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PUREX PLANT FLOWSHEET
FOR HIGH CAPACITY STUDY

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R. G. Geier
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PUREX PLANT FLOWSHEET FOR HIGH CAPACITY STUDY

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PUREX PLANT FLOWSHEET FOR HIGH CAPACITY STUDY

The attached flowsheet has been prepared to serve as a guide for an engineering study to be made to determine the costs and revisions required to increase the capacity of the Purex Plant to a 4.0 capacity factor.

The needs for such a study are outlined in documents HW-62952 (Ref. 1) and HW-63927 (Ref. 2), which include increased 100 Area production forecasts and maximizing Palm recovery by continuous recovery equipment as primary factors.

The flowsheet, shown graphically on the flowsketch - Figure I and specifically in tabular form under Table I, is a "best estimate" of process conditions and modifications which will be in operation by the third quarter of FY 1962. The modifications included are:

1. Formaldehyde Treatment of Concentrated Wastes - IWW (Ref. 5 and 6).
2. A Continuous Palm Recovery Cycle.
3. A Palm Ion Exchange Purification and Loadout Facility (Ref. 3).
4. Alkaline-Permanganate Washing of the No. 2 Organic System Solvent.
5. Rough-cut Fission Product Recovery and Shipping (Ref. 4).

Since the fission product recovery and shipping operations do not effect the equilibrium conditions of the plant, they are not included in the flowsheet.

TABLE I

PUREX PLANT FLOWSHEET FOR HIGH CAPACITY STUDY

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Stream			Rel. Flow	Sp.Gr. at 25°C	Temp. °C	Composition			
No. (1)	Designation	Phase (2)				HNO ₃ M	U M	Pu g/l (6)	Other Components
<u>Feed Preparation - Coating Removal</u>									
1	Standard Hanford Irradiated Uranium Slugs								
2	NaNO ₃	Aq	17	1.13	A	-	-	-	NaNO ₃ -2.4 M
3	NaOH	Aq	3.65	1.53	A	-	-	-	NaOH-19 M
4	Jacket Rinse Water	Aq	6.7	1.0	A	-	-	-	
5	Reaction Off- Gas	Vapor	-	-	30-35	-	-	-	Mol.% = 98.1 Air, 0.5 H ₂ O, 1.4 NH ₃
6	Scrubber Re- action Gas	Vapor	-	-	190-210	-	-	-	Mol.% = 99.0 Air, 0.8 H ₂ O, 0.2 NH ₃
7	Scrub Water	Aq	Constant 5 gpm	1.00	A	-	-	-	
8	Air Bleed	Vapor	Variable	-	-	-	-	-	
9	Coating Waste	Aq	27.5	1.15	A	-	-	-	NaOH-0.55 M, NaNO ₃ - 0.31 M, N ₂ AlO ₂ - 1.32 M, Na ₂ SiO ₄ - 0.031 M, NaNO ₂ -1.0M

Dissolution

10	Air Bleed	Vapor	Variable	-	-	-	-	-	
11	Dissolution Acid	Aq	45.3	1.31	A	10.4	0.02	-	
12	Dilution & Rinse Water	Aq	~ 12	1.00	A	-	-	-	
13	Reaction Gas (7)	Vapor	Variable	-	190-210	188 Flow Moles of HNO ₃ as NO & NO ₂ Gas			
14	Absorber Water	Aq	Variable	1.00	A	-	-	-	

