1.6800	1.8195	1.8938	1.9333	1.9544	1.9656	1.9716	1.9747	1.9764	1.9773	1.9778	1.9780	1.9782
Combined SBS WESP Returns	3.7013	5.6714	6.7200	7.2782	7.5753	7.7334	7.8176	7.8624	7.8862	7.8989	7.9057	7.9092	7.9112	7.9122	7.9127
To LVP (WESP + LCP Vents)	1.8507	2.8357	3.3600	3.6391	3.7876	3.8667	3.9088	3.9312	3.9431	3.9494	3.9528	3.9546	3.9556	3.9561	3.9564
LOP/LVP															
Post LVP HEPA	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Retained on HEPA	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Post Carbon Bed	1.8507	2.8357	3.3600	3.6391	3.7876	3.8667	3.9088	3.9312	3.9431	3.9494	3.9528	3.9546	3.9556	3.9561	3.9564
Retained Carbon Bed	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Post TCO	1.8507	2.8357	3.3600	3.6391	3.7876	3.8667	3.9088	3.9312	3.9431	3.9494	3.9528	3.9546	3.9556	3.9561	3.9564
Retained TCO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sent to Stack	0.9253	1.4179	1.6800	1.8195	1.8938	1.9333	1.9544	1.9656	1.9716	1.9747	1.9764	1.9773	1.9778	1.9780	1.9782
Caustic Scrubber Returns	0.9253	1.4179	1.6800	1.8195	1.8938	1.9333	1.9544	1.9656	1.9716	1.9747	1.9764	1.9773	1.9778	1.9780	1.9782
DEP															
Misc Effluents (line flush, Lab, drains, etc.)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Evaporator Emissions	0.0074	0.0113	0.0134	0.0146	0.0152	0.0155	0.0156	0.0157	0.0158	0.0158	0.0158	0.0158	0.0158	0.0158	0.0158
DEP returns to LCP	3.6939	5.6601	6.7066	7.2636	7.5601	7.7179	7.8019	7.8466	7.8704	7.8831	7.8898	7.8934	7.8953	7.8964	7.8969
Sent to LERF/ETF	0.9327	1.4292	1.6935	1.8341	1.9090	1.9488	1.9700	1.9813	1.9873	1.9905	1.9922	1.9931	1.9936	1.9939	1.9940
LERF/ETF															
To Surge Tank	0.9327	1.6374	2.0589	2.2937	2.4209	2.4892	2.5256	2.5450	2.5554	2.5609	2.5638	2.5654	2.5662	2.5667	2.5669
To UV/OX	0.9327	1.6374	2.0589	2.2937	2.4209	2.4892	2.5256	2.5450	2.5554	2.5609	2.5638	2.5654	2.5662	2.5667	2.5669
Retained on Peroxide Decomposer Carbon Bed	0.4654	0.8171	1.0274	1.1445	1.2080	1.2421	1.2603	1.2700	1.2751	1.2779	1.2794	1.2801	1.2805	1.2808	1.2809
