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HW-27796

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OPERATIONAL CHARACTERISTICS OF THE PUREX AND
REDOX PLUTONIUM CONTINUOUS CONCENTRATOR PACKAGE

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HW-41100
Page 2

OPERATIONAL CHARACTERISTICS OF THE PUREX AND
REDOX PLUTONIUM CONTINUOUS CONCENTRATOR PACKAGE

INTRODUCTION

The continuous plutonium concentration facilities proposed for the Purex Plant consist of (1) a stripper-concentration unit in which the organic is removed and a portion of the required evaporation is accomplished, (2) a plutonium concentrator (No. 1 Pu Conc.) in which the final plutonium concentrate is produced, and (3) a second concentrator which re-evaporates the totally condensed overhead from the No. 1 Pu Concentrator (see Figure 1). In this report the Purex concentration "package" has been examined to determine whether the design is suitable for concentrating the various Redox 3BP solutions which may be produced (variable nitric acid to plutonium ratios) during operation at Redox Phase II processing rates.

In Appendix A a short-cut method is presented for the calculation of the operating conditions to be employed around the No. 1 and No. 2 Pu Concentrators to produce a desired Pu-HNO₃ product stream from a given feed solution. This method is considerably simpler than the trial-and-error solutions generally employed for such problems.

ASSUMPTIONS AND BASES

In developing the data presented in this report, the following assumptions have been made.

1. The concentration of Pu from the final concentrator may be as high as 85 to 90 g./l.
2. The nitric acid to plutonium ratio in the concentrated product may not exceed the 0.1 mole of HNO₃/g. Pu desired for further processing.

SUMMARY AND CONCLUSIONS

A comparison of the design heat transfer and deentrainment capacities of the Purex plutonium concentration "package" (stripper, two concentrators, and two condensers) with the expected requirements imposed on the equipment when operating at Redox Phase II rates has been made. The comparison indicates that the design is adequate for the Redox service even during periods of off-standard operation (i.e., HNO₃/Pu ratios in the 3BP approximately 8 times the ratios expected when the unit is operated with normal HW No. 2 Purex Flowsheet 2BP), if the plutonium concentration of the product is increased to approximately 85 to 90 g. Pu/l. The nitric acid concentration of this worst-case product would be approximately 8.5 M and the solution would meet the HNO₃/Pu ratio requirement for further processing in Task 1 of 234-5.

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HW-27796

Page 3

Some steam stripping (i.e., dilution water addition to the No. 1 Concentrator) is possible in the "package" before the design capacities of the deentrainment columns and the condensers are exceeded. Since steam stripping might be employed to reduce the HNO_3/Pu ratio in the product, or to reduce the extent of concentration required (reduce product plutonium concentration) to produce specification product, it is considered advisable to include a line in both the Redox and Purex concentrator packages through which dilution water might be introduced to the No. 1 Pu Concentrator.

DISCUSSION

The important design characteristics of the plutonium concentrator package are the permissible vapor loads of the deentrainment towers and the heat duties of the condensers and reboilers. The Purex Facility Process Equipment Design Criteria (HW-26582) indicate the following design data.

Design Value

Stripper Tower

50% Flooding velocity = 4.85 ft./sec.

Vapor load = 4440 lb./day

Stripper Deentraining Section

Design Deentrainment factor = 10^4

Vapor Velocity = 2.0 ft./sec.

Vapor Load = 3200 lb./day

Concentrator Reboiler

Design Flux = 14,000 BTU/hr./sq.ft.

Area = 20.4 sq.ft.

Duty = 285,000 BTU/hr.

Load = 7,000 lb. vapor/day

Concentrator Condenser

Design Duty = 286,000 BTU/hr.

Peak Condensing Capacity = 6733 lb. vapor/day

Concentrator Towers

Design Deentrainment factor = 2.5×10^3

Peak vapor velocity = 3 ft./sec.

Peak vapor load = 5480 lb./day

DECLASSIFIED

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HW-27796

Page 4

Flowsheet Modifications

Normal HW No. 2 Purex Flowsheet flow rates and stream compositions for the operation of the concentrator "package" are shown in Figure 1.

o The 3BP solutions currently being obtained in the Redox Plant contain considerably more HNO_3 than the Purex 2BP. During periods of off-standard operation in Redox, the nitric to plutonium ratio may be as much as 8 times higher than in Purex HW No. 2 Flowsheet 2BP.

As indicated on Table I, the excess nitric acid present in the Redox 3BP may be removed by concentrating to higher product plutonium concentrations and/or adding dilution water to the No. 1 Pu Concentrator. For 3BP solutions with acid/Pu ratios 8 times higher than those shown on Figure 1, the product solution must be concentrated to between 75 and 85 g. Pu/l. before the amount of dilution water required to produce specification product is less than that which might be safely handled in the deentrainment tower and final condenser (see Table II) of the concentration "package". (Compare Cases 3, 6, and 9 of Table I.)