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Stream			Rel. Flow (3)	Sp.Gr. at 25°C (4)	Temp. °C (5)	Composition			
No. (1)	Designation	Phase (2)				HNO ₃ M	U M	Pu g/l (6)	Other Components
15	XD Acid	Aq	Variable	1.04	A	~ 5 Wt.%	-	-	
16	XC Acid	Aq	42	1.08	A	~15 Wt.%	-	-	
17	Dissolver Soln.	Aq	54	1.82	35-50	0.4	2.5	0.33	
18	HAF-HNO ₃	Aq	2.7	1.31	A	10.4	0.02	-	
First Decontamination Cycle									
19	HAF	Aq	75	1.60	50	0.67	1.8	0.24	
20	3WB	Aq	30	1.37	50	8.2	0.29	0.03	Fe ⁺³ -0.06 M, SO ₄ ⁼ -0.12 M, Na ⁺ -0.16 M
21	HAX	Org	383	0.85	45	-	-	-	No. 1 System Solvent (2)
22	HAO	Org	70	0.86	45	0.27	0.04	0.02	
23	HAX-NaNO ₂	Aq	0.12	1.07	35	-	-	-	NaNO ₂ -1.55 M
24	HAW	Aq	174	1.08	A	2.4	Trace	<0.02%	Fe-0.01 M, SO ₄ ⁼ -0.02 M, Na ⁺ -0.03 M
25	HAP	Org	470	0.96	A	0.28	0.32	0.05	NO ₂ ⁻ -<5.0x10 ⁻⁴ M
26	HSS	Aq	80	1.06	35	2.0	-	-	
27	HSR	Aq	85	1.10	A	2.6	0.06	0.01	
28	HSR-HNO ₃	Aq	3.2	1.31	A	10.4	0.02	-	
29	HSP	Org	466	0.96	A	0.15	0.32	0.04	
Partition									
30	IBXF	Org	500	0.95	55	0.14	0.30	0.04	NO ₂ ⁻ -0.004 M
31	IBX	Aq	20	1.01	35	0.30	-	-	Fe(NH ₂ SO ₃) ₂ -0.03 M
32	IBXP	Aq	21	1.09	A	1.86	0.13	1.0	Fe(NH ₂ SO ₃) ₂ -0.03 M
32-A	IBXP-HNO ₃	Aq	4.9	1.31	A	10.4	0.02	-	
32-B	IBSF	Aq	25.5	1.15	A	3.5	0.11	0.08	Fe ⁺³ -0.02 M, SO ₄ ⁼ -0.05 M
33	IBU-ICF	Org	498	0.95	A	0.08	0.30	0.0002	

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Stream			Rel. Flow (3)	Sp.Gr. at 25°C (4)	Temp. °C (5)	Composition			
No. (1)	Designation	Phase (2)				HNO ₃ M	U M	Pu g/l (6)	Other Components
34	IBS	Org	35	0.85	45	-	-	-	No. 1 System Solvent (2)
35	IBSU	Org	36	0.89	A	0.53	0.08	0.04	
36	HOO	Org	34	0.85	45	-	-	-	No. 1 System Solvent (2)
37	IBP	Aq	25.1	1.08	A	2.84	-	0.77	Fe ⁺³ -0.02 M, SO ₄ ⁼ -0.05 M
38	ICX	Aq	485	1.00	60	0.02	-	-	
39	ICW	Org	485	0.85	A	-	-	-	
40	ICU	Aq	499	1.12	A	0.09	0.30	0.0002	
40-A	IUC	Aq	70	1.69	A	0.61	2.1	0.001	
41	IUD	Vapor	429	-	A	< 0.01	-	-	
<u>Second Uranium Cycle</u>									
42	2DF	Aq	75	1.67	50	1.27	1.98	0.001	Fe(NH ₂ SO ₃) ₂ -0.004 M
43	2DF-Fe ⁺⁺	Aq	0.15	1.34	~ 30	-	-	-	Fe(NH ₂ SO ₃) ₂ -2.0 M
43-A	2DF-HNO ₃	Aq	5	1.31	~ 30	10.4	0.05	-	
44	2DS	Aq	40-61	1.00	35	-	-	-	
45	2DX	Org	400-350	0.85	45	-	-	-	No.2 System Solvent
46	2DW	Aq	104	1.07	A	0.9-1.4	0.13	< 0.001	Fe ⁺³ -0.003M, SO ₄ ⁼ -0.006M
47	2DU	Org	412-312	0.96	A	0.005	0.33	-	
48	2EX	Aq	400	1.00	50	0.015	-	-	
49	2EW	Org	400-300	0.85	~ 50	Trace	-	-	
50	2EU	Aq	413	1.11	~ 50	0.02	0.33	-	
50-A	2UC	Aq	65	1.67	A	0.11	2.1	-	
51	2UD	Vapor	348	-	A	< 0.01	-	-	
52	2UC-HNO ₃	Aq	2	1.37	35	13.0	-	-	
53	2UC-U Product	Aq	67	1.65	40	0.5	2.0	-	