To Degasser	0.4654	0.8171	1.0274	1.1445	1.2080	1.2421	1.2603	1.2700	1.2751	1.2779	1.2794	1.2801	1.2805	1.2808	1.2809
To RO Feed Tank	0.4645	0.8154	1.0253	1.1423	1.2056	1.2396	1.2578	1.2674	1.2726	1.2753	1.2768	1.2776	1.2780	1.2782	1.2783
To Ion Exchange Resin	0.4645	0.8154	1.0253	1.1423	1.2056	1.2396	1.2578	1.2674	1.2726	1.2753	1.2768	1.2776	1.2780	1.2782	1.2783
Sent to SALDS	0.2323	0.4077	0.5127	0.5711	0.6028	0.6198	0.6289	0.6337	0.6363	0.6377	0.6384	0.6388	0.6390	0.6391	0.6392
To SWRT	0.2323	0.4077	0.5127	0.5711	0.6028	0.6198	0.6289	0.6337	0.6363	0.6377	0.6384	0.6388	0.6390	0.6391	0.6392
To Thin Film Dryer	0.2318	0.4069	0.5116	0.5700	0.6016	0.6186	0.6276	0.6325	0.6350	0.6364	0.6371	0.6375	0.6377	0.6378	0.6379
Sent to ERDF/IDF	0.0231	0.0406	0.0511	0.0569	0.0600	0.0617	0.0626	0.0631	0.0634	0.0635	0.0636	0.0636	0.0636	0.0637	0.0637
To Vent System	0.0037	0.0065	0.0082	0.0092	0.0097	0.0099	0.0101	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102
Vent System HEPA (retained)	0.0019	0.0033	0.0041	0.0046	0.0048	0.0050	0.0050	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051
ETF Returns (to Surge Tank)	0.2082	0.3655	0.4596	0.5120	0.5404	0.5556	0.5637	0.5681	0.5704	0.5716	0.5723	0.5726	0.5728	0.5729	0.5729
Sent to Stack	0.0019	0.0033	0.0041	0.0046	0.0048	0.0050	0.0050	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051
Total Iodine in Output Streams	3.25	4.97	5.89	6.38	6.64	6.78	6.86	6.90	6.92	6.93	6.93	6.94	6.94	6.94	6.94
% of Iodine in Output Streams	46.77	71.67	84.92	91.97	95.73	97.73	98.79	99.36	99.66	99.82	99.90	99.95	99.97	99.99	99.99

Figure A-1: Inputs/Outputs

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Unit of Iodine in AP-106	6.94																
2	Loss from Venting (%)	0																
3																		
4				Cycle														
5				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
6		DF	% Removed	Units of Iodine														
7	ILST AP-106			6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94	6.94