For the 3BP solution currently being produced during "normal" operation in the Redox Plant (HNO_3 /Pu ratios four times Purex HW No. 2 Flowsheet), it appears that the "package" equipment could produce specification product either by concentration to a 75 g. Pu/l. product with no dilution water added, or by adding approximately all the dilution water allowable (design loads of towers and condensers not exceeded) to the No. 1 Concentrator containing 50 g. Pu/l. solution. (Compare Cases 2, 5, and 7 of Table I).

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TABLE I

VARIATION IN DILUTION WATER REQUIREMENTS
WITH PRODUCT PU AND HNO₃ CONCENTRATION

	Redox										Purex
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 10
Final Concentrate, Pu, g./l.	50	50	50	75	75	75	75	75	86	50	
Final Concentrate, HNO ₃ , M	5	5	5	5	5	5	7.5	7.5	8.6	5	
No. 1 Conc. Feed, gallons/day	270	270	270	270	270	270	270	270	270	225	
No. 1 Conc. Feed, HNO ₃ , M	0.94	1.6	3.2	0.96	1.6	3.2	2.2	3.2	3.2	1.0 ⁽²⁾	
No. 1 Conc. Feed, Pu Conc., g./l.	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	5.0	
Dilution water added gal./day ⁽¹⁾	0	304	1300	0	240	830	0	360	0	0	
L/D	0.014	0.014	0.014	0.017	0.017	0.017	0.037	0.037	0.16	0.014	
Y ₂	0.58	0.58	0.58	0.72	0.72	0.72	2.08	2.08	2.8	0.58	
Y ₁	0.65	0.65	0.65	0.81	0.81	0.81	2.31	2.31	3.7	0.65	
X ₂	5.6	5.6	5.6	6.05	6.05	6.05	8.5	8.5	9.3	5.6	

NOTES:

- (1) Dilution flows in excess of about 305 gal./day (at 8.33 tons uranium per day) will result in exceeding the design capacity of the No. 1 Concentrator deentrainment section and the No. 2 Condenser heat duty.
- (2) The nitric acid content of this Case 10 feed is considerably above that normally expected in the Purex No. 1 Concentrator feed. (0.48 M is the HW No. 2 Flowsheet concentration.) Consequently, the nitric/Pu ratio may increase at least two-fold before dilution water must be added or a more concentrated product must be obtained.
- (3) Nomenclature given on Page 7.

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HW-27796
Page 6

TABLE II

COMPARISON OF EQUIPMENT REQUIREMENTS FOR
VARIOUS REDOX AND PUREX PROCESSING SCHEMES
WITH EQUIPMENT DESIGN SPECIFICATIONS

	Peak Design Values	4.25 Kg/day Processing Rates ⁽¹⁾	
		Purex HW No. 2 Flowsheet Flows and Compositions	Redox ⁽²⁾
No. 1 Conc. Feed Rate, lb./day		2,760	2,290
No. 1 Conc. Feed, HNO ₃ , M		0.46	3.2
No. 1 Conc. Feed, Pu, g./l.		5.04	4.16
Dilution Water, lb./day		0	0
Final Concentrate, Pu, g./l.		75	86
Final Concentrate, HNO ₃ , M		5	8.6
Stripper vapor, ft./sec.	4.85	3.1	3.0
No. 1 Conc. tower vapor, ft./sec.	3	1.4	1.4
No. 2 Conc. tower vapor, ft./sec.	3	1.4	1.2
No. 1 Reboiler duty, BTU/hr.	285,000	110,000	103,000
No. 2 Reboiler duty, BTU/hr.	285,000	110,000	90,000
No. 1 Condenser duty, BTU/hr.	285,000	120,000	110,000
No. 2 Condenser duty, BTU/hr.	285,000	230,000	210,000

NOTES:

- (1) Equivalent to uranium processing rates of 8-1/3 Ton/Day.
- (2) This scheme shows the equipment flow and heat transfer requirements when excess nitric acid in the 3BP (eight times the HNO₃/Pu ratio of HW No. 2 Purex Flowsheet) is removed by concentration (no dilution water added).

DECLASSIFIED

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HW-27795
Page 7

APPENDIX A

CALCULATION OF OPERATING CONDITIONS
AROUND THE NO. 1 AND 2 UUTONIUM CONCENTRATORS OF
THE PUREX CONTINUOUS P-T CONCENTRATOR PACKAGE

The two stage concentrator facilities planned for the Purex and Redox (Phase II) Plants can be directly compared to a one-plate still equipped with a partial condenser. In order to avoid the time consuming trial and error calculations for the influent and effluent stream composition about such a system, a nitric acid operating diagram has been constructed and is presented herein. Two illustrative examples covering situations where dilution water is and is not necessary to produce the desired product HNO_3 concentration are also included.