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No. (1)	Stream		Rel. Flow (3)	Sp.Gr. at 25°C (4)	Temp. °C (5)	Composition			
	Designation	Phase (2)				HNO ₃ M	U M	Pu g/l (6)	Other Components
<u>Second Plutonium Cycle</u>									
54	2AF	Aq	26.1	1.12	55	2.7	-	0.73	Fe ⁺³ -0.02M, SO ₄ ⁼ - 0.05 M, NaNO ₂ -0.065 M
55	2AF-NaNO ₂	Aq	1.1	1.07	35	-	-	-	NaNO ₂ -1.55 M
56	2AS	Aq	4.65	1.02	35	0.75	-	-	
57	2AX	Org	7.5	0.85	45	-	-	-	No. 1 System Solvent (2)
58	2AW	Aq	30.4	1.11	A	2.4	-	0.006	Fe ⁺³ -0.02 M, SO ₄ ⁼ - 0.04M, Na ⁺ -0.55M
59	2AP	Org	7.55	0.86	A	0.14	-	2.5	NO ₂ ⁻ -0.22 M
60	2BX	Aq	2.52	1.00	35	0.1	-	-	H ₂ SO ₄ -0.045M
61	2BW	Org	7.5	0.85	A	0.01	-	0.01	NO ₂ ⁻ -0.22 M
62	2BP	Aq	2.57	1.02	A	0.5	-	7.4	SO ₄ ⁼ -0.04 M
<u>Plutonium Ion Exchange</u>									
63	XAF	Aq	5.37	1.22	65	7.0	-	3.5	SO ₄ ⁼ -0.02 M
64	XAF-HNO ₃	Aq	2.8	1.37	A	13.0	-	-	
65	XAS	Aq	0.85	1.22	60	7.0	-	-	
66	XAW	Aq	6.22	1.20	A	6.2	-	0.13	SO ₄ ⁼ 0.02 M
67	XAP-Resin (8)	Solid	0.42	-	A	-	-	43.5	
68	XCX	Aq	1.7	1.03	55	1.0	-	-	
69	XCW Resin (8)	Solid	0.42	-	-	-	-	-	
70	XSW	Aq	0.85	1.19	A	~6.5	-	0.12	
71	XCP	Aq	0.85	1.03	A	~1.0	-	21	
72	XPD	Vapor	0.78	-	A	0.65	-	-	
73	XPC	Aq	0.072	1.17	A	5.4	-	250	
74	Total N Cell Waste	Aq	8.8	1.18	A	5.6	-	0.10	SO ₄ ⁼ -0.01 M

Stream			Rel. Flow	Sp.Gr. at 25°C	Temp. °C	Composition			
No. (1)	Designation	Phase (2)				HNO ₃ M	U M	Pu g/l (6)	Other Components
<u>Palm Recovery Cycle - Phase I</u>									
75	3AF	Aq	23	1.24	50	5.8	0.23	0.03	Fe ⁺³ -0.04 M, SO ₄ ⁼ - 0.77 M, Na ⁺ -0.1 M
75-A	3AF-II (11)	Aq	27	1.17	35	5.3	-	-	Fe(NH ₂ SO ₃) ₂ -0.018 M (Used only during decontamination - Phase II)
76	3AS	Aq	5.2	1.09	35	2.0	-	-	Fe(NH ₂ SO ₃) ₂ -0.15 M, N ₂ H ₄ -0.15 M
77	3AX	Org	26	0.85	45	-	-	-	No. 1 System Solvent (2)
78	3AW	Aq	24	1.20	A	5.5	-	0.02	Fe ⁺³ -0.06 M, SO ₄ ⁼ - 0.14 M, N ₂ H ₄ -0.03 M, Na ⁺ -0.1 M
79	3AN	Org	27	0.93	A	0.35	0.21	-	
80	3BX	Aq	7.7	1.00	35	0.01	-	-	
81	3BW	Org	27	0.91	A	0.05	0.17	-	
82	3BN	Aq	7.7	1.07	A	1.1	0.1	~ 0.2	Np ~ 2.0 g/l, Max. Conc.