8	DEP-VSL-00003 (DEP Returns)			0.00E+00	3.69E+00	5.66E+00	6.71E+00	7.26E+00	7.56E+00	7.72E+00	7.80E+00	7.85E+00	7.87E+00	7.88E+00	7.89E+00	7.89E+00	7.90E+00	7.90E+00
9	LCP-VSL-00001			6.94E+00	1.06E+01	1.26E+01	1.36E+01	1.42E+01	1.45E+01	1.47E+01	1.47E+01	1.48E+01	1.48E+01	1.48E+01	1.48E+01	1.48E+01	1.48E+01	1.48E+01
10	LVP-001 (Vessel Vents)			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11	To LMP-MLTR-0001 (Melter)			6.94E+00	1.06E+01	1.26E+01	1.36E+01	1.42E+01	1.45E+01	1.47E+01	1.47E+01	1.48E+01	1.48E+01	1.48E+01	1.48E+01	1.48E+01	1.48E+01	1.48E+01
12	To LOP-SCB-00001	1.25	0.8	5.55E+00	8.51E+00	1.01E+01	1.09E+01	1.14E+01	1.16E+01	1.17E+01	1.18E+01	1.18E+01	1.18E+01	1.19E+01	1.19E+01	1.19E+01	1.19E+01	1.19E+01
13	To Glass Canistor			1.39E+00	2.13E+00	2.52E+00	2.73E+00	2.84E+00	2.90E+00	2.93E+00	2.95E+00	2.96E+00	2.96E+00	2.96E+00	2.97E+00	2.97E+00	2.97E+00	2.97E+00

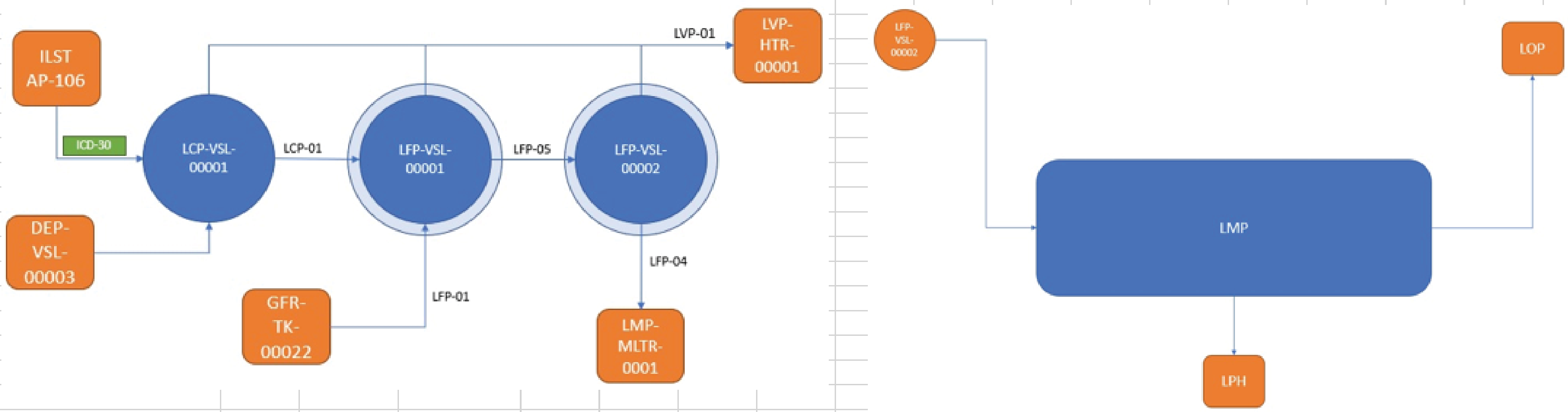

Figure A-2: Receipt, Melter Feed and Melter (LCP, LVP, LMP)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1																		
2				Cycle														
3				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4	WESP Operation		Units to Wesp	2.78E+00	4.25E+00	5.04E+00	5.46E+00	5.68E+00	5.80E+00	5.86E+00	5.90E+00	5.91E+00	5.92E+00	5.93E+00	5.93E+00	5.93E+00	5.93E+00	5.93E+00
5	Deluge Duration (%)	0	Units when Off	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	% Operational	100	Units During Operation	2.78E+00	4.25E+00	5.04E+00	5.46E+00	5.68E+00	5.80E+00	5.86E+00	5.90E+00	5.91E+00	5.92E+00	5.93E+00	5.93E+00	5.93E+00	5.93E+00	5.93E+00
7	WESP DF	1.5	To LVP	1.85E+00	2.84E+00	3.36E+00	3.64E+00	3.79E+00	3.87E+00	3.91E+00	3.93E+00	3.94E+00	3.95E+00	3.95E+00	3.95E+00	3.96E+00	3.96E+00	3.96E+00
8																		
9				Cycle														
10				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
11		DF	% Removed	Units of Iodine														
12	LOP-SCB-00001 (Initial SBS)			5.55E+00	8.51E+00	1.01E+01	1.09E+01	1.14E+01	1.16E+01	1.17E+01	1.18E+01	1.18E+01	1.18E+01	1.19E+01	1.19E+01	1.19E+01	1.19E+01	1.19E+01