Development of the operating diagram is based on the nomenclature of the following figure.

where F, W, V, L, D are volumetric flow rates

X, Y are nitric acid molarities

A nitric acid balance around the entire system leads to the equation,

$$Y_2 = \frac{F X_f - B X_1}{D} \quad (1)$$

or

$$D = \frac{F X_f - B X_1}{Y_2} \quad (2)$$

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HW-277,
Page 8

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A total material balance around the entire system is as follows:

$$W = D + B - F \quad (3)$$

A nitric acid balance around the No. 2 Concentrator produces the equation:

$$Y_1 = \frac{L/D \cdot X_2}{L/D + 1} + \frac{Y_2}{L/D + 1} \quad (4)$$

This equation may be solved for L/D.

$$L/D = \frac{Y_1 - Y_2}{X_2 - Y_1} \quad (5)$$

In order to illustrate the application of the above equations, two examples based on the Purex HW No. 2 Flowsheet are presented below.

Case A - No dilution necessary to produce the desired product.

Problem: A plutonium concentrate containing 50 g./l. plutonium and 3.25 M nitric acid is desired, when the solution fed to the No. 1 Concentrator contains 5.04 g. Pu/l. and 0.46 M HNO₃. (Relative flow of feed to No. 1 Concentrator (F) = 3.6.) What should the reflux ratio (L/D) be from the No. 2 Concentrator to the No. 1 Concentrator to produce the desired product?

From the above statement of the problem, the following may be calculated: $B = 0.36$, $X_1 = 3.25$ and $D = 3.24$.

- I. Calculate and plot Equation 1 on the equilibrium diagram as shown on Figure 2.

$$Y_2 = 0.511 - .111 X_1$$

- II. At $X_1 = 3.25$, $Y_2 = 0.150$. This value may be read from the plot or calculated.
- III. At $X_1 = 3.25$, $Y_1 = 0.230$. Read from the 50 g. Pu/l. equilibrium curve.
- IV. At $Y_2 = 0.150$, $X_2 = 3.45$. Read from the 0 g. Pu/l. equilibrium curve.
- V. $L/D = \frac{Y_1 - Y_2}{X_2 - Y_1} = \frac{0.230 - 0.150}{3.45 - 0.230}$
- $L/D = 0.0245$ $\circ L = 0.079$ when $D = 3.24$

For illustrative purposes this equation is also plotted on Figure 2.

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Inspection of the operating diagram reveals the following pertinent information:

1. Increasing the value of L/D (i.e., increasing the reflux to the first concentrator) to values above those calculated will result in an increase in X_1 and a decrease in Y_2 .
2. The minimum value of X_1 that may be obtained without the use of dilution water occurs at the intersection of the Equation 1 and the appropriate equilibrium curve (50 g./l.). At this point, $L/D = 0$, that is, the second concentrator is inoperative.
3. Increasing the Pu concentration in the 1st Concentrator bottoms (decreasing B) increases the minimum concentration of acid obtainable in the bottoms.
4. Preselection of a L/D ratio will result in a trial and error calculation.

Case B - Dilution Necessary

In order to illustrate the calculation procedure when dilution is necessary, it will be assumed that a Pu concentrate containing 50 g. Pu/l. and 2.5 M acid is desired when processing a No. 1 Concentrator feed solution (no water added yet) containing 5.04 g. Pu/l. and 0.46 M HNO_3 at a relative flow rate of 3.6. Figure 3 indicates that this is an impossible condition without dilution.

I. At $X_1 = 2.5$, $Y_1 = 0.140$. Read from the 50 g. Pu/l. equilibrium curve.

II. Y_2 is selected to be 75% of Y_1 . This will give an operating L/D of about 0.01.

$$Y_2 = 0.105$$

III. At $Y_2 = 0.105$, $X_2 = 2.95$. Read from the 0 g. Pu/l. equilibrium curve.

$$IV. \quad L/D = \frac{Y_1 - Y_2}{X_2 - Y_1} = \frac{0.140 - 0.105}{2.95 - 0.140} = 0.0124$$

$$V. \quad D = \frac{F X_f - B X_1}{Y_2} = \frac{3.6 \times .46 - 0.36 \times 2.5}{0.105} = 7.20$$

$$VI. \quad W = D + B - F = 7.20 + .36 - 3.6 = 3.96$$

Table I lists a number of cases which were calculated by the above described methods.

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RW-27796
Page 10

Figure 1

PLUTONIUM CONTINUOUS CONCENTRATOR FACILITY
PUREX HW #2 FLOWSHEET - RE: HW-27277

NOTE: The normal 2BP flow rate at a 4.25 Kg Pu per day (8.33 Tons U/day) processing rate will be about 450 gallons per day. Flows indicated are on the basis of IAF = 100.

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Page 11

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HW-27706
Page 12

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