Purge and Concentration Operation, ~ 24 Hour Per Batch - Phase III

82-B	3BN	Aq	2.9	1.02	A	0.6	0.001	0.04	Np-0.36 g/l Ave.
83	3BN-HNO ₃	Aq	0.09	1.37	A	13	(Acid used for first six hours of Phase III only)		
84	3ND	Vapor	2.6	-	A	0.01	-	-	
85	3NC	Aq	0.3	1.23	35	7.2	~ 0.01	~ 0.35	Np-3.5 g/l, Fe ³⁺ - 0.12 M

Palm Ion Exchange - Batch Operation

86	3XF-Chem.Add.	Aq	20 L (10)	1.34 (12)	A	-	-	-	N ₂ H ₄ -11 M, Fe (NH ₂ SO ₃) ₂ -2.0 M
87	3XF	Aq	360 L	1.21	25	6.0	0.01	0.28	Np - 3.1 g/l, N ₂ H ₄ -0.1 M Fe (NH ₂ SO ₃) ₂ -0.1 M

Stream			Rel. Flow (3)	Sp.Gr. at 25°C (4)	Temp. °C (5)	Composition			
No. (1)	Designation	Phase (2)				HNO ₃ M (6)	U M (7)	Pu g/l (8)	Other Components
88	3XS-PT	Aq	28 L	1.20	A	6.0	-	-	N ₂ H ₄ -0.1 M
88-A	3XS-PuW	Aq	420 L	1.20	<25	6.0	-	-	N ₂ H ₄ -0.1 M, Fe(NH ₂ SO ₃) ₂ -0.1 M
88-B	3XS-FPW	Aq	560 L	1.22	60-80	7.0	-	-	N ₂ H ₄ -0.05 M, HF-0.01 M
88-C	3XS-FW	Aq	28 L	1.25	A	8.0	-	-	N ₂ H ₄ -0.05 M
89	3XE	Aq	53 L	1.01	A	0.35	-	-	
90	3XN	Aq	25 L	1.07	A	0.6	-	-	Np - 30-40 g/l, Total Impurities <1%
91	3XW	Aq	1460 L	1.21	A	6.1	0.002	0.07	N ₂ H ₄ -<0.1 M, Fe ⁺⁺ - <0.05 M, AlF ₃ - <0.002 M

No. 1 Organic Treatment System

101	Solvent Make-up	Org	Variable	0.85	-	-	-	-	Fresh Solvent (2)
102	IOBR	Aq	1100	1.04	50	-	-	-	KMnO ₄ -0.02 M Ave., Na ₂ CO ₃ -0.23 M Ave.
103	IOB (9)	Aq	12	1.04	50	-	-	-	Na ₂ CO ₃ -0.41 M, KMnO ₄ -0.04 M
104	IOBW (9)	Aq	12	1.04	50	-	-	-	NO ₃ ⁻ -0.26M, Na ⁺ - 0.82M, K-0.04M, MnO ₂ - 0.04 M, CO ₃ ⁼ -0.15 M
105	IOF	Org	485	0.85	50	-	-	-	
106	IOS (9)	Aq	12	1.00	50	0.14	-	-	
107	IOSR	Aq	340	1.00	50	0.10 Ave.	-	-	
108	IOSW (10)	Aq	12	1.00	50	0.07	-	-	
109	IOC	Aq	18	1.02	~30	-	-	-	NaOH-0.51 M
110	IOD	Aq	18	1.02	~45	-	-	-	NaOH-0.51 M
111	IOO	Org	485	0.85	45	-	-	-	No. 1 System Solvent (2)
112	IOW	Aq	42	1.04	35	-	-	-	Na ⁺ 0.46 ^M , K-0.01 M, MnO ₂ -0.01 M, CO ₃ ⁼ - 0.12 ^M , NO ₃ ⁼ -0.12

Stream			Rel. Flow	Sp.Gr. at 25°C	Temp. °C	Composition			
No.	Designation	Phase				HNO ₃ M	U M	Pu g/l	Other Components
(1)		(2)	(3)	(4)	(5)			(6)	