13	To WESP	2	0.5	2.78E+00	4.25E+00	5.04E+00	5.46E+00	5.68E+00	5.80E+00	5.86E+00	5.90E+00	5.91E+00	5.92E+00	5.93E+00	5.93E+00	5.93E+00	5.93E+00	5.93E+00
14	To RLD-VSL-00005 (SBS Bottoms)			2.78E+00	4.25E+00	5.04E+00	5.46E+00	5.68E+00	5.80E+00	5.86E+00	5.90E+00	5.91E+00	5.92E+00	5.93E+00	5.93E+00	5.93E+00	5.93E+00	5.93E+00
15	To LVP-HTR-00001			1.85E+00	2.84E+00	3.36E+00	3.64E+00	3.79E+00	3.87E+00	3.91E+00	3.93E+00	3.94E+00	3.95E+00	3.95E+00	3.95E+00	3.96E+00	3.96E+00	3.96E+00
16	To RLD-VSL-00004 (WESP Bottoms)			9.25E-01	1.42E+00	1.68E+00	1.82E+00	1.89E+00	1.93E+00	1.95E+00	1.97E+00	1.97E+00	1.97E+00	1.98E+00	1.98E+00	1.98E+00	1.98E+00	1.98E+00

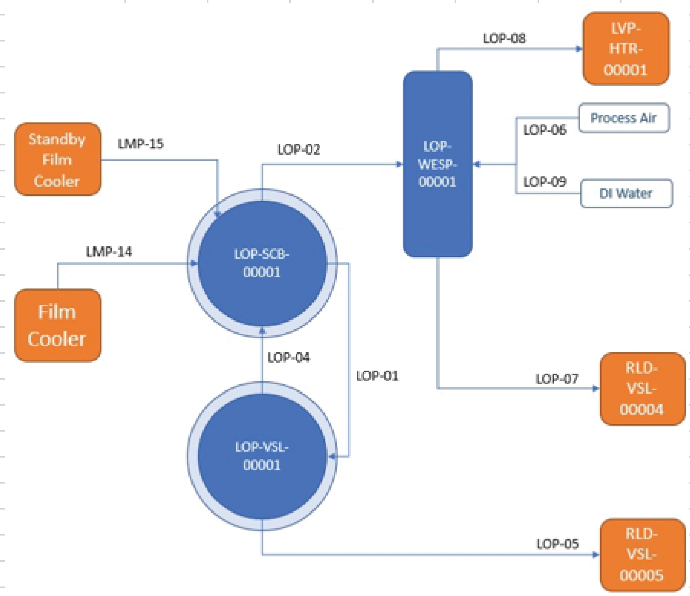

Figure A-3: Primary Offgas (LOP)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
2				Cycle														
3				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4		DF	% Removed	Units of Iodine														
5	From WESP			1.85E+00	2.84E+00	3.36E+00	3.64E+00	3.79E+00	3.87E+00	3.91E+00	3.93E+00	3.94E+00	3.95E+00	3.95E+00	3.95E+00	3.96E+00	3.96E+00	3.96E+00
6	From Vessel Vents			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7	To LVP-HTR-00001			1.85E+00	2.84E+00	3.36E+00	3.64E+00	3.79E+00	3.87E+00	3.91E+00	3.93E+00	3.94E+00	3.95E+00	3.95E+00	3.95E+00	3.96E+00	3.96E+00	3.96E+00
8	HEPA to ADBR (Carbon Bed)	1	1	1.85E+00	2.84E+00	3.36E+00	3.64E+00	3.79E+00	3.87E+00	3.91E+00	3.93E+00	3.94E+00	3.95E+00	3.95E+00	3.95E+00	3.96E+00	3.96E+00	3.96E+00
9	HEPA Retained			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
10	ADBR to TCO Skid	1	1	1.85E+00	2.84E+00	3.36E+00	3.64E+00	3.79E+00	3.87E+00	3.91E+00	3.93E+00	3.94E+00	3.95E+00	3.95E+00	3.95E+00	3.96E+00	3.96E+00	3.96E+00
11	LV-ADBR-00001 Retained			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12	To LVP-SCB-00001 (Caustic Scrubber)	1	1	1.85E+00	2.84E+00	3.36E+00	3.64E+00	3.79E+00	3.87E+00	3.91E+00	3.93E+00	3.94E+00	3.95E+00	3.95E+00	3.95E+00	3.96E+00	3.96E+00	3.96E+00
13	TCO Retained			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14	LVP-TK-00001 to LVP-EXHR-00001 (Stack)	2	0.5	9.25E-01	1.42E+00	1.68E+00	1.82E+00	1.89E+00	1.93E+00	1.95E+00	1.97E+00	1.97E+00	1.97E+00	1.98E+00	1.98E+00	1.98E+00	1.98E+00	1.98E+00
15	LVP-TK-00001 To DEP-VSL-00004			9.25E-01	1.42E+00	1.68E+00	1.82E+00	1.89E+00	1.93E+00	1.95E+00	1.97E+00	1.97E+00	1.97E+00	1.98E+00	1.98E+00	1.98E+00	1.98E+00	1.98E+00

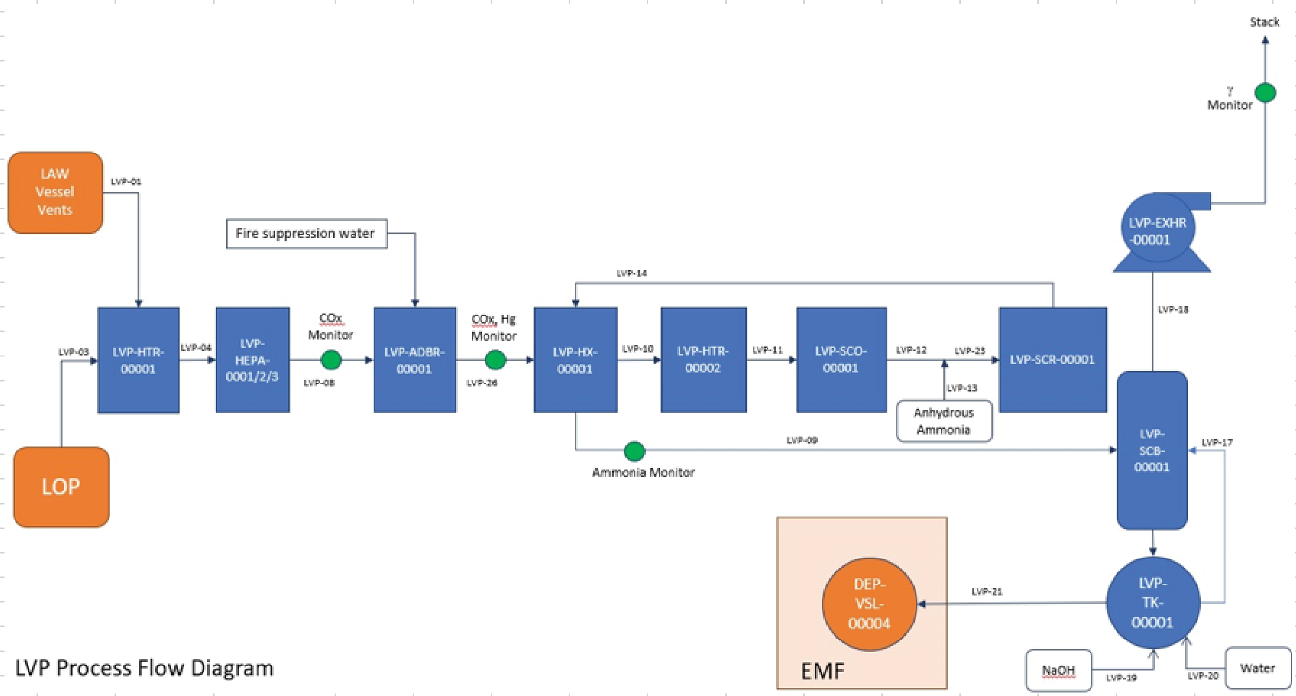

Figure A-4: Secondary Offgas and Condensate Handling (LVP, RLD)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1																		
2				Cycle														
3				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4			% Removed	Units of Iodine														
5	From LCP-VSL-0001 (Transfer Line Drain Line Flush)			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	From LVP-TK-00001			9.25E-01	1.42E+00	1.68E+00	1.82E+00	1.89E+00	1.93E+00	1.95E+00	1.97E+00	1.97E+00	1.97E+00	1.98E+00	1.98E+00	1.98E+00	1.98E+00	1.98E+00
7	From RLD-VSL-00003 (Misc Effluents)			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8	From RLD-VSL-00005 (WESP and SBS Bottoms)			3.70E+00	5.67E+00	6.72E+00	7.28E+00	7.58E+00	7.73E+00	7.82E+00	7.86E+00	7.89E+00	7.90E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00
9	LAB RLD (From Lab)			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
10	To DEP-VSL-00002	1	1	3.70E+00	5.67E+00	6.72E+00	7.28E+00	7.58E+00	7.73E+00	7.82E+00	7.86E+00	7.89E+00	7.90E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00
11	DEP-VSL-00002 to DEP-EVAP-00001			3.70E+00	5.67E+00	6.72E+00	7.28E+00	7.58E+00	7.73E+00	7.82E+00	7.86E+00	7.89E+00	7.90E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00
12	DEP-EVAP-00001 to DEP-COND-00001	0.2	0.002	7.40E-03	1.13E-02	1.34E-02	1.46E-02	1.52E-02	1.55E-02	1.56E-02	1.57E-02	1.58E-02	1.58E-02	1.58E-02	1.58E-02	1.58E-02	1.58E-02	1.58E-02
13	EVAP to DEP-VSL-00003			3.69E+00	5.66E+00	6.71E+00	7.26E+00	7.56E+00	7.72E+00	7.80E+00	7.85E+00	7.87E+00	7.88E+00	7.89E+00	7.89E+00	7.90E+00	7.90E+00	7.90E+00