No. 2 Organic Treatment System

121	Solvent Make-up	Org	Variable	0.85	-	-	-	-	Fresh Solvent (2)
122	20BR	Aq	1100	1.04	50	-	-	-	KMnO ₄ -0.02 M Ave. Na ₂ IO ₃ -0.23 M Ave.
123	20B (9)	Aq	10	1.04	50	-	-	-	Na ₂ CO ₃ -0.41 M, KMnO ₄ -0.04 M
124	20BW (9)	Aq	10	1.04	50	-	-	-	NO ₃ ⁻ -0.20 M, Na ⁺ - 0.82 M, K ⁺ -0.04 M, MnO ₂ -0.04 M, CO ₃ ⁼ - 0.15 M
125	20F	Org	400	0.85	50	-	-	-	
126	20S (9)	Aq	10	1.00	35	0.14	-	-	
127	20SI	Org	400	0.85	50	0.1 Ave.-	-	-	
128	20SW (9)	Aq	10	1.00	35	0.07	-	-	
129	200	Org	400	0.85	45	-	-	-	No. 2 System Solvent (2)
130	20M	Aq	20	1.03	35	-	-	-	NO ₃ ⁻ -0.2 M, Na ⁺ - 0.41 M, K ⁺ -0.02 M, MnO ₂ -0.02 M, CO ₃ ⁼ - 0.075 M

Back Cycle Waste Concentration

140	3WF-NaNO ₂	Aq	2	1.07	A	-	-	-	NaNO ₂ -1.55 M
141	3WF	Aq	200	1.07	50	1.58	0.07	0.004	Fe ³⁺ -0.01 M, SO ₄ ⁼ -0.03 M, NO ₃ ⁻ - 0.02 M, Na ⁺ -0.04 M, N ₂ H ₄ -0.003 M
142	E-FI Condensate	Aq	Constant 6 gpm	1.00	A	-	-	-	
143	3WD	Vapor	164	-	A	<0.01	-	-	
144	3WW	Aq	40	1.43	A	8.8	0.39	0.024	Fe ³⁺ -0.07 M, SO ₄ ⁼ -0.14 M, Na ⁺ - 0.2 M
145	3WB-HNO ₃	Aq	0.3	1.31	35	10.4	0.02	-	
146	3WB	Aq	45	1.37	50	>8.2	0.29	0.04	Fe ³⁺ -0.06 M, SO ₄ ⁼ -0.12 M, Na ⁺ - 0.16 M

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Stream			Rel. Flow (3)	Sp.Gr. at 25°C (4)	Temp. °C (5)	Composition			
No. (1)	Designation	Phase (2)				HNO ₃ M	U M	Pu g/l (6)	Other Components
147	3WB-HA	Aq	30	1.37	50	>8.2	0.29	0.04	Fe ⁺³ -0.06 M, SO ₄ ⁻ -0.12 M, Na ⁺ - 0.16 M
148	3WB-3A	Aq	15	1.37	50	>8.2	0.29	0.04	Fe ⁺³ -0.06 M, SO ₄ ⁻ -0.12 M, Na ⁺ - 0.16 M
<u>Waste Concentration</u>									
150	INT-Water	Aq	155	1.00	35	-	-	-	
151	INT	Aq	330	1.04	50	1.28	-	-	Fe ⁺³ -0.005 M, SO ₄ ⁻ -0.01 M, Na ⁺ - 0.02 M
152	2NI	Aq	1	1.19	A	6.2	-	-	
153	IND-2WF	Vapor	319	-	A	1.1	-	-	
154	INW	Aq	11	1.29	A	7.0	-	-	Fe ⁺³ -0.15, SO ₄ ⁻ - 0.32 M, Na ⁺ -0.45 M
155	2WD-AAF	Vapor	318	-	A	1.07	-	-	
156	AAR	Aq	104	1.00	35	-	-	-	
157	AAD	Vapor	348	-	A	~0.01	-	-	
158	AAA	Aq	74	1.14	50	4.55	-	-	
<u>Formaldehyde Treatment</u>									
159	CH ₂ O, CH ₃ OH	Aq	1.8	0.8	30	-	-	-	CH ₂ O-13.7 M, CH ₃ OH- 3.5 M
160	FTAR	Aq	>15	1.00	A	-	-	-	
161	FTAA	Aq	12.6	1.11	A	3.5	-	-	
162	FTAD Cond.	Aq	5	1.11	A	3.5	-	-	
162-A	FTAD	Vapor	> 3	-	A	3.5	-	-	
163	FTW	Aq	7.2	1.09	A	0.5	-	-	Fe ⁺³ -0.23 M, SO ₄ ⁻ - 0.48 M, Na ⁺ -0.7 M
<u>Waste Neutralization</u>									
164	NaOH	Aq	0.21	1.53	A	-	-	-	NaOH-19 M
165	Neut. Waste	Aq	11.0	1.09	A	-	-	-	Fe ⁺³ -0.15 M, SO ₄ ⁻ - 0.32 M, Na ⁺ -0.8 M