14	DEP-VSL-00004			9.33E-01	1.43E+00	1.69E+00	1.83E+00	1.91E+00	1.95E+00	1.97E+00	1.98E+00	1.99E+00	1.99E+00	1.99E+00	1.99E+00	1.99E+00	1.99E+00	1.99E+00
15	To LERF/ETF	1	1	9.33E-01	1.43E+00	1.69E+00	1.83E+00	1.91E+00	1.95E+00	1.97E+00	1.98E+00	1.99E+00	1.99E+00	1.99E+00	1.99E+00	1.99E+00	1.99E+00	1.99E+00

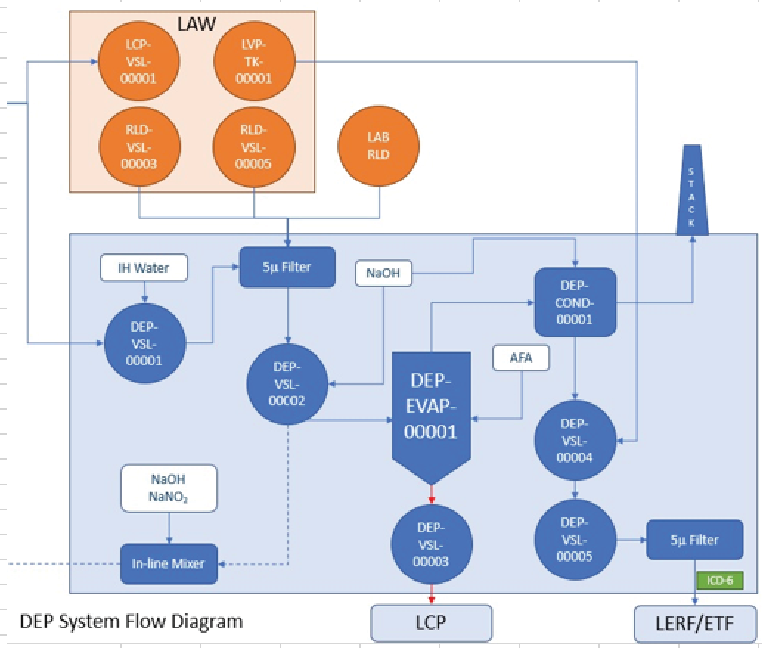

Figure A-5: Effluent Management Facility (DEP)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
11				Cycle														
12	**Main Treatment Train**			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13		DF	% Removed	Units of Iodine														
14	From DEP			0.933	1.429	1.693	1.834	1.909	1.949	1.970	1.981	1.987	1.991	1.992	1.993	1.994	1.994	1.994
15	To Surge Tank			9.33E-01	1.64E+00	2.06E+00	2.29E+00	2.42E+00	2.49E+00	2.53E+00	2.55E+00	2.56E+00	2.56E+00	2.56E+00	2.57E+00	2.57E+00	2.57E+00	2.57E+00
16	To UV/OX	1	1	9.33E-01	1.64E+00	2.06E+00	2.29E+00	2.42E+00	2.49E+00	2.53E+00	2.55E+00	2.56E+00	2.56E+00	2.56E+00	2.57E+00	2.57E+00	2.57E+00	2.57E+00
17	To Vent Off-Gas System (Peroxide Decompo	0.2	0.002	1.87E-03	3.27E-03	4.12E-03	4.59E-03	4.84E-03	4.98E-03	5.05E-03	5.09E-03	5.11E-03	5.12E-03	5.13E-03	5.13E-03	5.13E-03	5.13E-03	5.13E-03
18	To Degasser	2	0.5	4.65E-01	8.17E-01	1.03E+00	1.14E+00	1.21E+00	1.24E+00	1.26E+00	1.27E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00
19	Retained on Carbon Bed (Peroxide Decomposer)			4.65E-01	8.17E-01	1.03E+00	1.14E+00	1.21E+00	1.24E+00	1.26E+00	1.27E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00
20	To Vent Off-Gas System (From Degasser)	0.2	0.002	9.31E-04	1.63E-03	2.05E-03	2.29E-03	2.42E-03	2.48E-03	2.52E-03	2.54E-03	2.55E-03	2.56E-03	2.56E-03	2.56E-03	2.56E-03	2.56E-03	2.56E-03
21	To RO Feed Tank			4.65E-01	8.15E-01	1.03E+00	1.14E+00	1.21E+00	1.24E+00	1.26E+00	1.27E+00	1.27E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00
22	To Ion Exchange Resin	1	1	4.65E-01	8.15E-01	1.03E+00	1.14E+00	1.21E+00	1.24E+00	1.26E+00	1.27E+00	1.27E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00	1.28E+00
23	To SRWT (From RO)			0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