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No. (1)	Stream		Rel. Flow (3)	Sp.Gr. at 25°C (4)	Temp. °C (5)	Composition			
	Designation	Phase (2)				HNO ₃ M	U M	Pu g/l (6)	Other Components
166	Dilute Wastes	Aq	Variable	1.00	A	-	-	-	
167	Waste Self Con. 241-A Farm	Aq	4.5	1.52	A	-	-	-	Fe ⁺³ -0.37 M, SO ₄ ⁼ - 0.77 M, Na ⁺ -8.0 M, K-0.19 M, Mn ⁺² - 0.19 M, NO ₂ ⁻ , NO ₃ ⁻ 2.8 M
168	241-A Condensate	Aq	~68	1.00	A	-	-	-	
<u>Acid Recovery</u>									
170	UO ₃ Recovered HNO ₃	Aq	24.5	1.31	A	10.4	0.05	-	
171	Backup Facility HNO ₃	Aq	42	1.08	A	2.68	-	-	
172	AFF	Aq	153	1.15	A	4.86	0.008	-	
173	AFR	Aq	54	1.00	A	-	-	-	
174	AFD	Vapor	135	-	-	0.005	-	-	
175	AFA	Aq	71	1.31	A	10.4	0.017	-	

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Notes:

- (1) Stream numbers correspond to the number in the upper left hand corner of the stream block on the flowsketch - Figure I.
- (2) Organic phase or solvent refers to 30 ± 1 vol. per cent TBP in a hydrocarbon diluent of specific gravity equal to 0.801.
- (3) All flows are relative to 100 flows equals 747 gallons/ton uranium. 2828 L/Ton U
- (4) Specific gravities are given for all solutions at 25°C , regardless of operating temperature.
- (5) All temperatures are ambient except as otherwise noted.
- (6) Plutonium concentrations are based on uranium irradiated to 500 g Pu/ton U.
- (7) Composition of dissolver reaction gas has been averaged. Composition of gas will vary with time and mode of dissolver operation.
- (8) Anion exchange resin is Permutit SK, 20 - 50 mesh. Flow volumes of resin are for wet settled resin in the nitrate form.
- (9) Solvent wash solutions - IOB, IOBW, IOS, IOSW, 2OB, 2OBW, 2OS, and 2OSW changed 1000 gallons at one time.
- (10) Phase III - Palm purging, concentration and purification are conducted on a batch basis. The number given under the Relative Flow column refers to liters per 1000 gram batch.
- (11) 3AF II is a synthetic feed stream used to replace the 3WB stream during the decontamination - Phase II portion of the recovery. Phase II requires about 24 hours.
- (12) Anion Exchange resin in 3X Column T-Q3 is Dowex 1 x4, 50 to 100 mesh.

References:

- (1) HW-62952, "Continuity of Operations Program," by Members of the Chemical Processing Department, February 15, 1960.
 - (2) HW-63927, "Palm Plant Improvement Program," by S. J. Beard, J. B. Fecht and R. J. Pence, March 10, 1960.
 - (3) HW-62065, "Flowsheet for Palm Purification by Exchange for Palmolive Process," by J. S. Buckingham, September 24, 1959.
 - (4) HW-64105, "Hanford Fission Product Program," by B. F. Judson, March 10, 1960.
 - (5) HW-60161, "Denitration of Purex Plant IWW," by G. C. Oberg, May 1, 1959.
 - (6) HW-63024, "Scope Design - Denitration of Purex High Level Wastes," by C. W. Smith, December 28, 1959.
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