24	**To Verify Tanks/SALDS**	2	0.5	2.32E-01	4.08E-01	5.13E-01	5.71E-01	6.03E-01	6.20E-01	6.29E-01	6.34E-01	6.36E-01	6.38E-01	6.38E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01
25	To SRWT (From Ion Exchange)			2.32E-01	4.08E-01	5.13E-01	5.71E-01	6.03E-01	6.20E-01	6.29E-01	6.34E-01	6.36E-01	6.38E-01	6.38E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01
26																		
27	**Secondary Treatment**																	
28	SRWT - Sum			2.32E-01	4.08E-01	5.13E-01	5.71E-01	6.03E-01	6.20E-01	6.29E-01	6.34E-01	6.36E-01	6.38E-01	6.38E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01
29	To Vent Off-Gas System (from Evaporator)	0.2	0.002	4.65E-04	8.15E-04	1.03E-03	1.14E-03	1.21E-03	1.24E-03	1.26E-03	1.27E-03	1.27E-03	1.28E-03	1.28E-03	1.28E-03	1.28E-03	1.28E-03	1.28E-03
30	To Concentration Tank			2.32E-01	4.07E-01	5.12E-01	5.70E-01	6.02E-01	6.19E-01	6.28E-01	6.32E-01	6.35E-01	6.36E-01	6.37E-01	6.38E-01	6.38E-01	6.38E-01	6.38E-01
31	To Vent Off-Gas System (from TFD)	0.2	0.002	4.64E-04	8.14E-04	1.02E-03	1.14E-03	1.20E-03	1.24E-03	1.26E-03	1.26E-03	1.27E-03	1.27E-03	1.27E-03	1.28E-03	1.28E-03	1.28E-03	1.28E-03
32	**To ERDF/IDF**			2.31E-02	4.06E-02	5.11E-02	5.69E-02	6.00E-02	6.17E-02	6.26E-02	6.31E-02	6.34E-02	6.35E-02	6.36E-02	6.36E-02	6.36E-02	6.37E-02	6.37E-02
33	To Surge Tank			2.08E-01	3.65E-01	4.60E-01	5.12E-01	5.40E-01	5.56E-01	5.64E-01	5.68E-01	5.70E-01	5.72E-01	5.72E-01	5.73E-01	5.73E-01	5.73E-01	5.73E-01
34																		
35	Vent Off-Gas System - Sum			3.72E-03	6.54E-03	8.22E-03	9.16E-03	9.67E-03	9.94E-03	1.01E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02
36	**To Stack**	2	0.5	1.86E-03	3.27E-03	4.11E-03	4.58E-03	4.83E-03	4.97E-03	5.04E-03	5.08E-03	5.10E-03	5.11E-03	5.12E-03	5.12E-03	5.12E-03	5.12E-03	5.12E-03
37	Retained on HEPA/Carbon Filters			1.86E-03	3.27E-03	4.11E-03	4.58E-03	4.83E-03	4.97E-03	5.04E-03	5.08E-03	5.10E-03	5.11E-03	5.12E-03	5.12E-03	5.12E-03	5.12E-03	5.12E-03

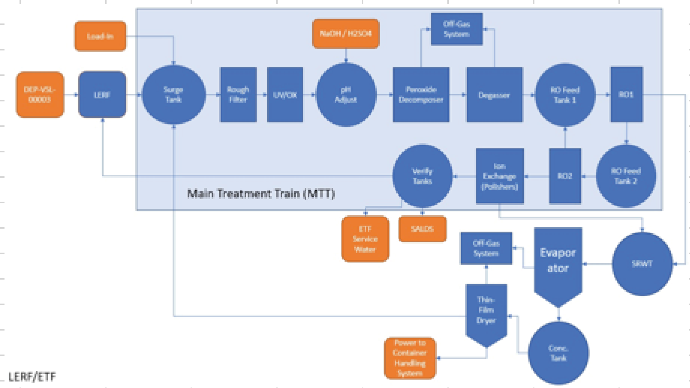

Figure A-6: LERF-ETF